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Keynote Address

AHSAN IQBAL

Mr Hasan Nawaz Tarar, Secretary Planning, Development and Reforms, Dr Asad Zaman, Dr Musleh ud Din, distinguished economists, members of the Pakistan Institute of Development Economics (PIDE) and the Pakistan Society of Development Economists, students, ladies and gentleman, it is indeed a great honour and privilege for me to open the PSDE's Conference, which has become an annual feature of the Pakistan Society of Development Economists. It offers us a great opportunity to deliberate on the challenges that our country is facing. Before I proceed with what I have to say, I would like to place on record my appreciation for the outgoialso ng Vice Chancellor of PIDE, Dr Musleh ud Din, who has provided leadership to PIDE and has been instrumental in arranging this Conference. I would also like to welcome Dr Asad Zaman as the new President of the PSDE and Vice Chancellor of PIDE. I hope that under his leadership PIDE will touch, *In šāʾ Allāh*, new heights and become a centre of excellence, not only in Pakistan but also in Asia.

Being in a meeting of economists and a leading public sector economic think tank, I am reminded of an anecdote about an economist. A man was walking by a road in countryside where he saw a flock of sheep. He could not resist and said to the shepherd that he would like to make a bet on correctly guessing the number of sheep in the flock. He said to the shepherd that he would give him a hundred dollars if he were unable to guess correctly the exact number of sheep. But if he were right, the shepherd would give him one sheep from the flock. Shepherd thought that it was a huge flock, this person had to be crazy, so it was an easy hundred dollars and accepted the bet. Within a few minutes, the man said that these were nine hundred and eighty one sheep. The shepherd was surprised because the man was exactly right. He said he was man of his word and told the man to pick up any of the sheep. The man picked up a sheep and started to walk away. As he was walking away, the shepherd said he wanted to get even with the man and asked him to make another bet. He said that he could tell him exactly what his occupation was, to which the man agreed. He was from a far off place and thought there was no way the shepherd could guess his profession. The shepherd asked him if he were an economist from a government think tank. The man was greatly surprised because the shepherd was right. He asked the shepherd how was he able to guess his profession. The shepherd asked him to put down his dog first. The man had picked up shepherd's dog instead of a sheep! I hope it is not the case here and hopefully we have economists who can not only count the sheep exactly but who can also pick sheep from the flock and not a dog.

Ahsan Iqbal is Deputy Chairman, Planning, Development and Reforms, Government of Pakistan, Islamabad.

The Keynote Address was transcribed at the PSDE Secretariat using the video recording of the speech.

Ladies and gentlemen, I am happy to note that the Society initiated in 1982 is continuing its tradition of promoting scholarly research and debate on critical socioeconomic issues that Pakistan faces. It helps to revive a tradition of exchanging ideas from which the country can benefit immensely. The 29th Annual General Meeting and Conference of the PSDE comes at a particularly opportune time. The country is in the midst of preparing the eleventh five-year plan, which is set to, *In šāʾ Allāh*, revive our economic fortunes after a period in which the Pakistan did not show a steller economic performance. You would all know that until nineties, Pakistan maintained an average of almost five and a half to six percent GDP growth rate and during the same period India had an average of two and a half to three percent GDP growth rate, which in the literature was known as the Hindu growth rate. Unfortunately, the fortunes have reversed—we have adopted the Hindu growth rate and have passed on the Pakistani growth rate to India, which has been, since then, growing at an average of 6-8 percent. Therefore, we need to reverse our fortunes and not only go back to the old growth rate but must also surpass it.

You may be aware that the five-year plan is being prepared in view of the framework of a vision for Pakistan. The Vision 2025 sets out the broad goals that we would like to see the country attain by the year 2025 and describes the macroeconomic and sectoral strategies for attaining these goals. The vision is being articulated after consultations with a wide range of stakeholders, including a conference of more than 1,500 stakeholders last month. The Conference was chaired by the Prime Minister in which all the chief executives of the federating units were present, regardless of their political affiliation. It is a very positive step forward because we have demonstrated to the world that whatever our politics may be but for the future of this country, and for the development of Pakistan, we are a one nation and we have one vision. It is important for any country to have a vision or a strategy because, as they say, strategy without tactics is the slowest route to victory and tactics without strategy is a noise before defeat. Therefore, without a direction towards which we want to go, tactics will not take us anywhere and unfortunately in last thirteen years we have run this country without a clear vision about in which direction we need to go.

In the last thirteen years, we had no five-year plan nor did we have an articulated vision. Only one document was prepared but it perhaps only remained in the libraries of the Planning Commission. But at the national level, we did not have a shared vision, a direction, or a framework. If you go to a bank to borrow, say, fifty thousand dollars as an SME, the bank would ask you for your business plan, which shows that even banks will not lend you a loan unless they have confidence in your business plan. Therefore, a country that has no medium or long-term business plan and is run on a year-to-year basis, eventually meets the fate we are facing today. It is very unfortunate that nobody looked at the gaps, or deficits, that were emerging between the demand and supply in different sectors. We do not have just a terrible energy crisis but we also have terrible economic imbalances. Since the theme of this Conference is energy, I would particularly like to mention the major energy deficit that we have to tackle for our future development needs. However, the energy deficit is not the only deficit we have to address in order to put this country on a fast track of development. In my opinion, there are eleven deficits that we have to overcome if we want to put this country on a fast trajectory of growth.

First is the savings and investment deficit. A country that has such low savings and investment rates, and where savings are less than investment, can never have the resources it needs to finance its infrastructure development and development needs. One lesson from all the successful countries of East Asia is that they developed and promoted policies, which enabled them to achieve higher savings and investment rates, with their savings being higher than their investment rates.

The second deficit that we have to overcome is the fiscal deficit, which had gone as high as nine percent of GDP. No economy that has such a huge fiscal deficit can have a sustainable development or growth trajectory. In order to overcome this fiscal deficit we need to find ways to mobilise resources through taxation reforms. We need to put in place better policies to cut down wasteful expenditures in the government so that we do not run huge deficit, which financed by more borrowing.

The third is the current account deficit. In the context of current account deficit, again we find that we normally have to borrow foreign loans to plug the gaps in our balance of payment account. All countries that have grown fast have focused on extraordinary growth in their exports so that they can have foreign exchange reserves that are not dependent on IMF tranches, inflow of remittances, or foreign aid. Rather, they have developed a robust, sustainable and dynamic export sector that is able to provide them with the foreign reserves to meet their needs of infrastructure development.

The fourth deficit is that of energy. We face energy deficit not to the tune of just about five thousand megawatts today, which is normally mentioned, but I would say there is a requirement for additional energy to meet the dormant demand which cannot be met due to energy shortage. If we want to provide more energy, probably there is a greater need to produce beyond six thousand megawatts. Moreover, it is not just today that we have to focus on but we also have to look for our future growth projections if we are aiming to grow at 7 to 8 percent growth rate. Therefore, we have to look at the extent of energy demand that we will have in the next 10 to 12 years. In addition, as it was pointed out elsewhere, we also need to take into account the kind of energy-mix we need.

The next deficit to me is the deficit in infrastructure. We did not invest in infrastructure in the past. During the past thirteen years, not many infrastructure projects have been undertaken in Pakistan. After the 9/11 incident, Pakistan was able to achieve very high growth rates because there was higher liquidity in the economy arising from huge inflow of remittances, higher foreign aid coming into the country, and relatively more liberal inflows by multi-lateral institutions. Unfortunately, that higher growth rate was driven by consumer economy and the inflow of money was not invested in infrastructure and productive sectors to create a more sustainable growth. In other words, the inflows were not invested in infrastructure so that it could be upgraded to take load of higher growth platforms. Today we think that it is the demand and supply issue in the energy sector. Even if we have twenty thousand megawatts by any magic, we do not have the transmission and distribution infrastructure that can carry twenty thousand megawatts. Therefore, there is an infrastructure deficit, or infrastructure gap, which we have to overcome not just in the energy sector but also in every sector, such as the railways and roads in the urban centres.

The sixth deficit that we have to overcome is in the housing sector. Our demand of housing is much greater than the supply of housing, which is creating problems in our cities. Due to gap in the demand and supply of housing, our cities cannot become growth centres and our social conditions are deteriorating. People do not have basic civic amenities and in order to provide people with good quality of life and in order to turn our cities into real engines of growth, we have to address this housing deficit aggressively.

The seventh deficit is the human resource deficit. Unfortunately, in all our past growth track record, we have focused mainly on the hardware of development, such as building physical monuments of development, dams, transmission lines, etc. but we overlooked the social and human capital, resulting in huge human and social capital deficit. We are ranked 142nd in the human development index. No country can develop and grow today without overcoming the human and social capital deficit. Pakistan is one of those countries that has actually not improved but has gone down in terms of the nutrition of its people. About 44 percent of children face stunting, more than 15 percent of children face acute malnutrition and most of them face malnutrition in their first one thousand days. Malnutrition does irreversible damage to the learning and social abilities and if we have young people growing up with learning disabilities, we can never compete in this knowledge revolution age. This is the age of knowledge economy in which it is the brainpower that rules over the muscle power. We need a nation that has creative and innovative minds and if we do not have good quality human resources, we can never provide the engine of growth to our economy, which we need because these young minds are our most valuable assets. We can overcome the human and social capital deficit in our society by investing more in human resources.

The eighth deficit is the productivity deficit. Unfortunately, in every sector—whether it is agriculture, industry, manufacturing, or the services sector—we still have one of the lowest benchmarks for productivity. Hence, there is a great room where we can gain a lot without making, relatively speaking, strong investments in physical inputs. Just by improving our systems and process innovation, we can make great productivity gains, and that is a challenge we must overcome. We are, *In šāʾ Allāh*, planning to dedicate 2014 as the year of quality and productivity in Pakistan and launching a quality and productivity movement in all sectors of economy to overcome this productivity gap. Because of this productivity gap, we are facing a major competitiveness deficit, which may be termed as the ninth deficit. If we look at the competitiveness figures in World Economic Forum’s report, we find that Pakistan is lacking and falling behind other nations in today’s global economy. It is the competitiveness of an economy which matters and sustains the country on the path of development. Therefore, we need to identify and focus on the contributors and the pillars on which a strong competitive economy can be built.

The tenth deficit is the governance deficit, or governance crisis. Our governance model is outdated, due to which we are not getting the value for money we are spending in public sector and on public sector programmes. Our public sector management is lacking behind the private sector management, which has transformed and revolutionised the concept of service delivery. But in the public sector, the service delivery standards have deteriorated. We need to overcome the governance deficit by introducing performance culture in the public sector by leveraging newer technologies, such as e-governance, mobile governance and introducing innovations and entrepreneurial spirit in the public sector. We are also starting a major reform and innovation programme with one billion rupees to encourage performance culture and also to promote innovation. We will set up an innovation fund for public sector officials who have innovative ideas to finance their projects so that we can bring a transformational change—a cultural change within the public sector through innovation.

Lastly, ladies and gentlemen, we have to overcome the confidence deficit. This crisis of confidence is mainly caused by our history. In this connection, however, I would like to submit through this Conference, with full respect, to the media owners and managers to please review their programmes. Though I am great advocate of media's freedom and admirer of the role the media has played in Pakistan for democracy and rule of law, but the news telecast and bulletins have become bulletins of gloom and doom and cynicism for the Pakistani nation. Indeed, there are things that are not right and it is media's duty to highlight all the shortcomings but it is not media's duty to dedicate the 90 percent of its news bulletins to negativities and the pessimistic view of this country. There is so much good happening in this country.

I was at the conference of the network of Pakistani entrepreneurs, OPEN, in Lahore. It was a pleasure to be in the company of a talented group of Pakistani entrepreneurs who have achieved success out of nowhere not only in Pakistan but also at the global level. Many of those Pakistani entrepreneurs have achieved great success in North America and have built huge empires. It is time to project these successful Pakistanis as role models for our youth and so that they understand and realise the good things happening in this country. There are many other positive things taking place in Pakistan. For example, there are so many innovations taking place and there are many scientists and researchers, who are conducting world-class research in universities today but none of those researchers ever get any space in the newspapers or any coverage on the electronic media. Today, sadly, all the people need to do to capture media attention is to wear turbans, hold guns or batons in their hands, go out on the streets and chant slogans. Or the media these days pays attention to the people like Sikandar, the odd fellow, who put the Blue Area in Islamabad under siege for a few hours. Unfortunately, the media never bothers to highlight the Pakistani scientists, economists and researchers who are winning laurels for the country internationally. The media needs to change its agenda and menu because we need to give the people of Pakistan self-confidence and hope. We are as good a country as any other country; we are not the most corrupt country in the world but we are only as corrupt as any other country and we are as honest as any other country. In short, we are a perfectly normal nation and people, so do not take away our confidence. *Al-ḥamdu lillāh*, you can see the change. There was a time when there used to be a corruption scandal every week on the media but now six months have passed and not a single corruption scandal has surfaced. *In šāʾ Allāh*, in the next four-and- a-half years not a single corruption scandal will appear because we are committed to having an honest and transparent government in this country.

Ladies and gentlemen, though I have many things to say on the energy crisis but I know there is a limitation of time, so let me just say that our challenges are known. It is not that most of our challenges are unknown or that there is any rocket science to fix our energy problem. We need to have actionable ideas and we need to overcome the knowing-doing gap that we have in this country. We need to have a roadmap that is both implementable and ambitious but that is also doable at the same time. The roadmap also needs to have backing of all the stakeholders. I hope the forums like these where researchers, economists and other stakeholders come together will be able to give us, through research and knowledge, new insight and show us the way forward. The Conference should come up with the way forward to fix the energy crisis. Pakistan is still one of the lowest energy consuming countries in the world as one third of our population lives without electricity. In the today's world, electricity is a fundamental right of every citizen. There is no quality of life without electricity. I think it is our duty not only to supply and provide electricity universally but also at affordable rates.

Unfortunately, in 1994 when energy policy was formulated, nobody calculated what should be the cap on thermal based power stations. We reversed the mix between hydro and thermal electricity from 30-70 to 70-30. It was fine to have thermal-based energy when price of fuel oil was between 20 to 40 dollars a barrel but with 110, 120, or 130 dollars a barrel price, this mix is not a sustainable mode for us. Therefore, the government has taken steps to address the energy challenge on short-, medium-, and long-term bases. In the short-term, ladies and gentlemen, we have been able to put on line, additional 1,700 megawatts by paying off the circular debt and you have seen that it has enabled us to improve the load-shedding situation in the country. We have also made improvements in the governance by trying to plug the holes of energy theft in this country and we are launching a campaign against the defaulters to recover dues of energy companies. We have taken steps to promote renewable energy as a short-term solution because it is the fastest way to put up wind and solar energy plants. However, the problem with solar and wind energy is that it still has relatively high cost of generation. The cost is almost the same as the cost of furnace oil power generation. If we have to change to the cheaper mix, we have to go to hydel-, gas-, or coal-based power generation. We have run out of gas, so we are trying to develop Liquefied Natural Gas (LNG) terminals and we hope that by the next year LNG would be available, which will help us to ease the gas situation.

In short- to medium-term, our next option is to promote coal as a medium of energy generation, which is cheaper than oil and the Government has announced to set up 6,600 megawatts coal power project in Gadani. The government is developing Thar Coal so that indigenous resources can be used for cheaper electricity in the country. Similarly, along with Thar and Gadani coal power projects, we are replacing the existing thermal-based units with coal-based units in Jamshoro, which was based on furnace oil. We hope that these measures will bring down the cost of generation and in the medium- to long-term, our ultimate solution lies in harnessing the hydel potential with which Allah has blessed this country. We have started work on two mega projects, namely Dasu and Diamer-Bhasha dams and both will, *In šāʾ Allāh,* produce about 8,000 megawatts in the next five to ten years. This 8,000-plus megawatt capacity in the next five to ten years will help not only to provide for new demand but will also drastically change our energy mix. At the same time, we are doing the spadework on Bhoji dam, which will have capacity to produce about 6,500 to 7,000 megawatts. The government is also using nuclear energy as a cheaper mode of power generation and recently we have inaugurated 2,100-megawatt power project in Karachi, called the Karachi Coastal Nuclear Power Plant, which will be the biggest nuclear power plant in Pakistan yet. These measures, *In šāʾ Allāh,* are going to bring dividends.

At the same time, we should not just focus on electricity. Energy has a much wider connotation and one of our weaknesses has been that we have failed to take an integrated view of the energy picture. When CNG licenses were being given, no one paid attention to what was happening in the industrial and domestic sectors. As a result, today we have a situation that if we provide gas to CNG stations, we have to interrupt supply to the domestic and industrial sectors or vice versa. Therefore, this whole energy planning has to be integrated. We must look at our water resources, oil and gas resources, coal resources, and renewable resources and come up with an optimal mix that will provide us with the solution that is best and cheap. Moreover, the solution has to be "green" for the future because we have to be very conscious of emissions and the environment. I think it is a challenge for the planners and economists to give us a way forward that will optimise our resources, with which Allah has blessed us.

At the same time, we must not ignore the challenge of governance in the power and energy sector. We have to look at why we are going with privatisation of the distribution and generation companies. We also have to look at the kind of regulatory regime we should have so that NEPRA can play an effective regulatory role to avoid cartelisation in energy sector, just as the role the State Bank of Pakistan played in the financial sector when we allowed privatisation. State Bank was able to perform the role of a regulator effectively because of the reforms in the State Bank. Without an effective regulatory body, privatisation can also become a great menace. Therefore, if we have to reap the full advantage of private potential, we must simultaneously focus on developing effective regulatory mechanisms and bodies in the country so that the rights of the consumers are protected.

Ladies and gentlemen, energy price variations are set to affect industrial competitiveness, which will influence investment decisions and company strategies. Therefore, it is very important that we have an efficient energy sector and a renewed focus on energy. I am very glad that after my address, the theme of Dr Ilhan Öztürk's lecture is on energy efficiency, which is an area where we still have large benefits to harvest.

Let me also say that when we look to the future, we should not ignore the innovation and the genius of mankind through technology, which will change our projections for the future. When we plan, we can do extrapolative planning in incremental mode, where we project the present and assume that the future will be like present. But, ladies and gentlemen, there have been disruptive innovations in the history of mankind where mankind has used its genius to create new ideas and technologies, which have revolutionised the every area of production. Similarly, recent breakthroughs in natural gas extraction highlight the speed with which game changing technologies can transform the natural resource landscape. Just over the horizon are electric vehicles with advanced internal combusting engines, solar photovoltaic system, and LED lighting that are benefiting from the convergence of software, consumer electronics and traditional industrial processes and each has the potential to grow by a factor of 10 in the next decade. Placing rapidly evolving technologies, such as these, on a resource cost curve is difficult but their impact could be very big or very small and that is even more the case for technologies that require significant scientific and engineering innovations to reach commercial scale at viable cost. However, there are five technologies that could start arriving in earnest by 2020 or so. One is the grid scale energy storage due to which the concept of storage at the grid stage is going to undergo a revolutionary change in the coming years. Second is the digital power conversion. Third is the compressor-less air conditioning and electrochromic windows, which is going to change the whole energy efficiency landscape, fourth is clean coal, and fifth is the electrofuels and new biofuels, which again have great potential in energy sector. When we look at the future we must also look at the new technologies and the new trends, which have the ability to carry out massive transformational change in the energy sector.

In the end, I wish the organisers of this Conference success. I hope the outcomes will not be just theoretical but that these outcomes will have practical relevance for the future. I would like to request Dr Asad Zaman that we all need to work together and put up a research agenda for this country that has direct development and economic relevance. This is a society of development economists and we must produce research that will provide us with evidence and data to make better choices to ensure that we have maximum value for money that we spend in the public sector. It must give us research and ideas so that we are able to spot challenges and opportunities when they begin to emerge, rather than letting them become crises so that we have to deal with them in crises management mode. We need to deal with our future challenges and opportunities in a more proactive manner so that we become beneficiaries of change and create great opportunities in Pakistan, which is a land of opportunity, for our most wonderful resource which is the youth of Pakistan. I think if they are given right opportunities, the youth has the enterprise, intellect, vigour and commitment to take Pakistan to a path of glory, which it rightfully deserves.

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The Presidential Address

Energy Security and Economic Sustainability: The Way Forward

ASAD ZAMAN

Honourable Minister for Planning, Development and Reforms and Chancellor PIDE, Past Presidents and Distinguished Members of the Society, Excellencies, Ladies and Gentlemen,

It is my pleasure to welcome you all to the 29th Annual General Meeting and Conference of the Pakistan Society of Development Economists.

On behalf of the members of the PSDE, I would like to thank you, Honourable Prof. Ahsan Iqbal for having spared your precious time to open this important meeting. I would also like to especially thank our members and guests who have come from different parts of the country and from different continents to participate in the Conference. We are extremely pleased to see here today many young students—Pakistan's future economists and business leaders—who I am sure are enthusiastic to learn from the many leading specialists attending this Conference on the critical issue of 'Energy' that we in Pakistan face today.

Let me join Dr Durr-e-Nayab in especially welcoming Dr Ilhan Ozturk, Professor at the Çağ Üniversitesi in Turkey who will be delivering the The Mahbub Ul Haq Memorial Lecture. Dr Prof. Zhaoguang Hu, Vice-President and Chief Energy Specialist at the State Grid Energy Research Institute in Beijing who will deliver Gustav Ranis Lecture. Professor Mohan Munasinghe, Chairman of the Munasinghe Institute of Development, Sri Lanka who will be delivering The Allama Iqbal Lecture and Dr Rajendra K. Pachauri, Chief Executive of the Energy and Resources Institute, New Dehli who will deliver The Quaid-i-Azam Lecture this year.

Ladies and Gentlemen,

The limited access to commercial energy combined with widespread shortages is inhibiting economic growth and employment generation. In the last ten years or so, growth in the supply of energy has failed to keep pace with the growth in demand. The energy constraint has contributed significantly to the Pakistan's economic growth along a low trajectory for the past couple of years.

Asad Zaman <vc@pide.org.pk> is President of the Pakistan Society of Development Economists, and Vice-Chancellor of the Pakistan Institute of Development Economics, Islamabad.

It is this backdrop that has led us to hold this year's annual conference on the theme of 'Energy', to look deeply into the causes of the crisis and develop recommendations to address it. Moreover, to encourage research on the subject of 'Energy' we, at the Pakistan Institute of Development Economics, also initiated a research competition for our staff. Research proposals were invited in the month of May this year. After a thorough and competitive process, five studies were awarded. I am pleased to report that three of these studies will be presented in this conference.

Ladies and Gentleman,

Pakistan's energy crisis, as we know well, has many facets. Supply shortages, transmission losses, power theft, circular debt, high cost, inefficient use, poor governance and weak regulation, all have contributed to the crisis that we face today. To overcome the crisis, a comprehensive policy that accounts for these issues was called for and I am happy to note that the national power policy announced by the government seeks to address all the issues that plague the power sector.

It is well known that our current energy mix is too costly. In the Power Sector, out of the total installed capacity, only about one third is accounted for by hydro power and the balance comes from thermal sources. The costly energy mix is not only at the root of the problem of circular debt but is also straining the macroeconomic environment. The costly mix contributes to excessive government borrowing from the central bank, inflation, depreciation of exchange rate, depletion of foreign reserves and higher trade deficit.

We know that hydro power is one of the cheapest sources of power and that huge hydro power potential is available in the country. Regrettably we have not been able to tap the potential due to lack of political consensus over large dams. Focus on small hydro power projects on the canal and river system will help increase the share of hydro power in the power mix. Reportedly the potential for this source is significant and the projects can be developed quickly with relative ease.

Coal based technologies and the nuclear technology offers cheaper ways of generating power and the government has decided to increase reliance on these sources for developing the cheaper energy mix. The environmental concerns associated with coal based thermal power projects are substantial, which call for using clean coal combustion technologies to conform to international standards. Similarly, one hopes that the best available safety measures will be introduced in the nuclear power plants.

Under the 18th amendment the provinces have been allowed to generate electricity but still the provinces have to look towards the centre for a host of issues like the sovereign guarantees. Given that almost all the potential for generating electricity is in fact located in the provinces, the number of power generation projects that the provinces have initiated and the megawatts of electricity that these would generate, is rather low. Perhaps greater attention is required to resolve the problems faced by the provinces in this regard. A dedicated intergovernmental forum involving the federal and provincial governments is called for to speed up the resolution of the issues being faced by the provinces in initiating power generation projects.

The renewable energy sources can be used in a decentralised setup which saves the investment required for extending the grid to the generation point. The added benefit of using alternate energy sources is that these are environment friendly. Therefore efforts should be made to use alternate energy sources like wind, solar and biomass to generate electricity. I am pleased to note that the letter of support for a 450 megawatt wind project has already been issued by the government and the feasibility of several wind, solar and biomass power projects is being assessed.

While we make efforts to bridge the demand-supply gap, we should be cognizant of the possibility that demand may increase rather rapidly. Currently we are using only a fraction of the per capita energy used in developed countries. Our per capita energy consumption at 489 kg of oil equivalent is even less than India's 575 kg of oil equivalent. This clearly suggests that demand may increase at a fast pace as the economy and the population grows. The measures aimed at meeting demand should keep in view the possibility of very rapid growth in demand for energy.

The severity of the power crisis should not be allowed to lessen our focus on the oil and gas sector and fortunately this has not happened. While the initiatives under consideration to import gas through pipelines are needed to meet the energy needs in the coming years we should continue to focus on oil and gas exploration for a sustainable supply over a long period of time.

Roughly around 29 trillion cubic feet of natural gas remains unexplored. To encourage exploration we need to revisit the policy in this regard. The well-head gas price has failed to offer adequate incentives to the exploration and production companies to explore indigenous gas resources. Though, the Petroleum Policy 2012 offers good enough well-head gas prices but still Pakistan is far behind the countries of the Asia-Pacific region in attracting upstream investments. Not only policies are fragmented, a uniform policy for exploration in all geographic locations of Pakistan, may not provide enough incentives, to explore and produce in difficult locations.

Shale Gas is relatively new area that calls for immediate policy attention. Crude estimates suggest that over 50 trillion cubic feet of Shale Gas in the lower Indus Basin and approximately 150 trillion cubic feet in the entire Indus Basin is available for exploration. However due to the inadequate policy incentives, absence of geological data, lack of know-how and lack of access to required technology, initiating the exploration of Shale gas seems difficult in the next few years.

Moreover with the emphasis upon altering the energy mix and relying more upon coal for power generation, the known coal fields need to be developed at a fast pace. This, however, requires huge capital investments in addition to transmission networks. Both require appropriate incentives from government.

So far I have discussed measures required to increase the supply of energy however managing demand is equally important.

Energy intensity in Pakistan is more than double the world average and more than five times that of Japan and the UK. Moreover, for each dollar of GDP, Pakistan consumes 15 percent more energy than India and 25 percent more than the Philippines.

A conservation culture should be inculcated right at the schools by emphasising upon and demonstrating conservation to the kids. The culture needs to be fostered by using energy efficient technology and equipments, designing energy efficient buildings and improving the efficiency of existing energy infrastructure. The chief merit of the conservation strategy is that it is environment friendly.

A conservation programme based upon use of energy savers is already underway. It is said that if all the 50 million consumers are converted to fluorescent bulbs a saving of 1000 megawatts is possible. If this is true, one should give a thought to enacting a legislation banning the manufacture and import of non-fluorescent bulbs thereby gradually phasing out their use.

While we put in efforts to alter the present costly energy mix and conserve energy, we should be cognizant of and stand ready to tackle sinister moves aimed at killing such initiatives. For instance, efforts were made in the past to blend fuel ethanol with gasoline. Evidence suggests that efforts from the oil lobby led to calling off this initiative.

Finally, Ladies and Gentlemen, the regulation of monopolies or industries that have few players is crucial to safeguard the interests of the consumers. The two regulators of the energy sector, NEPRA and OGRA are still young and need strengthening to become independent, transparent and strong regulators. For instance the NEPRA is primarily focused on determination of tariffs and licensing and has not indulged in making power producers efficient. Reportedly the thermal power plants in Pakistan consume substantially more fuel than power plants in Bangladesh and India. However, the NEPRA, despite enjoying the mandate, is yet to force the power producers, to augment the efficiency of their plants to international standards.

With privatisation of the electricity distribution companies and further privatisation in the oil and gas sector, the role of the regulator will become all the more crucial. It is very important that a sound institutional framework is developed to ensure that lobbying by the private sector does not influence the regulator. It will promote the cause of transparency if the NEPRA widely publicises the dates when the applications of the distribution companies for revision in tariffs are to be heard, so that the public, including experts may attend. It would also further the cause of transparency if the two regulators can widely publicise the detailed computation of price/tariff revisions. Public scrutiny of such tariff revisions will force the regulator to be more meticulous in determining tariffs.

Ladies and Gentlemen, I conclude with the hope that this conference will offer practical recommendations for alleviating the energy crisis.

I thank you for your patient hearing.

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The Quaid-i-Azam Lecture

Energy, Environment and Sustainable Development in South Asia

RAJENDRA K. PACHAURI

Honourable Federal Minister for Planning, Development and Reform, his excellency Mr Ahsan Iqbal, the President, Pakistan Society of Development Economists, discussants, Dr Ashfaque Hasan Khan and Dr Rehana Siddiqui, Dr Durr-e-Nayab, distinguished ladies and gentlemen, let me say at the outset that it is a great privilege for me to be here and to be given this opportunity to deliver the Quaid-i-Azam Lecture. I regard this as a signal honour and I feel particularly privileged coming from India being able to speak in honour of the Quaid-i-Azam, the founder of this country. I want to express my gratitude for this particular privilege which I have been given. I also want to acknowledge the very warm sentiments expressed by his Excellency the Minister. I certainly believe that in this day and age we have to look forward, we have to look at the future and I think we have to erase some of the problems, demolish some of the barriers and the hindrances that have prevented South Asian cooperation in the past. So Sir, your words in that context are certainly appreciated and I would say that we have to put them into effect by ushering in a new future for this region. I want to mention that when I had the privilege of accepting the Nobel peace prize on behalf of Inter-governmental Panel on Climate Change (IPCC) in 2007 along with Mr Al Gore, in my acceptance speech I used a Sanskrit phrase which is Vasudhaiva Kutumbakam and that means the universe is one family. Now if the universe is one family, may I submit that, we particularly in Pakistan and India are really the core of that family. I believe the future lies in our ability to develop a model of economic growth and development that serves as an example for the rest of the world.

Let me at the very outset say that we have been somewhat negligent and perhaps short sighted in emulating what has been established as a form of development in other parts of the world and I will say a little more about this as I move on. Let me start by referring to the definition of sustainable development which essentially comes out of the work of the Brundtland Commission that was completed in 1987 and it's a very simple definition. It defines sustainable development as that form of development which allows the current generation to meet their own needs without compromising on the ability of future generations to meet their own needs. So, therefore, it essentially takes into account the issue of intergenerational equity. Whatever we do today should not be selfishly oriented by which we might meet more than our needs today but we certainly make it

Rajendra K. Pachauri <pachuri@teri.res.in> is Chief Executive, The Energy and Resources Institute (TERI), New Delhi, India.

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difficult for future generations to be able to meet their own needs. May I also submit that the emphasis here is on needs, which of course is a very difficult concept to really come down to grips with. A billionaire's needs or what he calls needs might be very different from the needs of a poor person who has to look for his next meal. However, I think both in terms of humanitarian as well as purely biological considerations we can define certain needs which include adequate nutrition, shelter and livelihood.

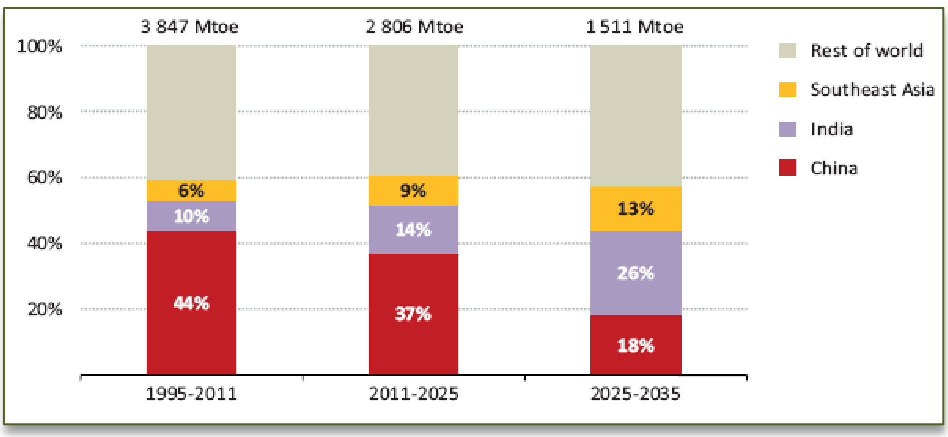
I believe that in coming up with directions for the future we would necessarily have to keep in mind the concept of sustainability. Now this was also something that was clearly articulated in the very first conference on the human environment which was held in Stockholm in 1972, and to a large extent it was also given attention in the Rio plus Twenty (Rio+20) conference which took place last year. But may I say the world has moved on in several respects but it has not moved on in several other aspects. Now this is why I would like to refer to what is known as the *tragedy of the commons*, a tragedy which you see around you everywhere. This was a concept that was perpetrated by a biologist of all people and to my mind it represents a very powerful new way of looking at economics. The *tragedy of the commons* was defined by Garrett Hardin who as I said was a biologist and I quote from what he wrote. He said, "The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is the day when the long desired goal of social stability becomes a reality. At this point the inherent logic of the commons remorselessly generates tragedy". Because essentially what he is trying to say is that global commons, whether it is the air that we breathe, the forest and the pastures which are open to the use of various societies and communities or for that matter the water that flows through our rivers and oceans from which we derive a lot of benefits are commons. They are resources that everybody benefits from but nobody has responsibility for looking after. If we exploit them to a level where they get damaged and degraded, then that clearly represents a tragedy and that also defines the conditions that go against the very concept of sustainable development. If you degrade and damage these common resources then clearly future generations are going to find it very difficult to be able to meet their own needs.

This is something that Amartya Sen and Sudhir Anand have talked about. As they say, and I quote, "It would be a gross violation of the universalist principle if we were to be obsessed about intergenerational equity without at the same time seizing the problem of intergenerational equity". There is a terrible problem of poverty in our part of the world and clearly that is also something that goes totally against the concept of sustainable development. Our society has stark disparities and large number of people are living in abject poverty. In India this is a reality that you see despite the fact that we have had fairly healthy growth over the last fifteen odd years. The fact, however, is that we still have a very large number of people in India who are living in abject poverty. Now that clearly goes against the very concept of sustainable development because the society which has these disparities cannot possibly be a sustainable society. It will have tensions. It will have conflict and it will certainly have inherent in it the problems that often spill over borders as well, and I think we need to be concerned about the multifarious impacts of poverty that make it one of the worst problems that we have and therefore, the most important challenges for us to meet.

Sustainable development can reduce vulnerability to climate change, and here let me introduce the concept of climate change. In my view, climate change is one of the biggest threats we face across the globe that imperils and endangers the possibility and potential of sustainable development. For making development more sustainable we need to enhance mitigative and adaptive capacities, reduce emissions and also reduce vulnerabilities, but there may be barriers to implementation. The point I would like to get across is that if we were to integrate the challenge of meeting the problem of climate change and facing that challenge effectively through adaptation as well as mitigation efforts then clearly that would also define a sustainable path of development.

Let me now move to the concept of planning for energy within the context of sustainable development. Energy is something which is essential to development and in our part of the world we have some serious challenges in that regard. I would like to focus now on some of the serious challenges that the world as a whole and certainly we in South Asia face in respect of meeting the energy problem. If you look at Figure 1, you see the share of the growth in world primary energy demand by region in the new policy scenario. This new policy scenario is a progressive scenario developed by the international energy agency and published in the *World Energy Outlook*. What this shows clearly is, as you would notice, that how energy is going to change over a period of time. If you look at the period from 1995 to 2011 you have a 44 percent of the total energy being consumed by China. By 2011 to 2025 it goes down to 37 percent of the total and is projected that by 2025 to 2035, China's share would go down to 18 percent. On the other hand India's share is going up quite sharply and I would say that it will also apply to the rest of South Asia. It is unfortunate that we do not have projections for South Asia as a whole and that to my mind is symptomatic of the lack of cooperation that we have. Certainly in respect of defining our challenges and the problems that we should meet in the future, this kind of joint exercise would be extremely helpful. If you look at Southeast Asia their share also goes up significantly and the rest of the world by and large stays more or less constant. The South Asian region, I believe, is certainly going to be the driver that is going to account for changes in the energy market of the world.

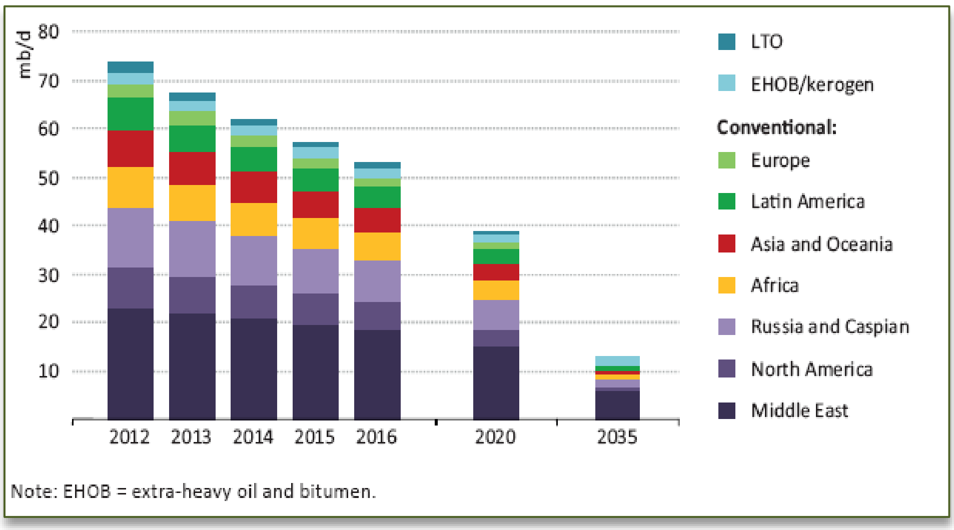
Fig. 1. Share of the Growth in World Primary Energy Demand by Region in the New Policies Scenario



Source: WEO (2013).

Figure 2 shows something that clearly is of common interest to all of us and certainly to us in South Asia. It shows the production that would be observed from all currently producing fields in the absence of any further investment. Now this is not to say that there would not be further investment. I want to point out to you that in North America for instance you have got a major revolution which has taken place with the exploitation of shale gas. Deep sea drilling for exploration of oil is becoming quite common but may I submit that it carries a number of environmental and other risks. You would be aware of what happened at the deep water horizon well in the Gulf of Mexico about 3 years ago, when as a matter of fact the amount of damage that took place as a result of the oil spill that occurred has still not been mitigated effectively and BP which was the company responsible for that well is still facing a lot of litigation and paying out large sums of money to be able to meet the legal demands of its responsibility. So the point I would like to make is that the new areas where oil is to be explored for and drilled are going to be increasingly difficult and perhaps fraught with technical as well as economic risks that we have to keep in mind. The arctic ice is melting as a result of climate change. That region is being looked on as a very attractive area for exploration and drilling but may I submit that it will carry several environmental hazards. The reality is that whether it is 10 years, 20 years or 30 years, the depletion of oil is certainly going to raise the price of oil over a period of time.

Fig. 2. Production that would be Observed from All Currently Producing Fields in the Absence of Further Investment (Excluding NGLs)



Source: WEO (2013).

For energy security, while we do need to move ahead with some large projects which are essential for our countries, there are ample opportunities to bring about improvements in energy efficiency and also to be able to exploit renewable sources of energy particularly on a decentralised basis but not confined only to decentralised sources. Here if I could deviate just for a minute and introduce my institute, The Energy and Resources Institute (TERI). It is a fairly large non-profit organisation, now having a staff of over twelve hundred people with a presence in several parts of the world. We have launched a programme called Lighting a Billion Lives, which essentially addresses the stark reality of 1.3 billion people in the world who have no access to electricity. This to my mind is in some sense worse than the tragedy of the commons because well over a hundred years ago Thomas Edison discovered the filament incandescent lamp but you still have 1.3 billion people who have never seen a lamp light up or do not have a lamp in their homes in the twenty first century. So what we are doing is to implement solutions at the grassroot level in a number of villages in India as well as in Africa, and I would submit that even though Pakistan has a large number of villages that are electrified there might still be opportunities for implementing some of these renewable energy solutions. I will just take a minute to describe one such solution. We train women in a village to install a solar panel on the roof. She charges about fifty odd lanterns during the daytime and rents them out to the whole village at night, and they come back to her in the morning to get the lamps recharged again. The benefits are that people in villages can work longer hours, and children can do their homework over clean, pollution-free and totally reliable lighting. They also have health benefits because otherwise people are sitting around a kerosene lamp and inhaling all those toxic fuels. That is just one example of what can be done, and what I wanted to point out over here is the imperative of energy independence. We really need to set out on a direction by which we reduce and minimise our consumption of fossil fuels, and this of course will require changes on the demand side as well, for instance in the transport sector. We know that the proliferation of personalized motor vehicle is something we all aspire but in essence if we were to provide good public transport options people would not drive to work in their own cars.

The total energy consumed by the SAARC countries shows large disparities, as can be seen in Figure 3. Some of those differences are inherent in the size of the countries of this region but the growth in energy use is somewhat even, as we can see from the graphs on the right hand side of Figure 3. There is in my view a very strong and compelling logic for us to work together in finding energy solutions. One of the things that we are doing in India, and my institute has been involved in carrying out its feasibility study, is to set up solar parks which would be about three thousand megawatts each and these would use concentrated solar power. The benefit of this is that most of the equipment can be fabricated within the country itself and, therefore, the cost would be substantially lower than if we were to import all the equipment that is needed. I was very happy to see the honourable Chief Minister of Punjab show lots of interest in the Cholistan Region in Punjab. I believe it is a perfect region for the purpose as it has plenty of land, very high levels of insulation and, therefore, solar energy could be an option but before that there are also options for photovoltaic. The benefit of a country of the size of India is that we can exploit economies of scale. If there is trade between the two countries, including that of energy, it would be possible to ensure that if you set up a plant in Cholistan, using large scale power generation on the solar source, then you need not consume all that electricity yourself, part of it could be exported to India due to growing demand there over time. So I think some of these renewable energy solutions clearly would benefit from cooperation across all of South Asia.

Fig. 3. Energy Consumed by SAARC Countries

Country	Energy Consumption in Quadribillion Btu	Previous Trends (History)
Pakistan	2.561	1980-2011
India	23.611	1980-2011
Afghanistan	0.104	1980-2010
Nepal	0.084	1980-2010
Bangladesh	1.013	1980-2011
Maldives	0.015	1980-2011
Sri Lanka	0.228	1980-2010
Bhutan	0.057	1980-2010

Source: US Energy Information Administration website.

At TERI we have carried out very extensive energy economic modelling for India and we have got a number of very detailed models for the country as a whole and we have come up with different scenarios as presented in Figure 4 for the year 2031. The bar on the extreme right hand side of Figure 4 is particularly important because it comes up with solutions that would be low cost, assuming technological developments in the renewable energy field. This is going to happen because cost reduction in renewable energy is around the corner which would lower the production costs. So my submission is that each of us, perhaps on an integrated basis, should carry out a detailed exercise on the choices that we have in the energy sector by which we can minimise the total cost of energy supply and also ensure a much higher level of energy security by exploiting those particular sources of energy that are in abundance. With this the benefit that you would see is the substantial reduction in fossil fuel dependency across scenarios (see Figure 5). It should be one of the objectives of any energy policy that we must reduce such imports simply because we have an abundance of solar energy, in some cases wind and certainly biomass. Agriculture residual is also a significant source of energy supply and I think with the technologies that research and development is now trying to develop it would be possible to produce even liquid fuels from agriculture residual.

Fig. 4. Distribution of Primary Commercial Energy Supply—2031 India

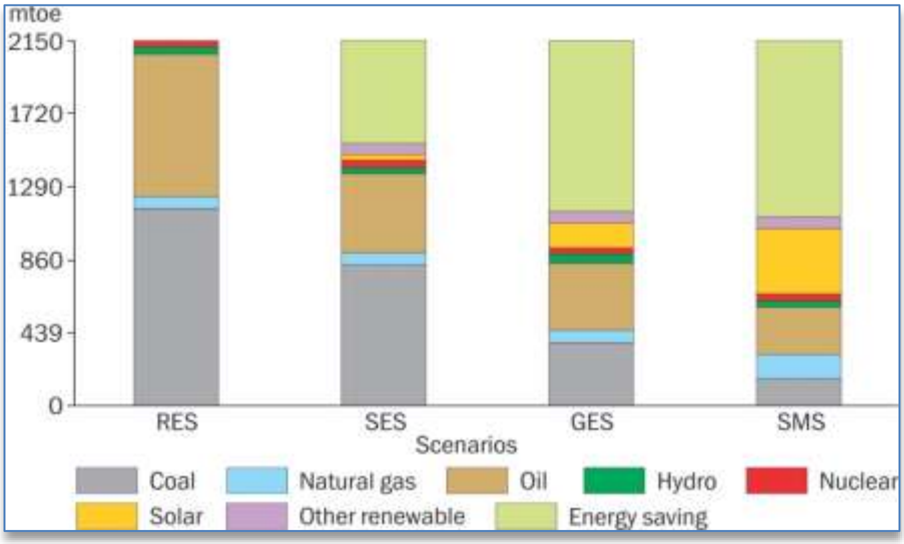
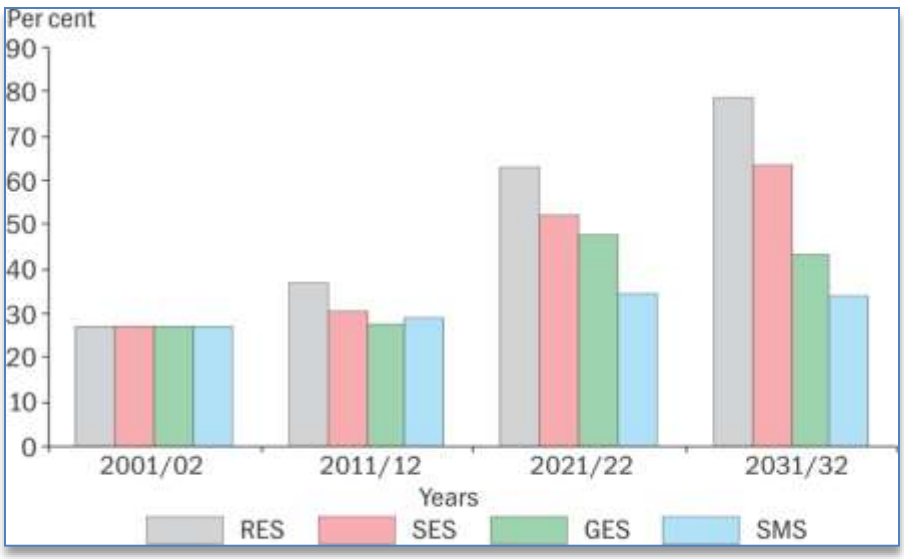
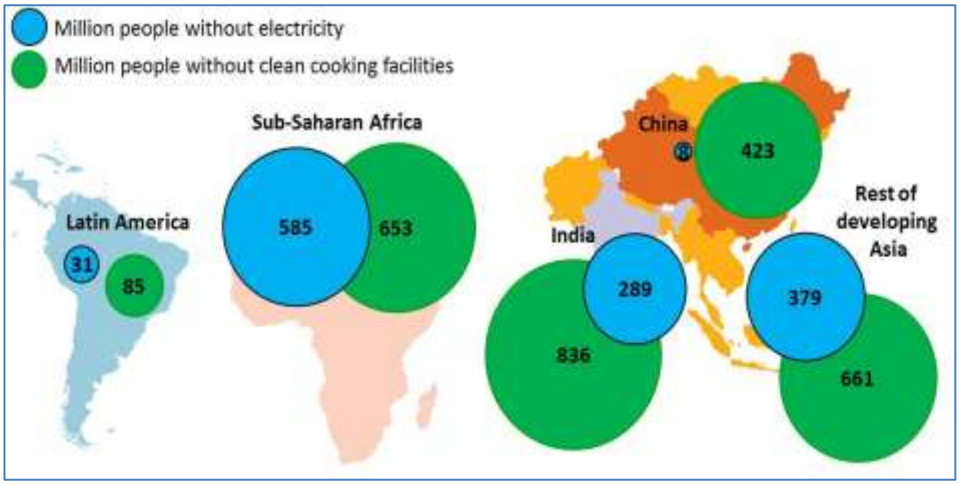


Fig. 5. Fossil Import Dependency Across Scenarios—India



The stark reality is that energy poverty is very wide spread. A large number of people, around 1.3 billion as I have told you about, have no access to electricity and more than twice the number who are totally dependent on biomass for cooking and other domestic applications. That to my mind is again a massive tragedy as those burning biomass in the house are often living in little huts where you have very poor ventilation. Women and children in particular inhale large quantities of these forms of pollutions and they have very serious health problems as a result. So there are enormous benefits in moving to clean renewable forms of energy.

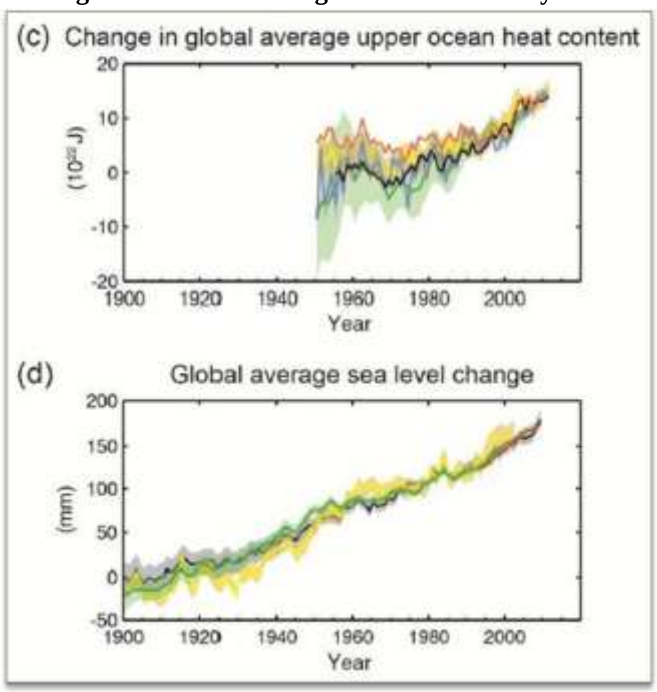
Fig. 6. Energy Poverty is Widespread



There are also other environmental problems that we need to address. These include: increasing air pollution that largely comes from transport and biomass; indoor air pollution; rivers, wetlands and ground water reserves being polluted; depletion of ground water; deforestation and loss of biodiversity; and degradation of soil. Soil is something we get from nature literally as a free gift. If we are going to deplete that then clearly we have to substitute that with chemical fertilisers which in themselves have serious problems. We carried out a very detailed exercise in 1997, on the eve of the fifty years of independence of India, and this created a major stir because we found that India was losing over 10 percent of its GDP on account of pollution and environmental cost. The loss of agricultural output due to soil degradation was between 11 to 20 percent. Decline in water availability was very serious and in fact in 1997 it had gone down to about one third its value since the time of independence, and we projected that it will go down even further to about two thirds of the value it had in 1997 over time in 2047. May I submit here that we really need to come up with the path of development which is resource efficient, which ensures that we maintain our natural resources and that we minimise environmental degradation and damage. Here I would like to invoke a little anecdote of Gandhi which is one of my favourite anecdotes. Gandhi-ji was once asked would if he like India to become as prosperous as Britain and his answer was, "It took Britain half the resources of this planet to achieve this level of prosperity. How many planets will a country like India require?". We have to accept the fact that even though technology and human ingenuity makes possible for us to exploit resources almost on an unlimited basis, there is finiteness in resources. There is a certain quality that we have to maintain whether it is the air that we breathe, the water that we drink or the soil on which we grow our crops. My submission, therefore, is that South Asia has to evolve a pattern of development that is highly resource efficient and can serve as a model for the rest of the world.

This brings us to the problem of climate change and why is it that we need to take that into account very seriously in our development planning strategies. I had occasion to fly over Pakistan in the year 2010 and it was a very clear day. What I saw below me was something that I just could not believe. A huge area of land was under water, muddy water, so not only were you losing water but also losing very rich top soil. That is a major loss quite apart from the fact that this was a major threat to life and property. I want to submit to you that we at the Inter-governmental Panel on Climate Change (IPCC) have projected that extreme events are going to increase in the future. It is virtually certain that the upper ocean, that is 0 to 700 meters, has warmed from 1971 to 2010 and the rate of sea level rise since the mid nineteenth century has been larger than the mean rate during the previous two millennia (see Figure 7). Why is sea level rise taking place? It is because of thermal expansion of the ocean with warming and also the melting of the bodies of ice across the globe—over the period 1901 to 2010 global mean sea level rose by 19 cm. That is close to a foot and definitely something to worry about.

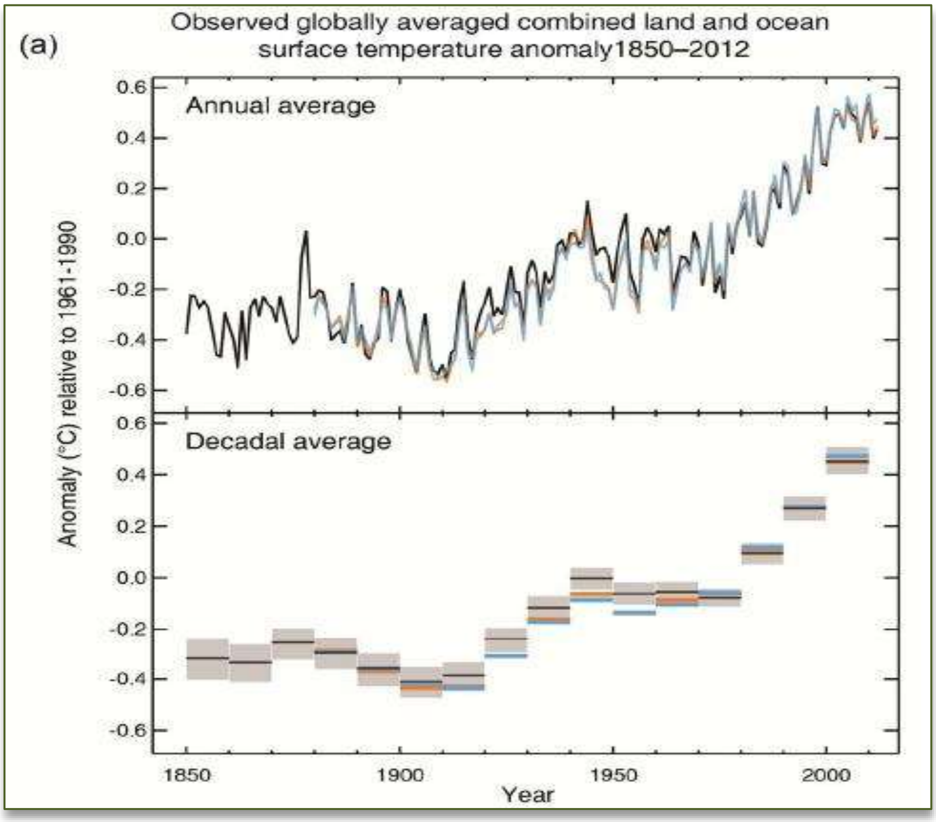
Fig. 7. Observed Changes in the Climate System



Source: IPCC AR5.

If you look at the Maldives islands, most of the island, in over a thousand plus islands, are just about a meter high, or may be a little more, and if the sea level rises by one foot that clearly represents a major threat to that nation as also to low line coastal areas everywhere else in the world. I also want to draw your attention to the fact that since the 1950s many of the observed changes have been unprecedented over the last millennia (see Figure 8). The atmosphere in the oceans are warm, the amounts of snow and ice have diminished, sea level has risen, the concentration of greenhouse gases has increased and each of the last three decades has been successively warmer at the earth surface than any preceding decade since 1850. So we are affecting the climate of this planet in a very serious way.

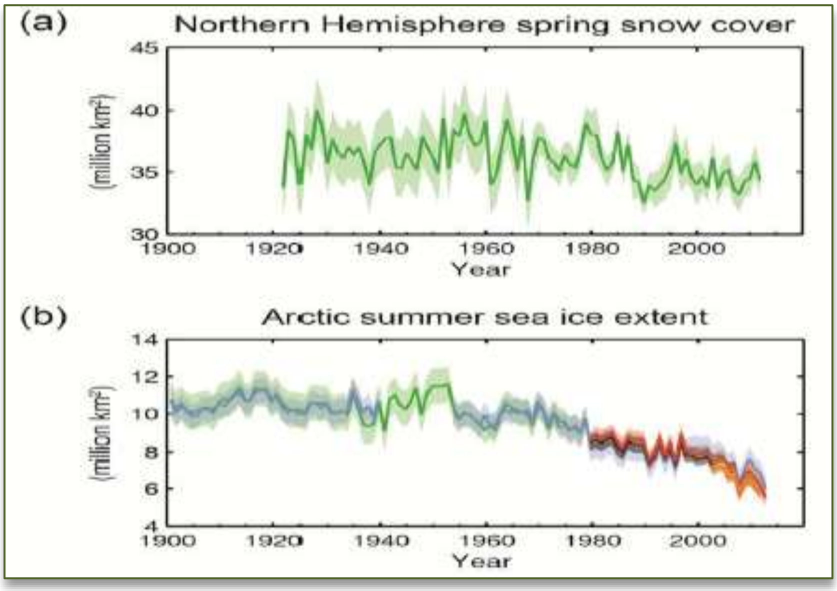
Fig. 8. Warming of the Climate is Unequivocal



Source: IPCC AR5.

Over the last two decades, I want to highlight the fact that, the Greenland and the Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease rapidly. The arctic region was covered entirely with ice not so long ago but not any longer. Since the early 1970s, glacial mass loss and the ocean thermal expansion as a result of warming explain about 75 percent of the observed global mean sea level rise, as can be seen in Figure 9. The increase in carbon-dioxide concentration from two hundred parts per million at the beginning of industrialisation has gone up to over four hundred part per million now. We in a short period of time, in the age of industrialisation, have affected the atmosphere of this planet to an extent where it is really leading to the very serious problem of climate change. The ocean has absorbed about 30 percent of the entire anthropogenic carbon dioxide causing ocean acidification. The overall human influence on the climate system is, therefore, very clear and it could be said with confidence that changes in total solar irradiance have not contributed to the increase in global mean surface temperature over the period 1986 to 2008. And of course, if we continue with increasing our emissions of greenhouse gases, climate change will become far more serious.

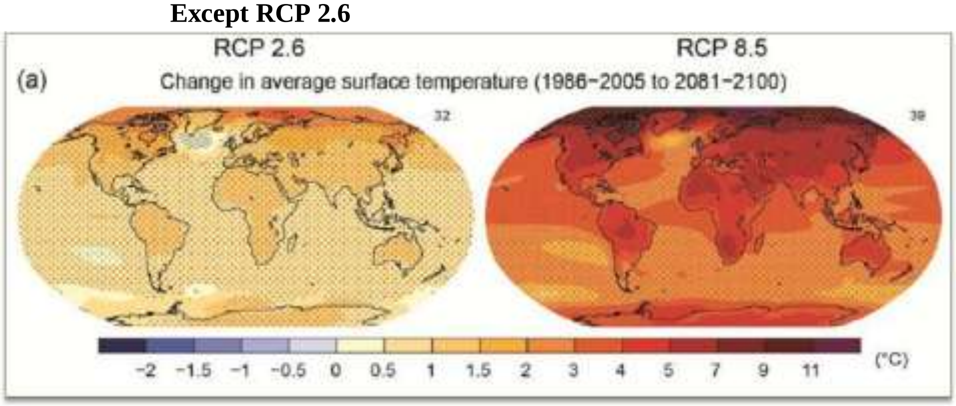
Fig. 9. Observed Changes in the Climate System



Source: IPCC AR5.

We have developed four different scenarios of economic growth and development for the future and Figure 10 presents two of these scenarios—the RCP 2.6 and RCP 2.8. The darker the shade in Figure 10, the higher the temperature. The lower emission scenario on the left hand side, which involves some very stringent mitigation of emission of greenhouse gases, gives you a much lower temperature increase but the one on the right hand side which involves low mitigation of emissions leads to very high temperature increase. In fact at the upper end of that range, by the year 2100 you would end up with the temperature increase of 4.8 degree Celsius and that can really play havoc with our ecosystem and all forms of life on the planet.

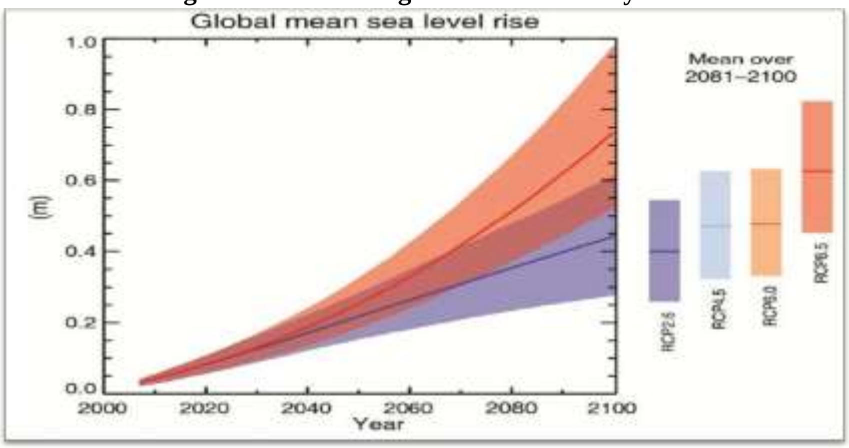
Fig. 10. Warming will Continue Beyond 2100 under All RCP Scenarios Except RCP 2.6



Source : IPCC AR5.

Figure 11 shows the global mean sea level rise under different scenarios and we see that the highest increase projected can get the sea level rise close to a meter, 0.98 cm to be precise. Clearly if that were to happen large parts of the globe would be submerged, and we would practically have a changed geography of the planet.

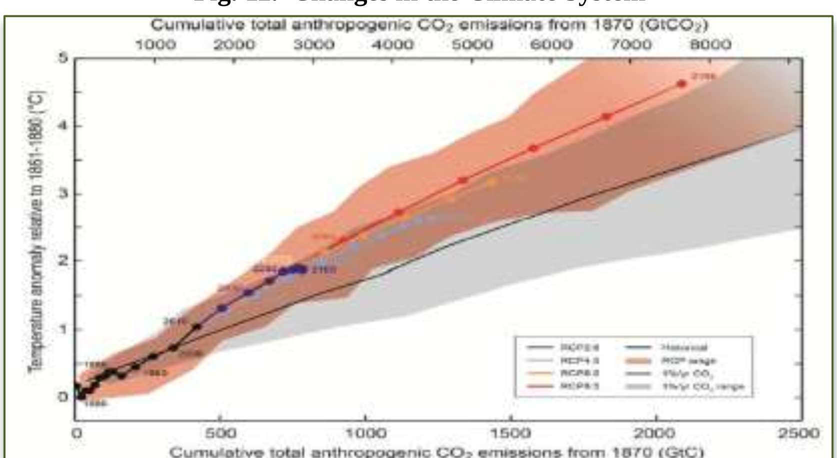
Fig. 11. Future Changes in the Climate System



Source: IPCC AR5.

Figure 12 gives changes in temperature that would take place and the global mean surface temperature increase that is shown here as the function of the cumulative total global CO_2 emissions from various lines of evidence. It is evident that there is a range because you cannot predict the future with perfect certainty but indeed what you find over here are temperature increases that would cause some very serious problems. As I mentioned earlier, at the upper end you could get a temperature increase of up to 4.8 degree celsius.

Fig. 12. Changes in the Climate System



Source: IPCC AR5.

A far more serious problem and consequences of climate change is the increase in extreme events during and by the end of twenty first century and here I want to highlight two types of extreme events. It is very likely that the length, frequency, and/or intensity of warm spells or heat waves will increase over most land areas. So much so that under some scenarios, a one in twenty year hottest day is likely to become a one in two year event in most regions. In other words, heat waves will increase to the extent that those heat waves which currently take place once in twenty years can occur in the future once in two years. What is even more serious, and I think this is something that in our part of the world we have to be concerned about, is the fact that it is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase over many areas of the globe. You could, thus, get very heavy rainfall as a result of which flooding is likely to become more frequent and more intense.

Countries like Bangladesh, China and India are susceptible to increasing salinity of their ground water and surface water resources due to increases in sea level. In India, gross per capita water availability will decline from 1820 cubic meter per year in 2001 to about 1140 cubic meters per year in the year 2050. There would also be serious impacts on human health. These include: malnutrition with implications for child growth and development; death, disease and injury due to heat waves; floods; storms; fires; droughts; diarrheal disease; and frequency of cardiorespiratory diseases. The projected climate change exposures are likely to affect the health status of millions of people particularly those with low adaptive capacity. Please do remember that there are a large number of people in the world who are living in the state of malnutrition. Partial loss of ice sheets on polar land could imply meters of sea level rise, major changes in coastlines and inundation of low lying areas. We also found that 20 to 30 percent of the species that we assessed were likely to be at risk of the extinction if increases in warming exceed 1.5 to 2.5 degree Celsius.

The interactions among climate change mitigation and adaptation and disaster risks reduction may have a major influence on resilient and sustainable pathways. We, therefore, have to create communities, we have to create cities that are sustainable and resilient and are able to meet the threats of climate change. I want to give you an example here. Little over a month ago we had a terrible cyclone which hit the eastern part of India in the state of Orissa. Ten years ago a cyclone of similar intensity hitting that region would have led to a loss of lives of hundreds of thousands of people but today with early warning system and government taking preventive steps they were able to protect life and property by giving people shelter and moving them to safer locations. This is a form of adaptation that I wanted to bring to your attention. All of us have to assess the impact of climate change in the future and start adapting to them and taking steps by which we can save life and property.

Some key findings of the special report we brought out highlight heavy precipitation events, warm/cold daily temperature extremes, heat waves and sea level rise. As I have already mentioned the fact that some scenarios show a one in twenty year heat wave becoming one in two years, and the trend in disaster losses unfortunately are very unfavourable for developing countries. Now total economic losses from natural disasters are higher in developed countries no doubt. Economic losses as a proportion of GDP are higher in developing and middle income countries, which have borne the highest burden. I also want to mention that the economic losses from weather and climate related disasters vary from year to year and place to place but overall have increased. In the year 2005 we had hurricane Katrina which hit part of the US, a city in New Orleans, and in that year total losses worldwide were about two hundred billion dollars. That is only the economic aspect but there is the loss of heritage, the loss of culture, the loss of lives and those things on which you cannot possibly put a dollar value. As it happens the fatalities are higher in developing countries and over the period of time from 1970 to 2008 these have been 95 percent in developing countries as opposed to five percent in developed countries.

Our development strategies have to focus on adaptation as well as mitigation because neither one nor the other alone is going to be able to help us meet the challenge of climate change and the cost of doing so is really very low. We have assessed the cost of mitigation that means reducing emissions of greenhouse gases. As it happens in 2030, the total cost of very stringent mitigation would be less than the three percent of the GDP which basically means that the level of prosperity or GDP growth that you would attain will be postponed by a few months or years at the most and that clearly is not a very high price to pay for saving lives and be able to take care of some of the worst impacts of climate change. In Table 1 below I want to focus on the top most line which shows that if we want to limit temperature increase globally by 2 to 2.4 degree Celsius, the CO_2 emissions will have to peak no later than 2015. Delayed emissions reduction significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts. So that is the challenge before the global society, and here I come to the importance of exploiting renewable sources of energy.

Table 1

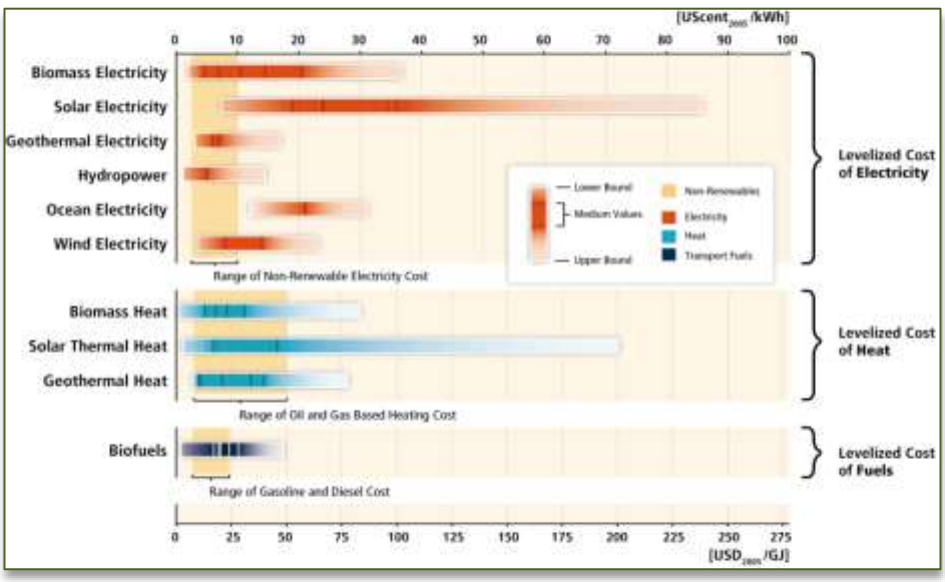
Characteristics of Stabilisation Scenarios

Stabilisation Level (ppm CO2-eq)	Global Mean Temp. Increase (°C)	Year CO2 Needs to Peak	Global Sea Level Rise above Pre-industrial from Thermal Expansion (m)
445–490	2.0–2.4	2000–2015	0.4–1.4
490–535	2.4–2.8	2000–2020	0.5–1.7
535–590	2.8–3.2	2010–2030	0.6–1.9
590–710	3.2–4.0	2020–2060	0.6–2.4

Source: IPCC AR4.

We carried out a detail study at the IPCC and brought out the report on renewable energy resources and climate change mitigation and found that in several applications, renewable resources of energy are already economically viable. If we look at the left hand side of Figure 13 we see a band which represents the cost of conventional forms of energy. In those applications you could find that the renewable energy overlaps with that band, which in other words mean that the costs are identical and very favourable and, therefore, I think the time has come for us to look at these opportunities and achieve economies of scale and cost reduction through technological up-gradation. The future really belongs to renewable sources of energy and the sooner we move on that path the better. We actually carried out an assessment of how renewable energy can contribute to total energy supply. We assessed 164 different scenarios which have been produced by scholars and researchers and found that the range varies. According to this assessment, at the upper end by 2050, the world could get almost 80 percent of its energy needs from renewable resources. By implication this means that we have to put in place policies today which promote research, development, commercialisation and large scale installation of renewable energy devices. We have to basically overcome a number of barriers if we want to bring about a transition to a high share of renewable energy. We would need investments in technologies and infrastructure and policies, of course play a crucial role and these policies include regulations for instance. What I would propose is, let us say a city like Islamabad or Lahore can go in for a large scale roof top solar programme with buyback arrangements. You would, of course, have to make some improvements in the grid to be able to buyback power when people are not consuming it on their own. We have reached the point today with photovoltaic prices where this could be a very attractive option. So I think if we can come up with some of these solutions it would help alleviate the problem to a large extent. What we really need is a set of enabling policies.

Fig. 13. Costs of Renewable Energy and Existing Energy Prices



Source: IPCC SRREN.

Mahatma Gandhi rightly said, “We may utilise the gifts of nature just as we choose but in her books the debits are always equal to the credits”. So my submission is that when we devise development policy we have to keep in mind that at present stock of natural resources does not enter the GDP system. We have to put in place accounting systems through which we see how our policies are really affecting the stock of natural resources and the quality of natural resources because neglecting them clearly go against the very concept of sustainable development and have an unfavourable impact on the generations to come. This is a responsibility that we have to shoulder. We have to ensure that the future generations do not justifiably have a basis to blame us for leaving a planet to them that is degraded, that is denuded and that has destruction of the ecosystem on which all forms of life depend. There is no religion in the world that does not highlight the importance of taking care of nature, '*qudrat'* and what we have inherited from those before us.

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The Allama Iqbal Lecture

Sustainable Energy Development (SED)—
New Path for Pakistan

MOHAN MUNASINGHE

1. BASIC FRAMEWORK

1.1. Background

Following the 1992 Earth Summit in Rio de Janeiro, the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, and the 2012 Rio+20 Earth Summit in Rio de Janeiro, sustainable development has become a widely accepted concept. World decision makers are seeking a more sustainable development path through the ongoing UN Post-2105 Agenda discussions, which includes key themes like the Green Economy (GE) and the Sustainable Development Goals (SDG). They are hoping to find integrated solutions to many critical problems, including traditional development issues (such as energy scarcity, economic stagnation, poverty, hunger, and illness), as well as newer challenges (like climate change and globalisation).

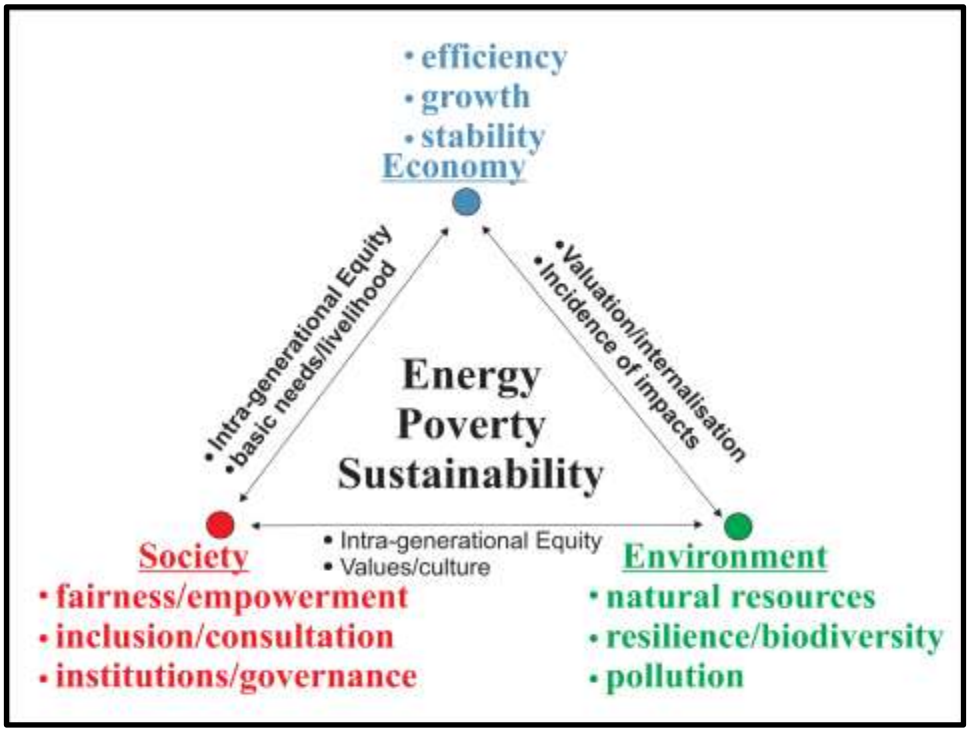
Energy is critical for sustainable development. Sustainable energy development (SED) is an operational framework involving the harnessing of energy resources for human use, in a manner that supports lasting development [Munasinghe (1995)]. We begin with a review of sustainable development itself, before describing the key role of energy. The World Commission on Environment and Development originally defined it as "development which meets the needs of the present, without compromising the ability of future generations to meet their own needs", and there have been many subsequent re-definitions.

Given the lack of an operational approach or practical framework that attempts to define, analyse, and implement sustainable development, Munasinghe first proposed the Sustainomics framework at the 1992 Rio Earth Summit, as "a transdisciplinary, integrative, comprehensive, balanced, heuristic and practical meta-framework for making development more sustainable" [Munasinghe (1992, 2002, 2010)]. One key element of this approach is the widely-accepted sustainable development triangle shown in Figure 1. It encompasses three major perspectives—economic, social and environmental. Each viewpoint corresponds to a domain (and system) that has its own distinct driving forces and objectives. The economy is geared towards improving human welfare, primarily through increases in consumption of goods and services. The environmental domain

Mohan Munasinghe <mohan@mindlanka.org> is Founder Chairman, Munasinghe Institute for Development (MIND), Colombo, Sri Lanka.

focuses on protection of the integrity and resilience of ecological systems. The social domain emphasises enrichment of human relationships, achievement of individual and group aspirations, and strengthening of values and institutions.

Fig. 1. Sustainable Development Triangle—Harmonising Economic, Social and Environmental Dimensions



Source: Munasinghe (1992).

Meanwhile, energy has emerged as a key resource, which interacts critically with the economic, social and environmental dimensions of sustainable development. First, it has long been perceived as a major driving force underlying economic progress, and in turn, economic growth itself further stimulates energy demand. Second, energy production and use are strongly interlinked with the environment. Third, energy is a basic human need, which significantly affects poverty and social well-being. Recently, growing energy demand has also become associated with global climate change—posing an unprecedented challenge to humanity. The wide-ranging inter-linkages between energy and sustainable development are analysed in this article, especially the role of renewable energy.

1.2. Risks to Current Development Prospects

The world is currently facing multiple economic, social, and environmental threats, which can interact catastrophically, unless they are addressed urgently and in an integrated fashion—by making development more sustainable [Munasinghe (2009)]. Piecemeal responses have proved to be ineffective, since the problems are interlinked. Sustainable Energy Development (SED) is a key part of the solution.

Economic, Social and Environmental Threats

The economic collapse is the most urgent and visible global problem (Figure 2). An asset "bubble" driven by investor greed rapidly inflated the value of financial instruments well beyond the true value of the underlying economic resource base. The collapse of this bubble in 2008 caused the global recession [OECD (2009) and Taylor (2009)].

Fig. 2. Multiple Global Crises and Human Priorities

Source: Author.

Major social problems of poverty and inequity are also shown in Figure 2, which continue to undermine the benefits of recent economic growth, excluding billions of poor from access to productive resources and basic necessities [World Bank (2009)]. In 2000, the top 20 percentile of the world's population by income, consumed 60 times more than the poorest 20 percentile [Munasinghe (2010)]. Economic recession now exacerbates poverty, worsening unemployment and access to survival needs.

Finally, mankind faces major environmental problems, because myopic economic activities continue to severely damage the natural resource base on which human well-being ultimately depends [MA (2005); UNEP (2008); UNEP (2011)]. Climate change is one major global outcome, but equally serious issues are the degradation of local water, air, and land resources. It is a potent risk multiplier, systematically worsening the other crises described earlier. Ironically, the worst impacts of climate change will fall on the poor, who are not responsible for the problem [IPCC (2007)].

Unfortunately, our current policy priorities are inadequate to face these challenges. Governments very quickly found over six trillion dollars for stimulus packages to bail out rich banks and boost consumption [G20 (2009)]. However, only about 100 billion dollars per year are devoted to poverty reduction, and far less to combat climate change [World Bank (2009)]. Annual military expenditures at almost $2 trillion are 20 times larger than development aid. The asset bubble (over $100 trillion) far exceeded annual global GDP ($60 trillion), while the high share of trade (>30 percent) in GDP underlines global connectivity that increases systemic risk. Furthermore, the recession has dampened enthusiasm to address more serious sustainable development issues.

1.3. Elements of Sustainomics

In the sustainomics framework, sustainable development is described as a process for improving the range of opportunities that will enable individual human beings and communities to achieve their aspirations and full potential over a sustained period of time, while maintaining the resilience of economic, social and environmental systems. The precise definition and implementation of sustainable development remains an ideal, elusive (and perhaps unreachable) goal. Sustainomics proposes a less ambitious, but more focused and feasible strategy that merely seeks to *'make development more sustainable'*. Such an incremental (or gradient-based) method is more practical, because many unsustainable activities are easier to recognise and eliminate. This approach seeks continuing improvements in the present quality of life at a lower intensity of resource use, thus leaving behind for future generations an undiminished stock of productive assets (i.e., manufactured, natural and social capital) that will enhance opportunities for improving their quality of life.

Decision makers are invariably pre-occupied with immediate problems like growth, poverty, food security, unemployment, and inflation. The best method of seizing their attention is to pursue an integrated approach that addresses all these issues within a broad national sustainable development strategy. Economic analysis has a special role in national policy making, since many important decisions are economic ones. The practical and holistic Sustainomics framework (Box 1) seeks to overcome the shortcomings of mainstream (neoclassical) economic policy-making, which often ignores many crucial environmental and social aspects.

Box 1.

Principles of Sustainomics

First, making development more sustainable (MDMS) becomes the main goal. It is a step-by-step method that empowers people to take immediate action, which is more practical because many unsustainable activities are easy to recognise and eliminate—like conserving energy. While implementing such incremental measures, we also continue parallel efforts to achieve long term sustainable development goals. One key test for potential climate policies would be whether they would make development more (or less) sustainable.

Second, policy issues need balanced and integrated analysis from three main perspectives: social, economic and environmental (described earlier in Figure 1). Interactions among these three domains are also important.

Third, we need to transcend conventional boundaries imposed by values, discipline, space, time, stakeholder viewpoints, and values. It is essential to replace unsustainable values like greed and selfishness with sound ethical principles including altruism and enlightened self-interest—this is a longer term task involving education, communication and leadership, especially focusing on the young. Trans-disciplinary analysis is needed to find innovative solutions to complex problems of sustainable development and climate change that cut across conventional disciplines. Spatial analysis must range from the local to the global—typically from the community to the trans-boundary river basin and planetary scales. The time horizon needs to extend to decades or centuries. Cross-stakeholder data sharing, transparency and cooperation (especially civil society and business working with government) need to be strengthened, by promoting inclusion, empowerment and participation.

Finally, the sustainomics framework uses a variety of practical full cycle tools—both new methods and conventional ones. They are applied innovatively to encompass the full operational cycle from initial data gathering to practical policy implementation, monitoring and feedback. Munasinghe (2002, 2010) describes practical tools of sustainomics at the global and national levels, including integrated assessment models (IAMs), macro- and sectoral-modelling, environmentally adjusted national income accounts (SEEA), poverty analysis, and the Action Impact Matrix (AIM). At the project level, other useful methods for sustainable development analysis (SDA) are cost-benefit analysis (CBA), multicriteria analysis (MCA), environmental and social assessment (EA, SA), and economic valuation of environmental and social impacts. At all levels, the choice of appropriate sustainable development indicators is also vital, derived from the basic economic-social-environmental metric (UNCSD 2007). The range of policy instruments includes both economic methods (like pricing, taxes and charges, tradable permits, investments and financial incentives), and non-economic ones (like regulations and standards, quantity controls, voluntary agreements, information dissemination, and research and development).

In general, sustainomics leads to the following solutions. First, wastes ought to be generated at rates within the assimilative capacity of the environment. Second, scarce renewable resources should be utilised at rates below the natural rate of regeneration. Third, non-renewable resource use rates should depend on the substitutability between these resources and technological progress. Both wastes and natural resource inputs might be reduced, by moving from linear throughput to closed loop (or recycling) mode. Finally, inter- and intra-generational equity, and poverty alleviation, pluralistic and inclusive decision making, and enhanced social values and institutions, are important additional considerations.

2. SUSTAINABLE ENERGY DEVELOPMENT (SED)

2.1. Linkages between Energy Use and Sustainable Development

Energy-economy Linkages

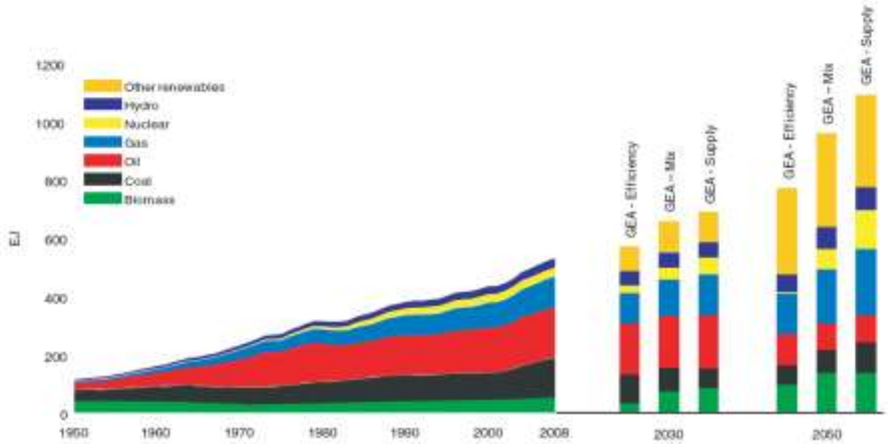
Energy has become a driving force for modern economies, with extensive use of commercial energy. Figure 3 shows that past energy supply has been dominated by fossil fuels like oil, natural gas and coal, while the share of renewable energy is expected to increase sharply from 17 percent in 2009 to 30-75 percent of total primary energy by 2050—in various future growth scenarios [GEA (2012)]. The main renewable sources in 2009 were traditional biomass and hydropower (Figure 4), but new renewables (like wind, solar, geothermal, and ocean energy) will dominate in 2050, since their technical potential is much greater (Figure 5) and relative costs will fall. An estimated US$260-1120 billion per year will need to be invested in renewables to achieve 2050 targets.

Technological progress and efficiency improvements have reduced the energy intensity of economic production (i.e., lower requirements of physical energy per unit of economic output). Electricity will continue to play an increasingly important role, as a safe, clean and convenient form of energy.

Energy-Environment-Society Linkages

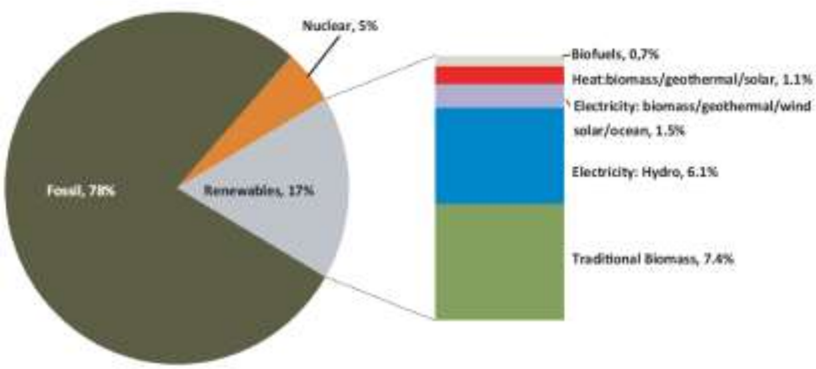
The environmental and social implications of energy use have not been as well analysed as energy-economy linkages. Complete life-cycle analyses of the mining, refining, processing, transport, conversion and transformation of various fuels like oil, coal and nuclear materials, all show significant impacts. While electricity has relatively few environmental and health consequences at the point of end use, key environmental and social issues arise from power generation, depending on the energy sources. Oil- and coal-fired plants not only have national impacts but also regional and global environmental and health effects. Even renewable energy sources, which are perceived to be “clean,” have some negative social and environmental impacts. Yet, access to affordable energy (especially electricity), yields substantial social benefits, often transforming the quality of life of poor households.

Fig. 3. Growth of World Primary Energy by Source 1950-2008, and Three Future Scenarios Developed by the Global Energy Assessment (GEA).



Source: GEA (2012).

Fig. 4. 2009 Shares of Energy Sources in Total Primary Energy—Renewables Provide 17 percent, Mainly Biomass and Hydroelectricity



Source: GEA (2012).

Fig. 5. Renewable Energy: Global Utilisation in 2005 and Technical Potential (Exajoules/Year)

Utilisation 2005 [EJ]	Technical Potential [EJ/yr]	
46.3	160–270	Biomass, MSW, etc.
2.3	810–1545	Geothermal
11.7	50–60	Hydro
0.5	62,000–280,000	Solar
1.3	1250–2250	Wind
–	3240–10,500	Ocean

Source: GEA (2012).

Transnational Issues

Acid deposition is perhaps the most serious of the transnational issues faced today. It is caused by oxides of sulphur and nitrogen that originate from fossil fuel combustion, falling to the ground as particulates and acid rain. Coal- and oil-fired power stations emit significant amounts of sulphur dioxide and nitrogen oxides into the atmosphere. The transport of sulphur dioxide occurs over distances more than 1000 km, across national boundaries. Acid depositions caused by sulphur and nitrogen oxides result in damage to trees and crops, and sometimes extend to acidification and destruction of aquatic ecosystems like streams and lakes. They also lead to the corrosion, erosion, and discoloration of buildings, monuments and bridges. Indirect health effects are caused by the mobilisation of heavy metals in acidified water and soil. Other important transnational issues include environmental and health impacts of radiation due to severe nuclear accidents, oceanic and coastal pollution due to oil spills, downstream siltation of river water in one nation due to deforestation of water sheds and soil erosion in a neighbouring country, and changes in hydrological flow and water conditions caused by dams.

Global Issues

The Intergovernmental Panel on Climate Change [IPCC (2007)] has identified that energy use is the major contributor to anthropogenic greenhouse gas (GHG) emissions—mainly CO_2 and other gases like N_20, CH_4 and CFCs that will lead to climate change and undermine sustainable development prospects. First, global warming poses a significant potential threat to the future economic well-being of the majority of human beings. Second, climate change will harm the poorest groups disproportionately, undermining social welfare and equity. Third, from the environmental viewpoint increasing anthropogenic emissions and accumulations of GHGs will significantly perturb a major global subsystem—the atmosphere. Climate change will also threaten the stability of a range of critical, interlinked physical, ecological and social systems and subsystems.

2.2. Framework for SED

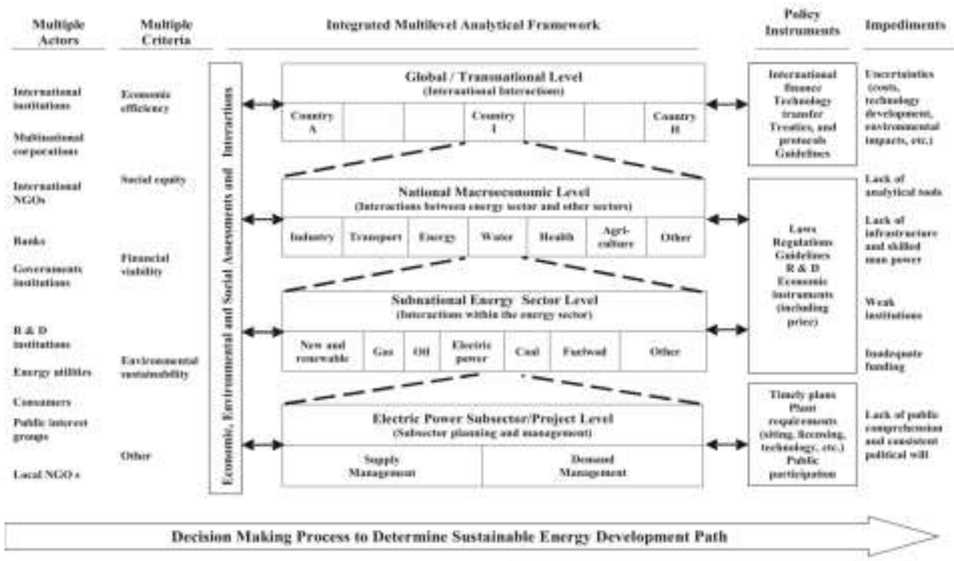
Sustainable development is the broad rationale underlying most national level planning and policy-making. Ideally, power and energy planning must also be part of and closely integrated with overall sustainable development strategies, to meet many interrelated and frequently conflicting national objectives. Specific goals for sustainable energy development might include: (a) ensuring economic efficiency in energy supply and use to maximise growth, including energy efficiency; (b) raising sufficient revenues from energy sales, to finance sector development; (c) socioeconomic concerns, like meeting basic energy needs of the poor, or developing special regions (particularly rural or remote areas) and priority sectors of the economy; (d) preserving the environment; (e) diversifying supply, reducing dependence on foreign sources, saving scarce foreign exchange, and meeting national security requirements; (f) price stability; etc.

Integrated Approach

Successful planning and implementation of national energy programmes must explicitly link the energy sector to sustainable development of other parts of the economy. An integrated approach will help decision-makers to formulate policies and provide market signals and information to economic agents that encourage more efficient and sustainable energy production and use, as shown in Figure 6a.

The middle column shows the core—a framework for integrated, hierarchical, multilevel analysis and integrated national energy planning (INEP) [Munasinghe (1988)]. The top level of SED recognises transnational linkages. Thus individual countries are embedded in an international matrix, and global economic, social and environmental conditions impose exogenous inputs or constraints on national decision-makers.

Fig. 6a. Sustainable Energy Development (SED) Framework



Source: Munasinghe (2010).

The second hierarchical level in the figure focuses on the multi-sectoral national economy, of which the energy sector is a part. Thus, energy planning requires analysis of links between the energy sector and other sectors, including energy needs of user sectors (like industry, transport, and agriculture), input requirements of the energy sector, and impacts of energy supply and pricing policies.

The next level of SED disaggregates the energy sector into sub-sectors such as electricity, petroleum products, coal etc. This permits detailed analysis, with special emphasis on interactions among different energy sub-sectors, substitution possibilities, and resolution of policy conflicts.

The lowest hierarchical level pertains to energy analysis within each energy sub-sector, where line institutions (both public and private) carry out detailed energy resource evaluation, planning and implementation of projects—including sustainability assessments.

In practice, the various levels of SED merge and overlap considerably, requiring careful study of (inter) sectoral linkages. Energy-social-environmental interactions (represented by the vertical bar) cut across all levels, and provide important paths for incorporating environmental and social considerations into national energy policies.

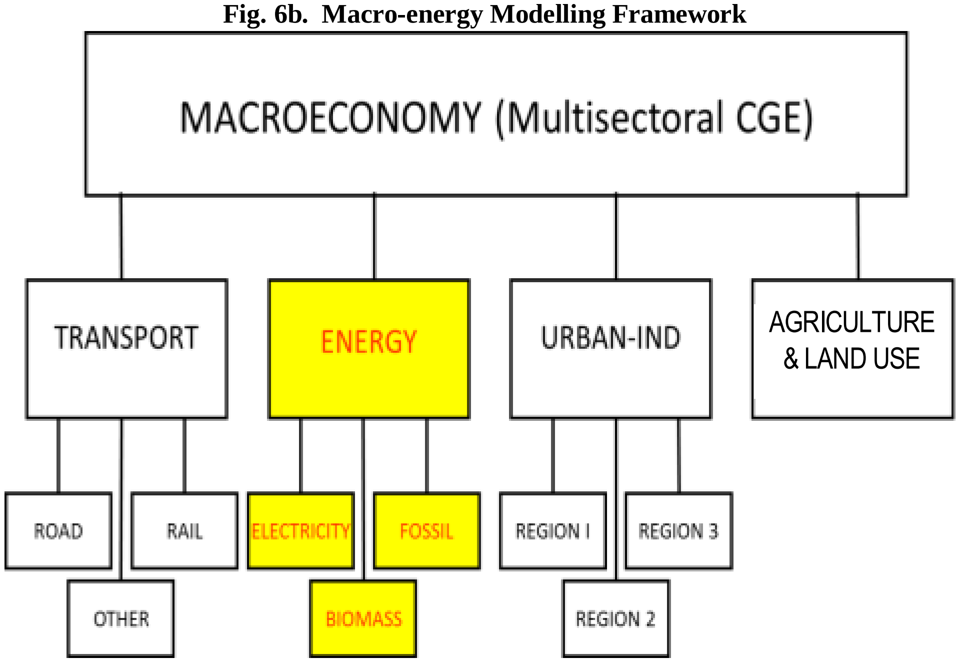
SED facilitates policy-making and does not imply rigid centralised planning. The process results in the development of a flexible and constantly updated sustainable energy strategy designed to meet national goals. This strategy (of which the investment programme and pricing policy are important elements), may be implemented through energy supply and demand management policies and programmes that make effective use of decentralised market forces and incentives.

In particular, SED implies improvements in overall economic efficiency through better energy management. Figure 6a shows various policy instruments available to decision-makers for implementing sound energy management. While formulating policy, one must consider the interests of multiple government, business and civil society stakeholders, ranging from international institutions to local energy users. This figure also indicates the most important impediments that limit the effectiveness of policies.

Investments offer a good opportunity to pursue sustainable energy development. In ten years, new plants will account for over half the industrial output of developing countries and in twenty years, for practically all of it. Therefore, it will be possible to have a major impact by putting in place policies, legislation, mechanisms, systems, and incentives that facilitate sustainable energy development.

A macro-energy modelling framework is needed to implement this approach—a typical example is shown in Figure 6b. A computable general equilibrium (CGE) multi-sector macroeconomic model links the energy supply and user sectors and shows impacts of broad macro-policies. The energy sector itself is disaggregated into different energy types, facilitating analysis of energy subsector interactions. Finally, each subsector is studied in detail using specialised submodels—e.g., the electric power sector is modelled in detail using a long term power system expansion planning model.

Fig. 6b. Macro-energy Modelling Framework



Source: Munasinghe (2010).

Identifying Sustainable Energy Options: “Win-Win” Options vs. Trade-offs

To identify sustainable energy options, policy-makers need to consider the economic, social and environmental aspects of sustainable development. Options that lead to improvements in all three indices are referred to as “win-win” options. Once “win-win” options are realised, policymakers are able to make tradeoffs among other available options.

Incorporating environmental and social externalities into energy decision-making is particularly important, where concerns (like pollution from nuclear or fossil-fuelled plants, and inundation at hydro plants) have hampered project implementation. Environmental and social concerns need to be addressed early—at the sectoral and regional planning stages, rather than at the final stage of project SDA. Unfortunately, when dealing with energy sector issues at this aggregate planning level, the application of many project-level valuation techniques becomes extremely difficult. First, the impacts are difficult to value (e.g., health effects of pollutants from coal-fired generating stations, biodiversity loss from large scale hydro storage, and impacts of greenhouse gas emissions). Doubts raised about the valuation techniques themselves, divert attention away from critical policy trade-offs. Second, many techniques appropriate at the micro-level, are less effective at the sector level. Thus, contingent valuation is more valid where respondents can be asked specific questions about local impacts of a project to which they can relate, and difficult to apply at the sector level where one deals with large numbers of technology, site and mitigation options.

In countries where inappropriate policies have encouraged wasteful and unproductive uses of some forms of energy, better energy management could lead to improvements in economic efficiency (higher value of net output produced), energy efficiency (higher value of net output per unit of energy used), energy conservation (reduced absolute amount of energy used), and environmental and social protection (reduced energy related environmental and social costs). However, it may not be possible to satisfy all the above goals simultaneously. For example, in some developing countries where existing levels of per capita income and energy consumption are very low, affordable energy might have a high priority, to meet basic energy needs.

The economic efficiency criterion which maximises the value of net output from all scarce resources in the economy (including energy) is usually applied through traditional cost-benefit analysis (CBA), which also subsumes purely energy-oriented objectives such as energy efficiency and conservation. Furthermore, costs arising from energy-related adverse environmental impacts may be included in the energy economics analytical framework by monetarily valuing such impacts, to determine how much other benefits society should be willing to forego, in order to avoid environmental damage. When valuation is not possible, methods like multicriteria analysis (MCA) could be used to supplement CBA.

Energy use and production may be improved in several ways to make them more sustainable. First, energy efficiency may be increased by supply and demand side improvements. Second, environmentally and socially more benign technologies can be introduced, including fuel switching and renewable energy sources. Finally, price, institutional and regulatory reforms could contribute to SED.

2.3. SED Options Matrix and Renewable Energy Costs and Benefits

Table 1 shows typical impacts of selected energy options on the three elements of sustainable development (+ is beneficial and – is harmful). While, efficient supply side options (e.g., reductions in T&D losses), have clear economic gains in terms of savings in capital investments and environmental benefits from reductions in greenhouse emissions that result from decreased energy supply, the social impacts are unclear. Efficient end-use options as shown in the case of an efficient fuelwood stove have benefits relating to all three elements. Although advanced technologies such as clean coal combustion technologies help reduce air pollutants such as CO_2 and NO_x that cause respiratory diseases and reduce productivity, many developing countries cannot afford such high cost technologies. Likewise renewable energy sources also provide environmental and social benefits by reducing a country's dependence on traditional fossil fuels. However, in terms of power generating costs, renewables may be more expensive than fossil fuels, especially if environmental and social externality costs are ignored.

Table 1

Selected Sustainable Energy Development (SED) Options Matrix I

	Impact		
Option	Economic	Environmental	Social
Supply Efficiency	+	+	
End Use Efficiency	+	+	+
Advance Technologies	–	+	+
Renewables	–	+	+
Pricing Policy	+	+	+/–
Privatisation/ Decentralisation	+	+/–	+/–

Broader social, environmental and economic benefits and costs associated more specifically with renewable energy options are summarised in Table 2.

3. APPLYING THE SED FRAMEWORK

In this section, practical case studies are presented which illustrate the application of the ideas presented earlier. While many sophisticated energy and electricity models exist for planning and policy analysis, we focus below on simpler SED examples linked to sustainability and renewable energy.

3.1. Global Scale: Carbon Mitigation, Energy Efficiency and Sustainable Development Paths

The energy-related problem involving greenhouse gas mitigation provides an interesting example of how such an integrative framework could help incorporate climate change policies within a national sustainable development strategy. The total GHG emissions rate (G) may be decomposed as follows:

$G = [Q/P] \, x \, [Y/Q] \, x \, [G/Y] \, x \, P;$

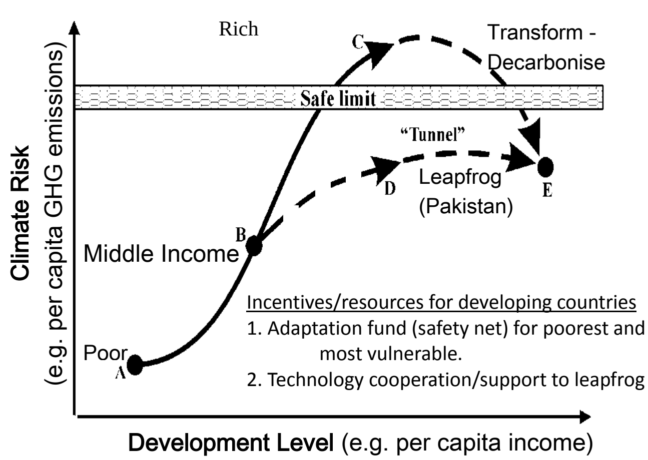
where [Q/P] is quality of life (Q) per capita; [Y/Q] is material consumption (Y) required per unit of quality of life; [G/Y] represents *GHG* emissions (G) per unit of consumption; and P is population.

A high quality of life is consistent with low total *GHG* emissions, provided that each of the three terms on the right hand side could be minimised. Reducing [Y/Q] implies 'social decoupling' (or 'dematerialisation') whereby satisfaction becomes less dependent on material consumption—through changes in tastes, behaviour and social values. Similarly [G/Y] may be reduced by 'technological decoupling' (or 'decarbonisation') that reduces the intensity of *GHG* emissions in consumption and production. Finally, population growth could be reduced, especially where emissions per capita are already high.

Focusing on the decarbonisation term [G/Y], Figure 7 illustrates the different challenges facing developed and developing countries [Munasinghe (2011)]. On this stylised curve of environmental risk against a country's level of development, poor nations are at point A (low *GHG* emissions and low *GNP* per capita), rich nations are at point C (high GHG emissions and high *GNP* per capita), and intermediate countries are at point B.

The sustainable development path to be followed by any country depends on its position along this curve. Industrial countries (already exceeding safe limits) should mitigate and follow the future growth path CE, by restructuring their consumption and production patterns to delink carbon emissions and economic growth, thereby making their development path more sustainable. Middle income countries could adopt innovative policies to "tunnel" through (along BDE—below the safe limit), by learning from past experiences of the industrialised world. Poorer developing countries should be encouraged (with technical and financial assistance) to increase their consumption and production more sustainably by following a growth path that is less carbon-intensive. Finally, the poorest countries and poorest groups must be provided an adaptation safety net, to reduce vulnerability to climate change impacts.

Fig. 7. Balancing the Development Path and Climate Risk



Clearly, the same generic arguments may be applied to all forms of natural resource use, to ensure that the basic consumption needs of the poor are met while limiting excessive consumption of the rich within the bounds of planetary sustainability.

3.2. National/Sectoral Scale: Energy Sector Planning in Sri Lanka

The incorporation of environmental and social externalities into decision-making is particularly important in the electric power sector. A Sri Lanka study [Munasinghe (2010)], demonstrates how externalities could be incorporated into power system planning in a systematic manner. Sri Lanka presently depends largely on hydro power for electricity generation, but over the next decade the main choices seem to be large coal- or oil-fired stations, or hydro plants whose economic returns and environmental impacts are increasingly unfavourable. In addition, a wide range of other options (such as wind power, increasing use of demand side management, and system efficiency improvements), complicates decision-making—even in the absence of the environmental concerns.

The methodology involves the following steps: (a) definition of generation options and their analysis using sophisticated least-cost system planning models; (b) selection and definition of attributes that reflect planning objectives; (c) explicit economic valuation of those impacts for which valuation techniques can be applied with confidence—the resultant values are then added to the system costs which is the main economic attribute; (d) quantification of those attributes for which explicit economic valuation is inappropriate, but for which suitable quantitative impact scales can be defined; (e) translation of attribute value levels into value functions (known as “scaling”); (f) display of trade-offs to facilitate decision making; and (g) definition of options for further study, which also involves discarding eliminating inferior options.

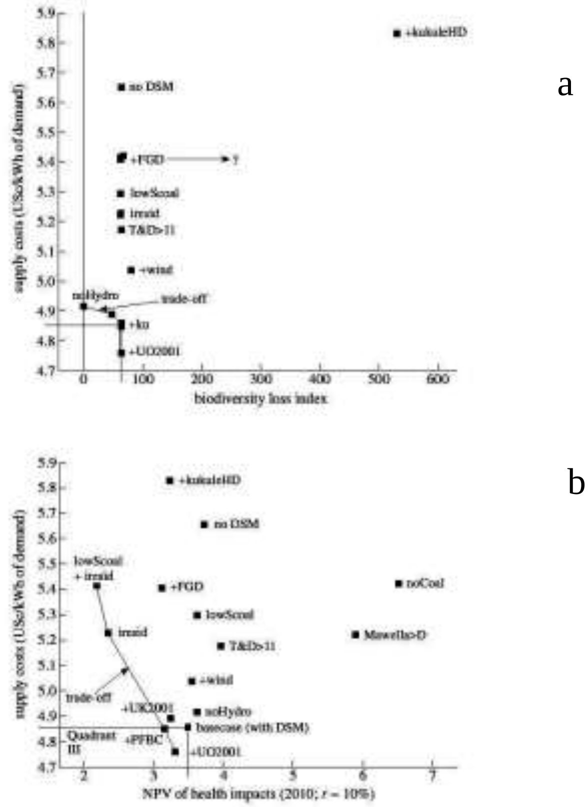
Main Results

The main set of sectoral policy options examined included: (a) variations in the currently available mix of hydro, and thermal (coal and oil) plants; (b) demand side management (e.g., compact fluorescent lighting); (c) renewable energy options (e.g., wind generation); (d) improvements in system efficiency (using more ambitious targets for transmission and distribution losses than the base case assumption of 12 percent by 1997); (e) clean coal technology (e.g., pressurised fluidised bed combustion (PFBC) in a combined cycle mode); and (f) pollution control technology options (e.g., various fuel switching and pollution control options like importing low sulphur oil for diesels, and fitting coal power plants with flue gas desulphurisation (FGD) systems).

A limited number of criteria or attributes should be selected with care, to reflect issues of national as well as local project level significance. CO_2 emissions were used as proxy for the potential impact on global warming. Health impacts were measured through population-weighted increments in both fine particulates and NO_x. To capture the potential bio-diversity impacts, a probabilistic index was derived. Employment creation was used as an illustrative social impact.

Figure 8(a) illustrates a typical trade-off curve for biodiversity. The “best” solutions lie closest to the origin. The trade-off curve is defined by the set of “non-inferior” solutions (or superior options) that are best in terms of both objectives. For example, on this curve, the option defined as “no hydro” is better than the option “wind”, in terms of both economic cost and biodiversity loss.

Fig. 8. **Trade-off Curves between Economic Costs and (a) Biodiversity Impacts; (b) Health Impacts**



Conclusions

There are several useful conclusions. First, the results indicate that those impacts for which valuation techniques are relatively straightforward and well-established (like the opportunity costs of lost production from inundated land, or benefits of establishing fisheries in reservoirs),are small compared to overall system costs. Therefore, including such impacts in the benefit-cost analysis does not materially change results. Second, even in cases where explicit valuation is difficult (e.g., mortality and morbidity effects of air pollution), implicit valuation based on analysis of trade-off curves can provide important guidance to decision-makers. Third, certain options were clearly inferior/superior to others, when one examines all impacts simultaneously. For example, the high dam version of the Kukule hydro project can be excluded from further consideration, because of poor performance on all attribute scales. Fourth, it is possible to derive attribute scales that provide useful proxies for impacts which are difficult to value. For example, the population-weighted, incremental ambient air pollution level was the proxy for health impacts, which yielded several important conclusions—independent of any economic values assigned to health effects.

Finally, with respect to the practical planning, the study identified several priority recommendations, including the need to re-consider (i) demand side management options, especially fluorescent lighting; (ii) whether the present transmission and distribution loss reduction target of 12 percent ought to be further reduced; (iii) possibilities of pressurised fluidised bed combustion (PFBC) technology for coal power; (iv) replacement of some coal-fired power plants (on the South coast) by diesel units; and (v) cooling system options for coal plants.

3.3. Local-project Scale: Multicriteria Analysis (MCA) of Renewable Energy Projects

Well accepted environmental and social assessment procedures at the project/local level may be readily adapted to assess environmental and social effects of micro-level activities. When monetary valuation of environmental and social effects is not feasible, MCA may be used. Here, we summarise how multi-criteria analysis (MCA) may be used to compare hydroelectric power schemes [Munasinghe (2011)]. The three main sustainable development issues considered comprise the economic costs of power generation, ecological costs of biodiversity loss, and social costs of resettlement.

The principal objective is to generate additional kilowatt-hours (kWh) of electricity to meet growing power demand in Sri Lanka. Assume that the benefits from each additional kWh are the same, the analysis seeks to minimise economic, social and environmental costs of generating one unit of electricity from different hydropower sites. Following the MCA approach, environmental and social impacts are measured in different (non-monetary) units, instead of attempting to economically value and incorporate them within the monetary-valued CBA framework.

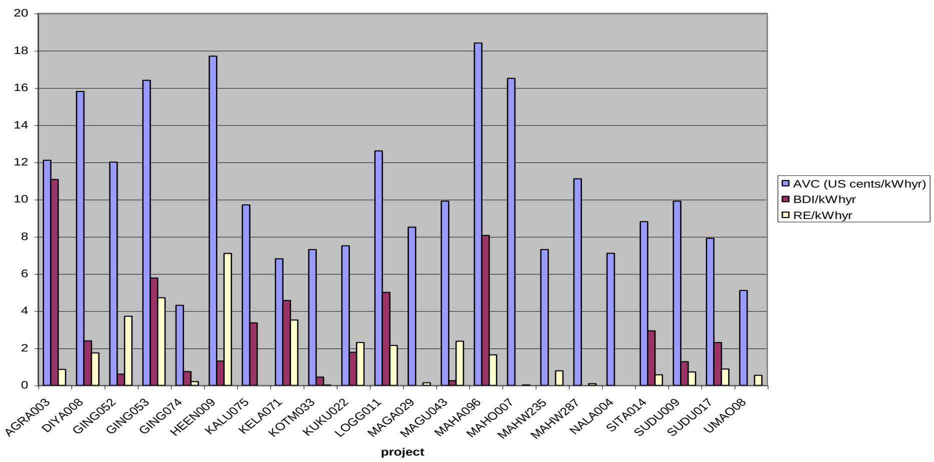
Environmental, Social and Economic Indicators

Sri Lanka has many varieties of endemic or endangered fauna and flora. Often, large hydro projects destroy wildlife at dam sites and in downstream areas. Hence, a biodiversity loss index was estimated for each hydroelectric site as the main ecological indicator (see previous case study). Although dam sites are usually in less densely populated rural areas, resettlement is still a serious problem. In general, people are relocated from the wet to the dry zone where the same level of agricultural productivity cannot be maintained, due to limited water and poor soil quality. Living standards often become worse and several problems (like malnutrition) could occur. Moreover, other social issues might arise, such as erosion of community cohesion and psychological distress due to changed living conditions. Hence, minimising the number of people resettled due to dam construction is an important social objective.

The project costs are available for each site, from which the critical economic indicator—average cost per kWh per year—may be estimated. The annual energy generation potential at various sites ranges from about 11 to 210 KWh (Figure 8). All three variables (biodiversity index, number of people resettled, and generation costs), are calculated per kWh of electrical energy generated at each site. This scaling removes the influence of project size and makes them more comparable.

Figure 10 provides a more comprehensive three-dimensional analysis of sustainable development indicators for these hydropower sites, where the respective axes represent economic, ecological, and social objectives. The closer to the origin any given coordinate point is plotted, the better is the corresponding project in terms of achieving these three objectives. This type of analysis gives policy-makers some idea about which project is more favourable from a sustainable energy development perspective.

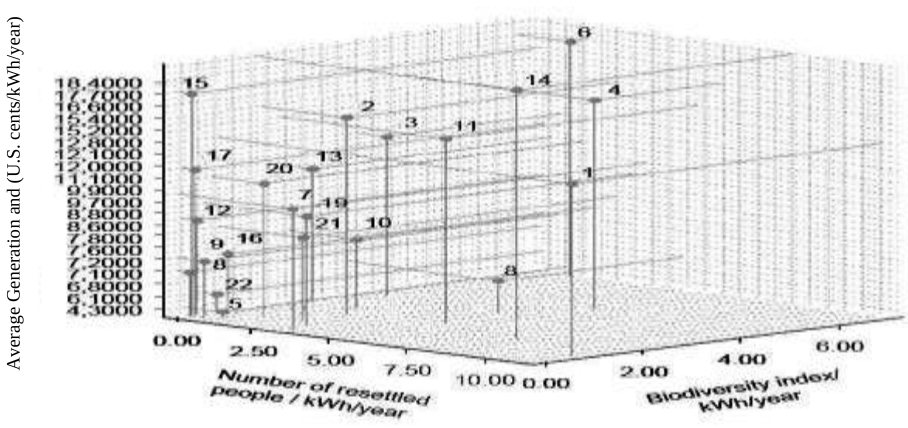
Fig.9. Average Generation Costs (AVC), Biodiversity Index (BDI), and Number of Resettled People (RE) by Hydroelectric Project.



Note: All indices are per kWh per year. Numbers of people resettled and biodiversity index are scaled by the multipliers 10^{-5} and 10^{-9} respectively, for convenience. Values across top of the graph indicate annual energy generation in gigawatt hours (GWh).

Suppose we arbitrarily give all three objectives an equal weight. Then, each project may be ranked according to its absolute distance from the origin. For example, rank 1 is given to the one closest to the origin, rank 2 is the second closest, etc. (Figure 10). On this overall basis, from a sustainable energy development perspective, the most favourable project GING074 (project 5) is closest to the origin, whereas the least favourable one MAHA096 (project 14) is the furthest.

Fig. 10. Three Dimensional MCA of Sustainable Development Indicators for Hydropower Options.



Source: Munasinghe (2011).

Conclusions

The strength of this type of analysis is in helping policy-makers to compare project alternatives more comprehensively and effectively. The simple graphical presentations are readily comprehensible, and clearly identify sustainable development characteristics of each scheme. The multi-dimensional analysis supplements more conventional CBA (based on economic analysis alone). Since each project has different features, assessing them by looking at only one aspect (e.g., generation costs or effects on biodiversity or impacts on resettlement) could be misleading.

The MCA approach used here could be improved. First, for simplicity each major objective is represented by only one variable. There may be additional key variables which could describe other important sustainable development impacts. Further analysis that includes other attributes might provide new insights. Second, the study could be extended to include other renewable sources of energy. Finally, more sophisticated 3D-graphic techniques may yield better and clearer representations.

4. CONCLUSIONS AND KEY POLICY IMPLICATIONS FOR PAKISTAN

The SED-INEP approach based on sustainomics leads to several generic conclusions.

(1) Integrated solutions are the most effective where energy policies are incorporated within the sustainable development strategy, using the SED-INEP framework.
(2) Transformation of energy systems is an urgent task because the issues are complex and serious, while changes take time to become effective. Applying the MDMS principle is important since we know enough already about technologies, policies and methods to take immediate steps to solve the problems.
(3) Energy options that have an important role, include energy efficiency (which yields quick returns), demand management, renewable energy and advanced technologies.
(4) Renewable energy is becoming less costly and more widely available, with increasing economies of scale. More rapid diffusion is possible with investment incentives and portfolio standards, better integration within conventional energy systems (e.g., feed in tariffs to power grids), including externality costs within fossil fuel prices, and improved R&D through training and tax credits, etc.
(5) SDA analysis will identify win-win energy solutions that simultaneously meet economic, social and environmental criteria, while facilitating trade-off decisions where different criteria might conflict.
(6) The full mix of policy options need to be applied, including sustainable energy pricing and economic incentives, regulation, advertising, etc. to encourage more sustainable consumption and production, especially with respect to energy use. In the long run changing social values will be critical.

(7) Energy poverty can be reduced sharply, by supplying basic energy needs of all human beings, and focusing on improved cooking stoves, cleaner fuels for homes, and greater access to electricity.

SED Options for Pakistan

The SED-INEP framework helps to identify broad issues and strategic options to support Pakistan's sustainable development efforts. As shown below, energy sector issues are complex and the structural changes required to address them calls for far-sighted leadership, guided by sustainability principles.

Pakistan's present (2012) total installed generation capacity is about 19.6 GW (hydro, fossil, independent power producers or IPPs, and nuclear sources). The existing capacity of thermal power generation in Pakistan stands at 12.6 GW, which is almost two-third (65 percent) of the country's total generation capacity. Hydro energy is the second largest source of electricity and accounts for 33 percent of total power generation. The national electricity demand is projected to increase to around 40,000MW by 2020 [WAPDA (2013)]. There is need for a high and sustained growth in energy supply and infrastructure capacity of 7-8 percent per annum to support economic growth in the country.

The strategic shift away from fossil fuels must be encouraged. Demand for energy in Pakistan has grown almost six-fold from 1980 to date and is expected to double again by 2015. The high dependence on hydrocarbons as the primary energy source needs to be reduced, to make energy development more sustainable.

From the perspective of *Environmental Sustainability*, SED analysis indicates that increasing hydro generation capacity would be a clean, and low cost method of meeting rising demand. However, the water storage capacity is decreasing rapidly due to sedimentation of existing reservoirs, caused by unsustainable environmental practices upstream. There is an urgent need to commence construction of large storage reservoirs to hold the water flowing in the only river that runs through Pakistan (Indus), while strengthening environmental and social safeguards. Better water storage will not only help with power generation but also help provide irrigation and potable water, promote fisheries and sustain communities. Pakistan has a potential for producing over 50 GW of electricity, if hydro power resources are used effectively.

Economic Unsustainability arises from costly electricity shortages and system losses. With the increase of population, urbanisation and industries, the demand-supply gap is large. Electricity shortfalls reached a peak of 8,500 megawatts (MW) in June 2012 or more than 40 percent of national demand. Load-shedding of up to 12-16 hours a day across the country has led to economic costs as high as 4 percent of GDP. Reasons for poor supply include inefficient energy utilisation, indiscriminate use of subsidies, lack of public awareness, ineffective or unenforced legislation, poor governance, under-developed infrastructure and theft, etc. The existing energy infrastructure needs to be urgently upgraded, transmission and distribution networks made more efficient, and the capacity of major water reservoirs restored.

An important manifestation of *Social Unsustainability* is the high incidence of energy poverty in Pakistan. Although overall energy demand continues to rise, per capita energy use remains one of the lowest in the world, especially among the poor. There are several reasons.

First, the energy sector is inefficient, and it is estimated that almost 20 percent of Pakistan's overall energy consumption could be saved by 2015. Such energy conservation will be more cost effective than building new generation capacity. Second, power generation from expensive thermal sources makes electricity less affordable to the poor. Third, the poor are still highly dependent on biomass and traditional fuels, which are inconvenient. Continued dependence on bio mass and petroleum products could worsen poverty issues.

In terms of indigenous energy resources; Pakistan is rich in natural gas, hydroelectricity, and coal. However, due to the high consumption of oil and gas, experts predict that indigenous oil reserves will be exhausted by 2025, and natural gas by 2030. Meanwhile, hydroelectricity supply is imperilled by climate change, with less rainfall reducing river flows. This trend is exacerbated by wasteful water consumption. For example, decades of water-intensive agriculture practices like subsidised flood irrigation—have helped deplete surface water tables and prompted farmers to make excessive use of electric tube wells to extract groundwater.

Alternative energy is being used only at a miniscule scale in the current energy mix but by 2030, the government plans to have a minimum of 5.0 percent of total commercial energy supply provided by wind, solar, and bio-waste (i.e., 2.5 percent of Pakistan's overall energy generation will come from new renewable sources). In addition, the government plans to invest in the country's vast coalfields (in Thar) where 200 billion tons of reserves have lain dormant since their discovery more than twenty years ago. Clean coal technology has more potential to address Pakistan's current energy supply crisis and to potentially reduce dependency on expensive imported oil and gas.

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The Mahbub Ul Haq Memorial Lecture

Energy Dependency and Energy Security: The Role of Energy Efficıency and Renewable Energy Sources

ILHAN OZTURK

National and international energy policies have very important role in regional and global power equilibrium and its importance is increasing. In this respect, diversification of energy resources and their transportations routes, efficient use of local resources and the use of existing energy resources with various technological and strategic practices in the most efficient way possible are necessary in order to improve energy security and reduce dependence on foreign energy sources.

Energy efficiency and renewable energy sources stand out as an important issues especially regarding energy supply security, reducing foreign energy dependency, economic development, maintaining the balance between environment and sustainability as well as making important gains in all these issues. Thus, Improving energy efficiency saves money, reduces carbon emissions and decreases country's dependence on foreign energy supplies. Energy security—the uninterrupted availability of energy sources at an affordable price—can also profit from improved energy efficiency by decreasing the reliance on imported fossil fuels. Possible improvements in energy efficiency are examined in six main categories: (1) buildings, (2) industry, (3) transportation, (4) electricity generation and distribution, (5) appliances and equipment, and (6) lighting.

According to the Turkish Energy Efficiency Strategy Document (2012–2023), it was observed that with rational policies and technological improvements, a minimum of 20 percent increase is possible in energy efficiency between 2013 and 2023. In the last year, major energy-consuming countries also have announced new measures: China is targeting a 16 percent reduction in energy intensity by 2015; the United States has adopted new fuel economy standards; the European Union has committed to a cut of 20 percent in its 2020 energy demand; and Japan aims to cut 10 percent electricity consumption by 2030.

The aim of this paper is to study the importance of energy efficiency and renewable energy sources and their roles in reducing energy dependency and promoting energy security. In addition, the energy efficiency applications of Turkey will be discussed and general energy Outlook for Pakistan and some policy implications to solve the energy crisis in Pakistan will be presented.

Keywords: Energy Efficiency, Energy Dependency, Renewable Energy, Energy Security, Turkey, Pakistan

1. INTRODUCTİON

National and international energy policies have very important role in regional and global power equilibrium and its importance is increasing. In this respect, diversification of energy resources and their transportations routes, efficient use of local resources and

Ilhan Ozturk <ilhanozturk@cag.edu.tr> is Associate Professor, Faculty of Economics and Administrative Sciences, Cag University, Turkey.

the use of existing energy resources with various technological and strategic practices in the most efficient way possible are necessary in order to improve energy security and reduce dependence on foreign energy sources.

All societies require energy services to meet basic human needs (e.g., lighting, cooking, space comfort, mobility, communication) and to serve productive processes. For development to be sustainable, delivery of energy services needs to be secure and have low environmental impacts. Sustainable social and economic development requires assured and affordable access to the energy resources necessary to provide essential and sustainable energy services. This may mean the application of different strategies at different stages of economic development. To be environmentally benign, energy services must be provided with low environmental impacts and low greenhouse gas (GHG) emissions. However, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) reported that fossil fuels provided 85 percent of the total primary energy in 2004, which is the same value as in 2008. Furthermore, the combustion of fossil fuels accounted for 56.6 percent of all anthropogenic GHG emissions (CO2) in 2004. The IPCC is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) to provide the world with a clear scientific view on the current state of knowledge on climate change and its potential environmental and socio-economic impacts.

Climate change is one of the great challenges of the 21st century. Its most severe impacts may still be avoided if efforts are made to transform current energy systems. Renewable energy sources have a large potential to displace emissions of greenhouse gases from the combustion of fossil fuels and thereby to mitigate climate change. If implemented properly, renewable energy sources can contribute to social and economic development, to energy access, to a secure and sustainable energy supply, and to a reduction of negative impacts of energy provision on the environment and human health.

Renewable energy is largely a domestic source of energy. When it displaces imported fuels, it contributes to greater national energy security and directly reduces import bills, which represent a fairly significant percentage of gross domestic product (GDP) in many importing countries and often contribute to a trade deficit. Renewable energy sources (such as wind, solar and biomass) have the potential to reduce these effects significantly. Moreover, greater use of renewables could indirectly put downward pressure on oil and gas prices and reduce price volatility. In the electricity sector, renewables mainly reduce the need to import gas or coal, as oil use is limited in this sector.

While GDP per capita and population growth had the largest effect on emissions growth in earlier decades, decreasing energy intensity significantly slowed emissions growth in the period from 1971 to 2008. In the past, carbon intensity fell because of improvements in energy efficiency and switching from coal to natural gas and the expansion of nuclear energy in the 1970s and 1980s. In recent years (2000 to 2007), increases in carbon intensity have been driven mainly by the expansion of coal use in both developed and developing countries, although coal and petroleum use have fallen slightly since 2007. In 2008 this trend was broken due to the financial crisis. Since the early 2000s, the energy supply has become more carbon intensive, thereby amplifying the increase resulting from growth in GDP per capita.

Baseline projections for the EU indicate that electricity consumption will grow on average by 2 percent/y to 2030, with a potentially slightly slower pace each year because of energy efficiency improvement measures and higher fossil fuel prices, in particular natural gas, which will consequently affect electricity pricing. This provides an impetus to improve technologies in coal- and gas-based power generation and more specifically to improve conversion efficiency, as this would result in substantial CO2 and fuel savings. For example, each percentage point efficiency increase is equivalent to about 2.5 percent reduction of CO2 emitted. Power plant efficiency is therefore a major factor that could be used to reduce global CO2 emissions.

Since 2008, China has become the largest emitter of GHG in the world overtaking the United States. Now China accounts for 25 percent of total global CO2 emissions, up from 11 percent in 1990. The top five countries with the highest energy related CO2 emissions in addition to China, include USA, India, Russia and Japan, which in total represented 58 percent of global emissions in 2011). Adding the cumulative emissions of the next five countries: Germany, South Korea, Iran, Canada and Saudi Arabia demonstrates that the top ten countries accounted for slightly more than two thirds of world emissions in 2011. The largest increase has taken place in China and India, where emissions per capita in China increased by a factor of three and in India by 2.5 respectively, and the Middle East (+75 percent), due to the high economic growth.

In 2009, the European Union released the Renewable Energy Directive, which set legally binding targets for the share of renewable energy (covering electricity, heat and biofuels) in gross final energy consumption of each member state by 2020, equating to 20 percent in total. To ensure that their targets are met, each country is required to prepare an action plan and provide regular progress reports. Renewable energy is expected to continue to be central to EU energy policy beyond 2020. A recent European Commission report indicated that renewable energy could meet 55-75 percent of final energy consumption by 2050, compared with less than 10 percent in 2010 [EC (2011); EU (2011)]. According to the Turkish Energy Efficiency Strategy Document (2013-2023), it was observed that with rational policies and technological improvements, a minimum of 20 percent increase is possible in energy efficiency between 2013 and 2023. In addition, major energy-consuming countries also have announced new measures in 2012: China is targeting a 16 percent reduction in energy intensity by 2015; the United States has adopted new fuel economy standards; the European Union has committed to a cut of 20 percent in its 2020 energy demand; and Japan aims to cut 10 percent from electricity consumption by 2030.

2. ENERGY EFFICIENCY

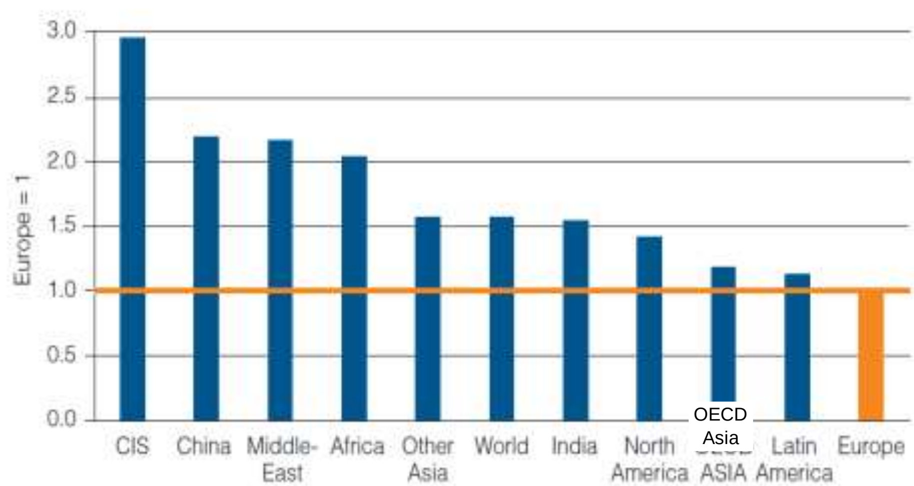
Efficient energy use, sometimes simply called “energy efficiency”, is the goal of efforts to reduce the amount of energy required to provide products and services. Energy efficiency is a way of managing and restraining the growth in energy consumption. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights or natural skylight reduces the amount of energy required to attain the same level of illumination compared to using traditional incandescent light bulbs. Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer than incandescent lights.

Energy efficiency stands out as an important issue especially regarding supply security, economic development and competitiveness on the one hand, and maintaining the balance between environment and sustainability as well as making important gains in all these issues on the other.

Energy efficiency offers a powerful and cost-effective tool for achieving a sustainable energy future. Improvements in energy efficiency can reduce the need for investment in energy infrastructure, cut energy bills, improve health, increase competitiveness and improve consumer welfare. Environmental benefits can also be achieved by the reduction of greenhouse gases emissions and local air pollution. In addition, energy efficiency reduces country's dependence on foreign energy supplies.

According to World Energy Council 2013 Report, most countries have significantly reduced their total energy use per unit of GDP over the last three decades. The decline in energy intensity has been driven largely by improved energy efficiency in key end-uses such as vehicles, appliances, space heating and industrial processes. Governments have implemented a wide range of policies and programmes such as energy efficiency standards, educational campaigns, obligations for market participants and financial incentives to accelerate the development and adoption of energy efficiency measures. Western Europe is currently the region with the lowest energy intensity, while among the large consumer countries; CIS uses almost 3 times more energy per unit of GDP than Europe. In China, Africa and the Middle East, the energy intensity is two times higher than the average in Europe. High energy intensities can be attributed to a number of factors, including the structure of the industry, the share of energy intensive sectors, low energy prices and other. Latin America and OECD Asia and Pacific are about 15 percent above the European level, while India and other Asia are at the same level as the world average with energy intensity 50 percent higher than in Europe and slightly less than North America.

Primary Energy Intensity Levels by World Regions (2011)

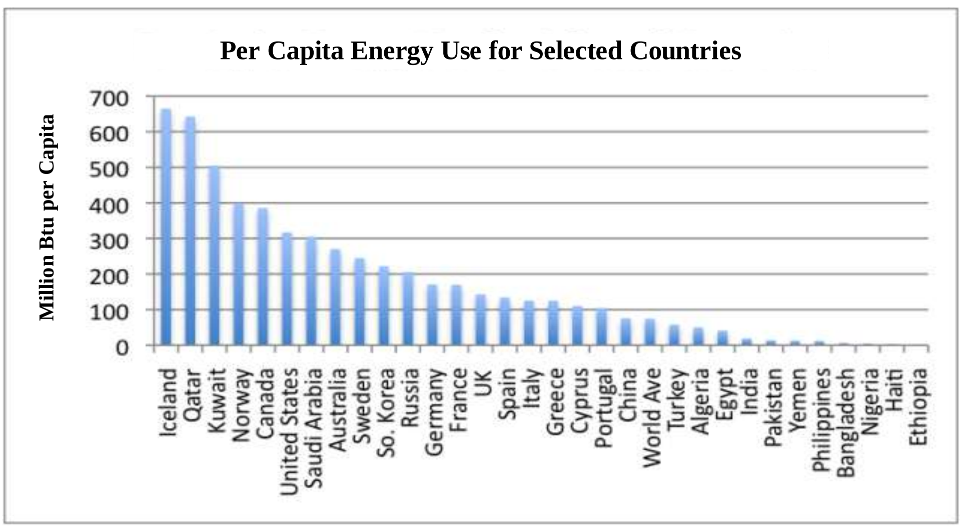


Source: WEC/ENERDATA.

Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily growing energy consumption. For example, the state of California began implementing energy-efficiency measures in the mid-1970s, including building code and appliance standards with strict efficiency requirements. During the following years, California's energy consumption has remained approximately flat on a per capita basis while national U.S. consumption doubled. As part of its strategy, California implemented a "loading order" for new energy resources that puts energy efficiency first, renewable electricity supplies second, and new fossil-fired power plants last.

Energy conservation is broader than energy efficiency in that it encompasses using less energy to achieve a lesser energy service, for example through behavioural change, as well as encompassing energy efficiency. Examples of conservation without efficiency improvements would be heating a room less in winter, driving less, or working in a less brightly lit room. As with other definitions, the boundary between efficient energy use and energy conservation can be fuzzy, but both are important in environmental and economic terms. This is especially the case when actions are directed at the saving of fossil fuels. Reducing energy use is seen as a key solution to the problem of reducing greenhouse gas emissions. According to the International Energy Agency (IEA), improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.

America is an "energy hog" and uses twice as much energy per capita as most European countries and perhaps ten times as much as most of Asia and Africa (see following figure).



It is due to a large extent to a greater degree of industrialisation. Much of industry is energy demanding. More industrialised countries in Asia, such as Japan, China and Taiwan, use more energy than the rest of the Asian countries but not as much per capita energy use as in the U.S. More of Asia is rapidly industrialising so it is certain that its energy demands will increase and offer more competition for energy supplies to the more energy intensive countries. These changes are inevitable and relate to the increase in the quality of life associated with such industrialisation, rising population and income. In any case, the energy needs of much of the rest of the world will increase, and if this is accompanied by the increasing energy use in America that we have experienced, the world's energy requirements are bound to grow. If this occurs in a time of limited resources, problems will arise. There will be increasing strife among competitors for the available resources and increased cost, leading to a limitation of the rate of growth. The burden of this limitation will fall more heavily on the poorer parts of society. To decrease these problems, it appears desirable to reduce the per capita energy use for ourselves and to find ways for others to grow in a less energy intensive way. This can be accomplished through changes in life style, finding ways for using energy more efficiently and using alternative energy sources such wind, solar and biomass.

In addition to the possibility of diminished sources of fossil fuels, there is a problem in the production of carbon dioxide from burning fossil fuels. The evidence is clear that the carbon dioxide (CO2) concentration in the atmosphere has greatly increased [Weart (2008)]. The increase in carbon dioxide has been accompanied by a change in the Earth's climate. The climate change in turn has been ascribed to the greenhouse effect. Human activity, that has increased the amount of the greenhouse gases in the Earth's atmosphere, has led to an increase in climate warming [Physical Geography (2009)].

It is evident that because of the limitations of fossil fuel supply and consideration of the environmental deterioration arising from their use, that other sources of energy should be considered. To secure energy supply and meet the energy demand in future, the importance of renewable energy (such as wind, solar and biomass) becomes even more critical.

Energy security—the uninterrupted availability of energy sources at an affordable price—can also profit from improved energy efficiency by decreasing the reliance on imported fossil fuels. Energy security is very important, especially for energy importing (energy dependent countries, such as Pakistan and Turkey) countries. Because rising energy prices or decreasing energy supply will have a negative impact on the growth of these countries.

In addition, the question of energy security also is one of the main concerns for the future of Europe because of the growing dependency of the European countries on third parties, namely Russia, for natural gas. The future of European energy security will be shaped by the EU's dependence on Russia and its ability to find alternative sources of energy as well as multiple routes of transport. Turkey's location between the major energy producers in the Caspian and the major energy consumers in Europe has increased Turkey's potential role as the transit country.

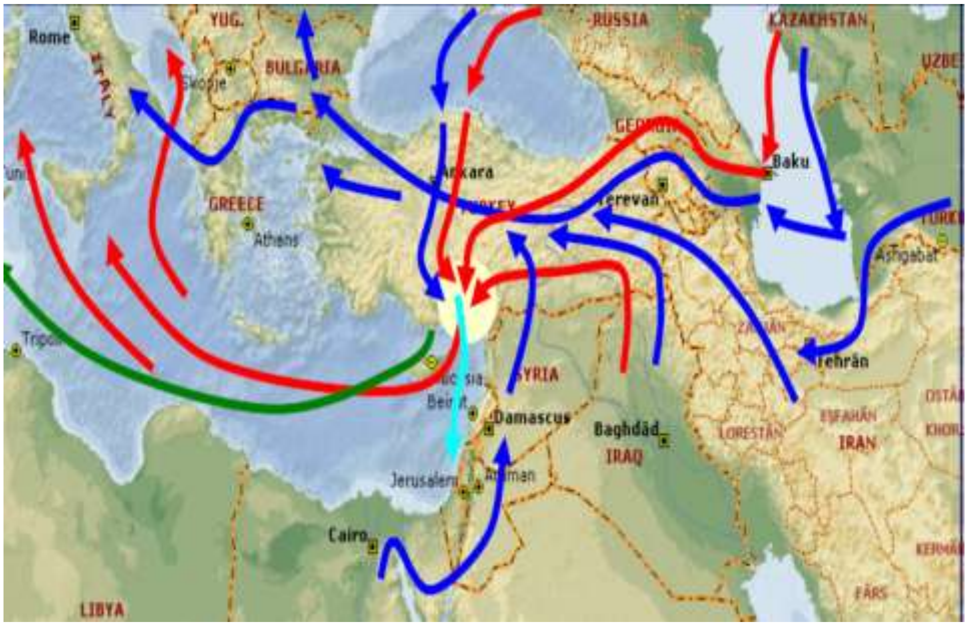
To promote energy security of Europe, Nabucco is projected to transport natural gas from the Caspian region through Turkey, Bulgaria, Romania and Hungary to Austria, and the Cooperation Agreement was signed between these five countries in October 2002 (see following figure). The Agreement signed on 13 July 2009 between these five countries enabled the operationalisation of these plans. The consortium for the pipeline, the Nabucco Gas Pipeline International, was founded in 2004 with the objective of constructing a new pipeline connecting the Caspian region, the Middle East and possibly

Egypt as a new supply route for Europe. The investment for the pipeline, which will be approximately 3,300 kilometres, is estimated to cost around 8 billion Euros. Potential suppliers to the pipeline are the Caspian states, Azerbaijan, Kazakhstan, Turkmenistan, Iran, and, if possible, Egypt and Iraq as well. The major supplier for the initial stage of the Nabucco pipeline is projected to be Shah Deniz fields of Azerbaijan.

3. TURKEY ENERGY OUTLOOK

Turkey's importance in the energy markets is growing, both as a regional energy transit hub and as a growing consumer. Turkey's energy demand has increased rapidly over the last few years and likely will continue to grow in the future.

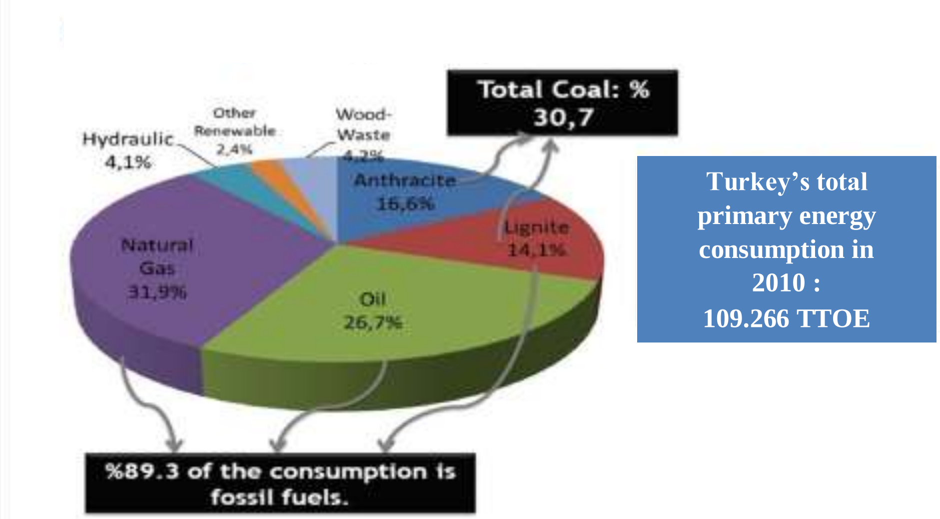
Over the last two years, Turkey has seen the fastest growth in energy demand in the OECD, and unlike a number of other OECD countries in Europe, its economy has avoided the prolonged stagnation that has characterised much of the continent for the past few years. The country's energy use is still relatively low, although it is increasing at a very fast pace. According to the International Energy Agency (IEA), energy use in Turkey is expected to double over the next decade, while electricity demand growth is expected to increase at an even faster pace. Meeting this level of growth will require significant investment in the energy sector, much of which will come from the private sector. Large investments in natural gas and electricity infrastructure will be essential. In addition to being a major market for energy supplies, Turkey's role as an energy transit hub is increasingly important. It is key to oil and natural gas supplies movement from Russia, the Caspian region, and the Middle East to Europe. Turkey has been a major transit point for seaborne-traded oil and is becoming more important for pipeline-traded oil and natural gas (see following figure).



In 2010 and 2011, Turkey's economy was one of the fastest growing economies in the world, at over 8 percent annual growth rates, and with this economic expansion, Turkey's oil consumption grew. In 2011, Turkey imported more than 90 percent of its total liquid fuels consumption. According to the IEA, Turkey's imports are expected to double over the next decade.

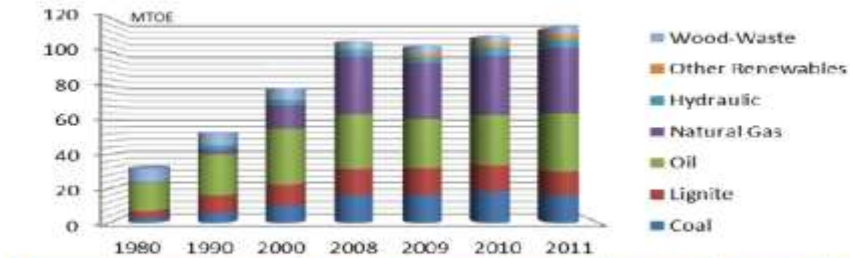
In the following figures, the developments in the energy demand and energy supply of all types are given.

Turkey Primary Energy Consumption (2010)

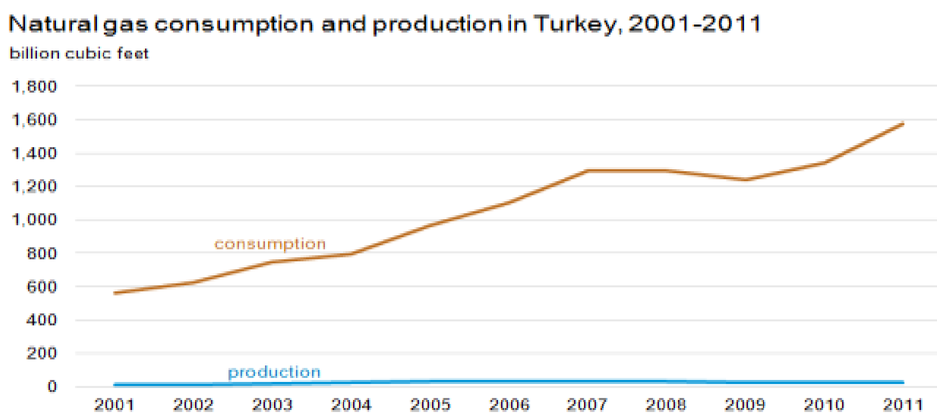


Source: MENR.

Development of Primary Energy Consumption of Turkey (1980-2011)

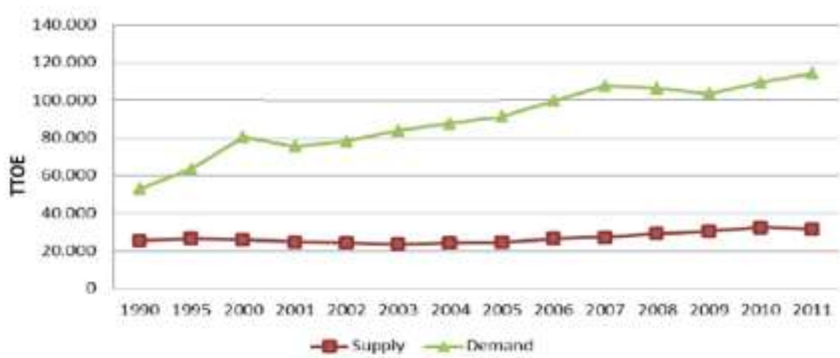


	Coal	Lignite	Oil	Natural gas	Hydraulic	Other Renewables	Wood-Waste	Total
1980	8,9	13,2	50,5	0,1	3,3	0,0	24,1	100,0
1990	11,7	18,8	45,3	5,9	4,6	0,1	13,7	100,0
2000	12,6	15,9	41,1	17,5	4,3	0,3	8,2	100,0
2008	15,2	14,3	29,9	31,8	3,8	0,5	4,5	100,0
2009	15,8	14,8	27,9	31,6	3,0	2,2	4,6	100,0
2010	16,6	14,1	26,7	31,9	4,1	2,4	4,2	100,0
*2011	14,1	12,2	29,7	33,3	4,1	2,5	4,1	100,0

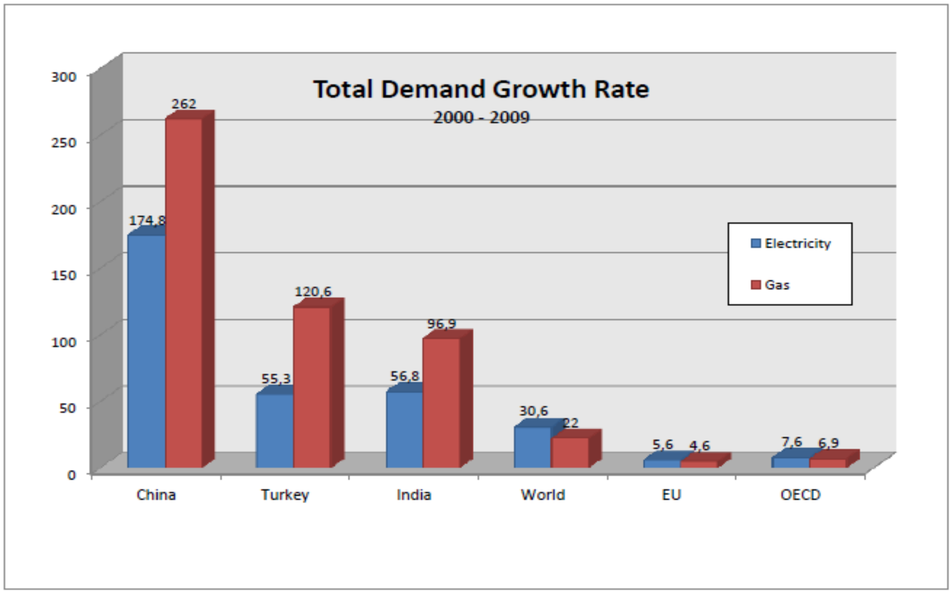


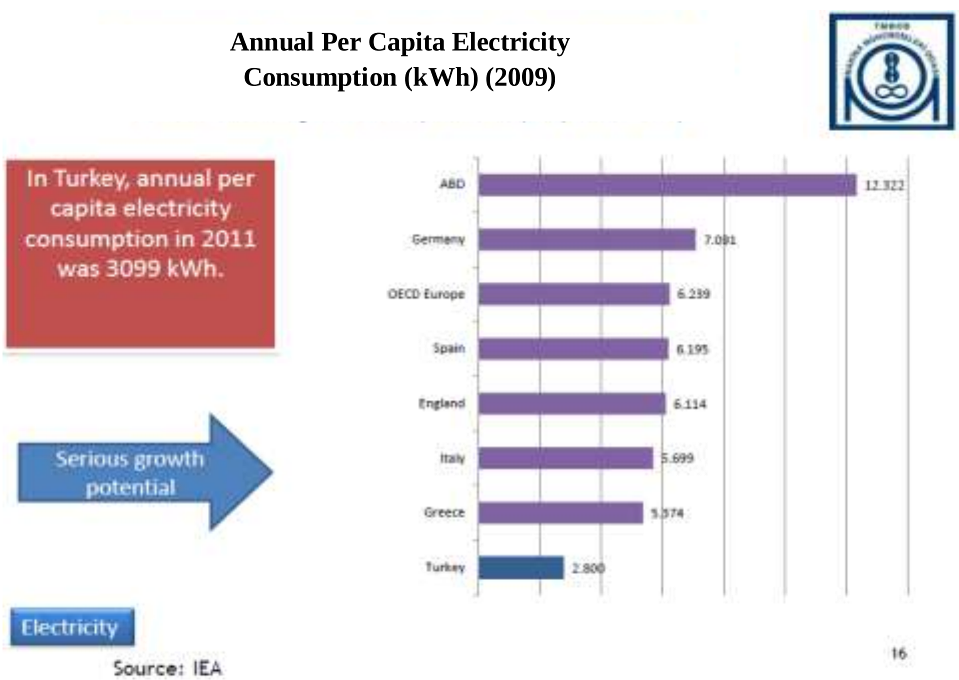
Source: U.S. Energy Information Administration, International Energy Statistics Database.

Development of Domestic Energy Supply and Energy Demand (1990-2011)



The Rate of İncrease of Aggregate Demand between 2000-2009





Annual per Capita Electricity Consumption for Pakistan was 449 kWh in 2011.

3.1. Energy Efficiency and Applications in Turkey

Turkey, forging ahead with confident and rapid steps to become a pivotal and strong country in her region and the world, should aim for more efficient use of energy resources, development of deliberate policies of energy security, diversification of energy resources (using renewable energy sources), and development of new technologies. Turkey's energy import (mainly crude oil and natural gas) in 2011 was around 54 billion dollars, which equals 69 percent of the account deficit. Turkey should reduce its dependence on foreign energy sources and become a pioneer rather than a follower in the energy sector, especially among developing economies.

Possible improvements in energy efficiency are examined in four main categories: (1) buildings, (2) industry, (3) transportation, (4) electricity generation and distribution. Data analyses and optimisation studies lead to the following conclusions: It is estimated that a saving of 20 percent to 60 percent in yearly energy consumption can be made with efficiency implementations in buildings; 10 percent to 40 percent increase in efficiency can be obtained with the use of energy management systems in the industry; compared to vehicles with internal combustion engines, electric vehicles provide 70 percent cost benefit and 65 percent decrease in CO2 emission; and 16 percent to 28 percent improvements in electricity generation and distribution can be achieved with compensation, introduction of SCADA systems, and smart grid implementations in distribution.[1]

As a result of the analyses by the academicians and government authorities of Turkey, it was observed that with rational policies and technological improvements, a minimum of 20 percent increase is possible in energy efficiency between 2012 and 2023. To achieve these objectives, Turkish government announced and applied the following "Turkey Energy Efficiency Strategy Document" in 2010.

Turkey Energy Efficiency Strategy Document (2012- 2023)[2]: This document targets to decrease at least 20 percent of amount of energy consumed per GDP of Turkey in the year 2023 (energy intensity).

- To reduce energy intensity and energy losses in industry and services sectors.
- To decrease energy demand and carbon emissions of the buildings; to promote sustainable environment friendly buildings using renewable energy sources.
- To provide market transformation of energy efficient products.
- To increase efficiency in production, transmission and distribution of electricity, to decrease energy losses and harmful environment emissions.
- To reduce unit fossil fuel consumption of motorised vehicles, to increase share of public transportation in highways, sea roads and railroads and to prevent unnecessary fuel consumption in urban transportation.
- To use energy effectively and efficiently in public sector.
- To strengthen institutional capacities and collaborations, to increase use of state of the art technology and awareness activities, to develop financial mechanisms in public financial institutions.
- To have at least 3 operating nuclear power plants.
- Turkey, which continues efforts to construct nuclear power plant, aims to use 36,000 MW hydroelectric, 20,000 MW wind, 3,000 MW solar, 600 MW geothermal, 2,000 MW biomass energy by 2023.

[1] http://oip.ku.edu.tr/energy-matters/turkeys-energy-efficiency-assessment-and-targets
[2] http://www.eie.gov.tr/verimlilik/document/Energy_Efficiency_Strategy_Paper.pdf

- Turkey's renewable energy resource potential is around 136,600 MW. However, Turkey uses only 13.6 percent of its domestic renewable energy resources.
- Turkey aims to drop natural gas' share in electricity production to 30 percent but raise renewable energy resource share to 30 percent by 2023.
- To increase the share of nuclear power to 5 percent in the electricity production.
- To increase utilisation of local and renewable energy sources to reduce excessive dependence on natural gas (15-20 percent of energy).

The envisioned goals can only be achieved with a National Energy Strategy that is future-oriented and holistic; has realistic objectives and measurement mechanisms; is oriented towards local resources, manpower, scientific research and technology development; is open to global opportunities and partnerships; is shaped by active participation of all stakeholders in the guidance of the public sector; and is implemented consistently and adamantly.

Japan, Switzerland, Germany, and Denmark are all very successful in energy efficiency, as well as the example of the United States should also be emulated, which continuously puts more and more emphasis on energy efficiency.

3.2. Energy Efficiency and Energy Dependency Relationship in Turkey

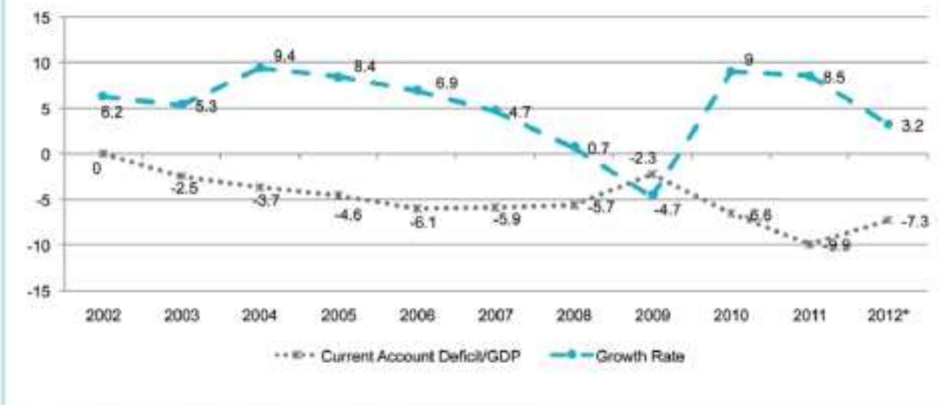
Let me first point at the relationship between import dependency in energy and current account deficit. Turkey is dependent on imported energy. More than 70 percent of energy consumption is imported. The energy import was 38,5 billion USD (20.8 percent of total import) in 2010 and 60,1 billion USD (25.1 percent of total import) in 2012.

As of 2011, Turkey's current account deficit was 10 percent of its GDP (see Chart 1 and 2). Turkey's dependency on energy imports is the main driver of the current account deficit. Deficit in current account was considered as one of the elements of fragility in Turkish economy. As a result, Turkish economy had to choose between economic growth and current account deficit.

Foreign Trade Developments in Turkey

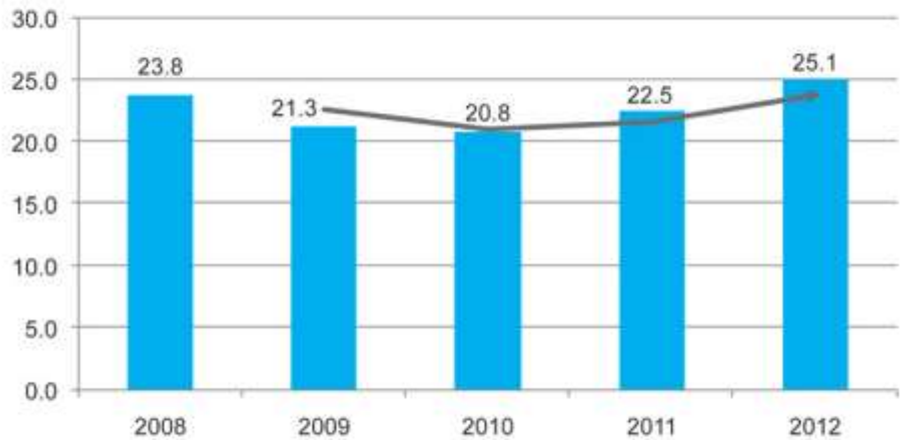
	Annual (Billion $)		Periodic (Billion Dollar)		
	2011	2012	2012 / (JAN - FEB)	2013 / (JAN - FEB)	Change (%) 2012/2013
Export	134.9	152.5	22.1	23.9	8.3
Energy Export	6.5	7.7	1.3	1.1	-14.5
Gold Export	1.5	13.3	0.7	1.0	41.6
Import	240.8	236.5	35.3	38.2	8.3
Energy Import	54.1	60.1	9.5	9.1	-3.6
Gold Import	6.1	7.6	0.4	1.7	307.2
Foreign Trade Volume	375.7	389.0	57.4	62.1	8.3
Foreign Trade Balance	-105.9	-84.1	-13.2	-14.3	8.4
Balance excl. Energy	-58.4	-31.6	-5.0	-6.2	25.2
Export/Import (%)	56.0	64.5	62.7	62.7	*

Chart 1. Growth Rate and Current Account Deficit/GDP Ratio



Source: Turkish Statitical Institute, Middle Term Programme (2013–2015).

Chart 2. Share of Energy Imports in the Total Imports of Tukey (%)



Because of Turkey's dependence on external sources for energy, it is clear that any problem or crisis in energy supply can negatively affect the economic growth of Turkey. Thus, policies that provide energy supply security should be put into practice, which is critical because of Turkey's geographic and geopolitical location. The expansion of renewable energy will reduce dependence on foreign energy sources, volatile oil and natural gas prices in international markets, and curtail the long-run environmental degradation associated with carbon emissions. Therefore, Turkey's energy policies should be such that they should diminish the country's dependency for external energy sources by substituting them with renewable energy sources of Turkey and increasing energy efficiency.

Turkey, forging ahead with confident and rapid steps to become a pivotal and strong country in her region and the world, should aim for more efficient use of energy resources, development of deliberate policies of energy security, diversification of energy resources (using renewable energy sources) and development of new technologies. Turkey should reduce its dependence on foreign energy sources and become a pioneer rather than a follower in the energy sector, especially among developing economies.

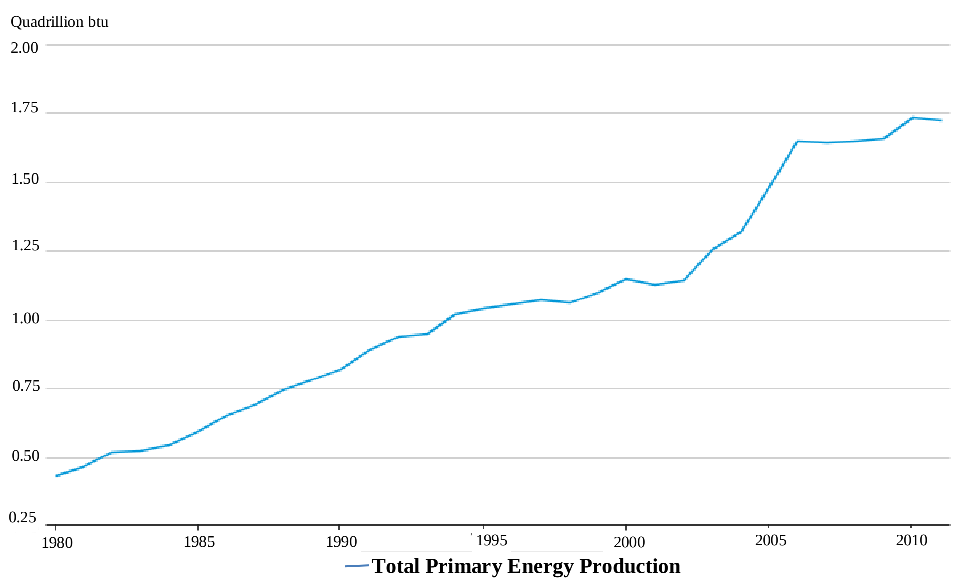
By increasing energy efficieny in Turkey, the energy dependency will be reduced and this will decrease the energy import and finally the current account deficit will be reduced. As a result, with energy efficiency policies current account deficit of Turkey can be decreased at least by 30 percent. In other words, current account deficit/GDP ratio can be decrased to 4-5 percent from 8 percent. Of course energy efficiency is one of the factors that will decrease the current accout deficit. The others are to export high value added products, increasing FDI and tourism revenues.

4. PAKİSTAN ENERGY OUTLOOK

The economy of Pakistan recovered modestly in 2012 compared to 2011. However, the overall economic outlook continues to be marked by low growth and high inflation imposed by energy shortages, security issues, and macroeconomic imbalances. Pakistan's inability to meet domestic energy demand has resulted in electricity outages, which is a key political and economic issue in the country. Thus, securing energy supply sources of natural gas, oil, hydro, and coal will be critical for Pakistan's economic growth.

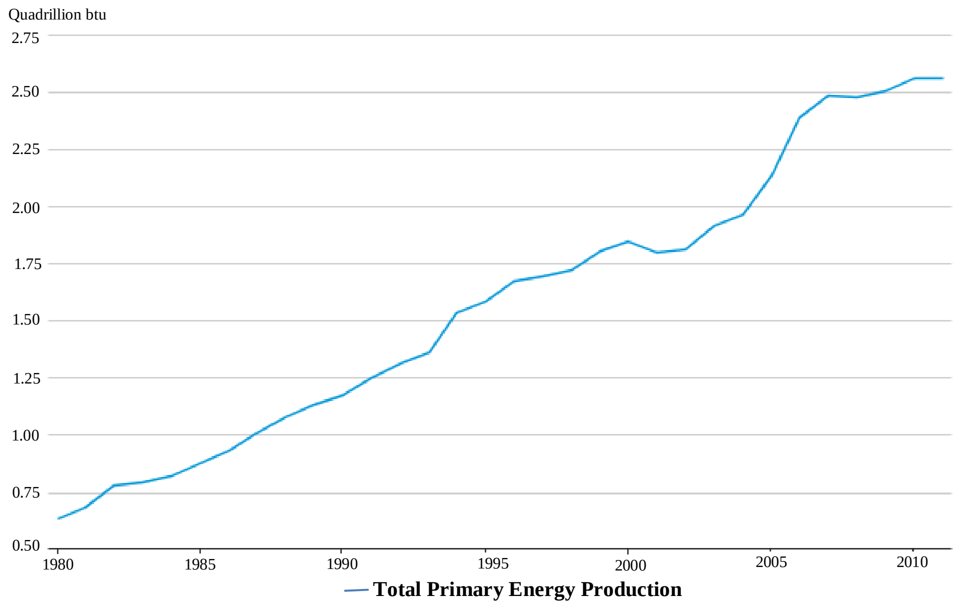
According to International Energy Agency and Asian Development Bank reports, the primary energy demand for Pakistan is projected to increase from 84.6 million tons in 2010 to 145.8 million tons in 2035, growing at an annual rate of 2.2 percent. With this growth, Pakistan's per capita energy demand will reach 0.59 tons per person as compared to that of 0.49 tons in 2010.

Pakistan Total Primary Energy Production (1980–2011)

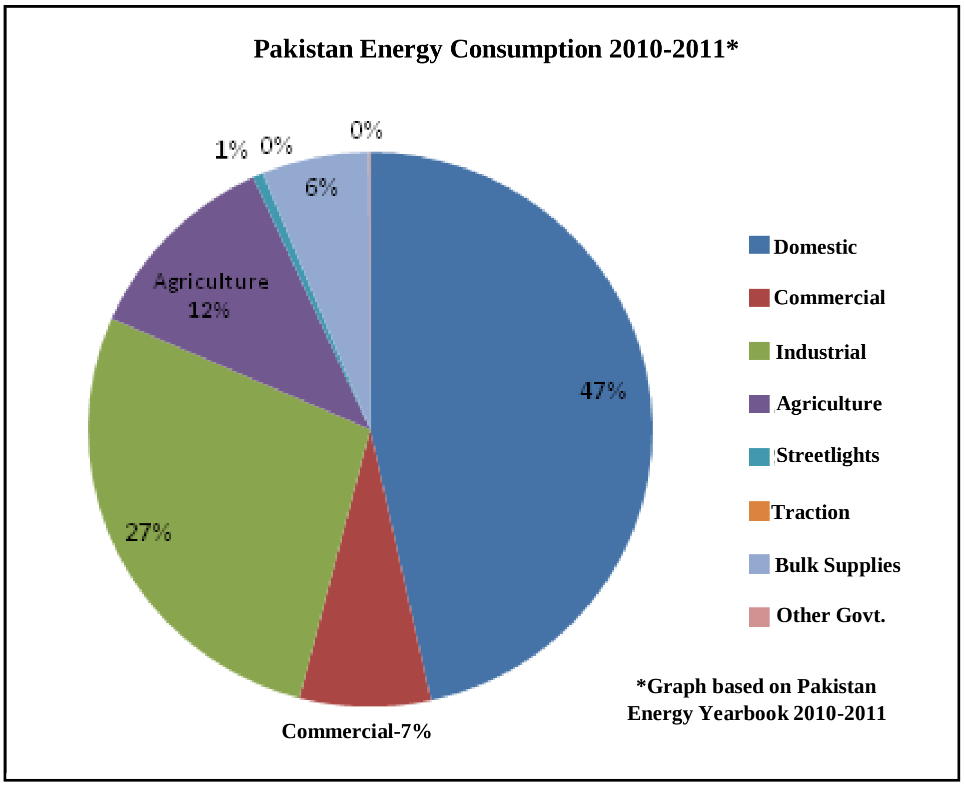


Source: U.S. Energy Information Administration.

Pakistan Total Primary Energy Production (1980–2011)

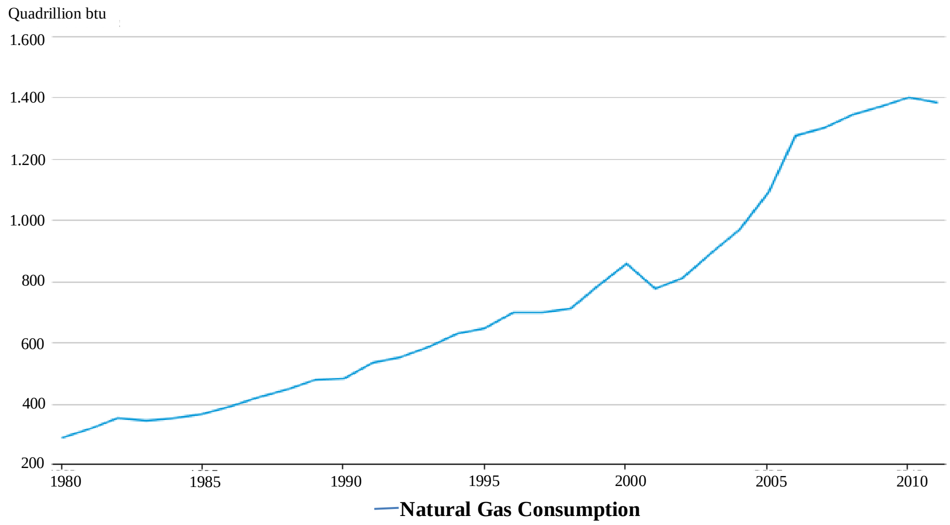


Source: U.S. Energy Information Administration.



Dry natural gas production has grown by more than 70 percent over the past decade from 809 billion cubic feet (Bcf) in 2002 to 1,383 Bcf in 2011, all of which was domestically consumed. Despite the growth of natural gas production, the country's demand is still constrained. Pakistan currently does not import natural gas because it lacks the infrastructure. Pakistan is self-sufficient in natural gas—the main energy source to meet its primary energy demand—while domestic production will decline from the current 38.4 billion cubic metres (bcm) to 13 bcm in 2035 and Pakistan will have to start importing natural gas sometime after 2015.

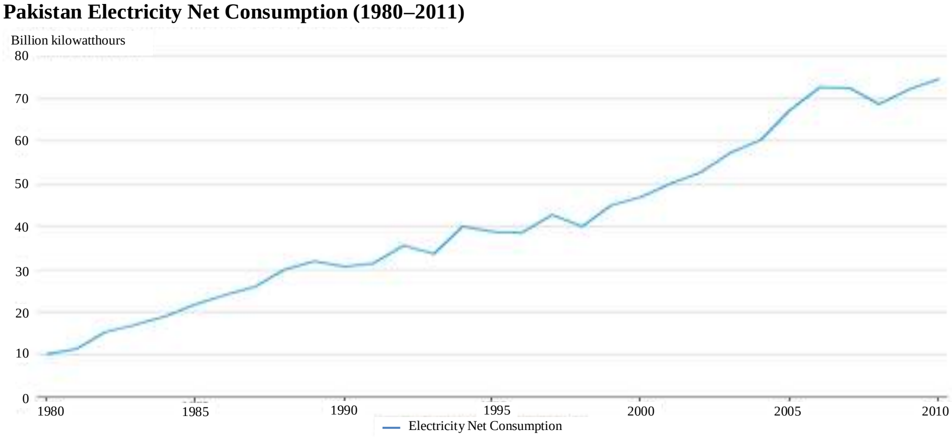
Pakistan Natural Gas Consumption (1980–2011)



Source: U.S. Energy Information Administration.

Electricity net consumption has increased from 47 billion kilowatthours (KWh) in 2000 to 74 billion KWh in 2010. According to the latest World Bank estimates, Pakistan had an electrification rate of 67 percent in 2010.

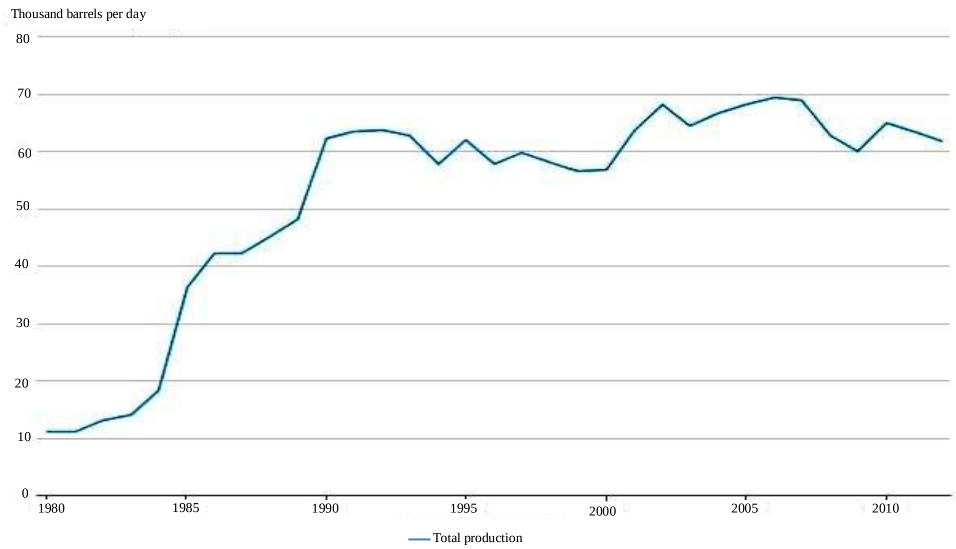
Pakistan Electricity Net Consumption (1980–2011)



Source: U.S. Energy Information Administration.

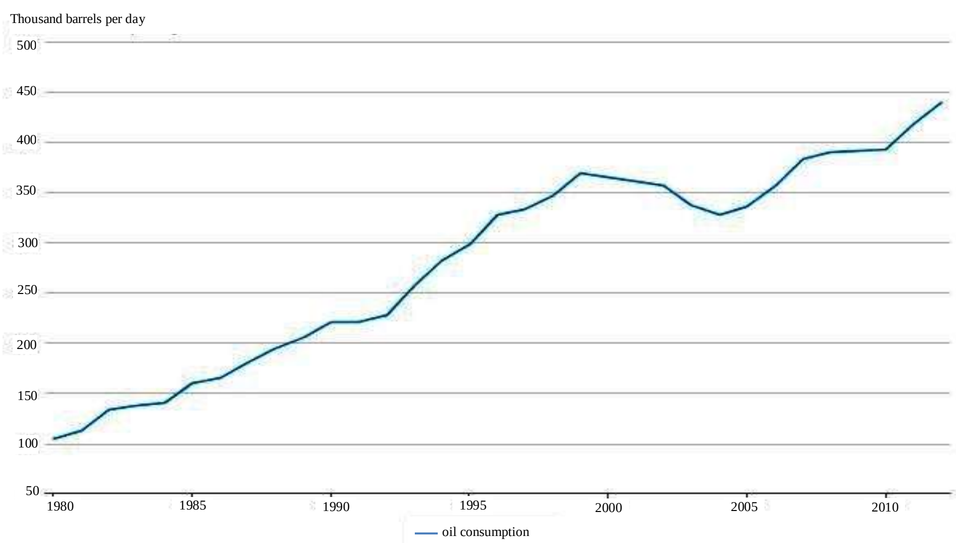
Pakistan is a net importer of crude oil and refined products. Oil production in Pakistan has fluctuated between 55,000 to 70,000 barrels per day (bbl/d) since the 1990s. The country produced 62,000 bbl/d of oil in 2012. Oil consumption has grown over time and averaged 440,000 bbl/d in 2012. Oil import dependency may rise to nearly 90 percent by 2035, if domestic oil production is maintained at a constant level.

Pakistan Total Oil Production (1980–2011)



Source: U.S. Energy Information Administration.

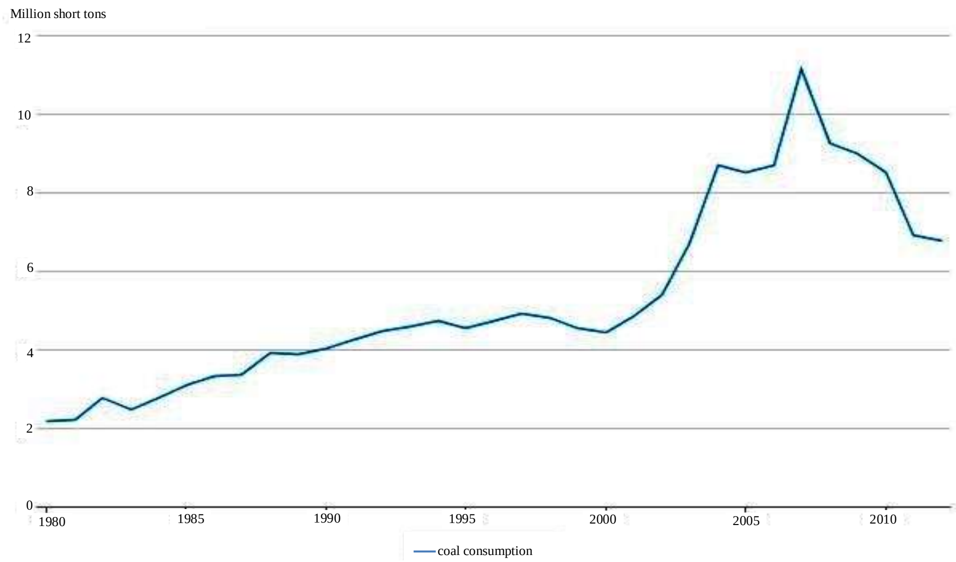
Pakistan Oil Consumption (1980–2011)



Source: U.S. Energy Information Administration.

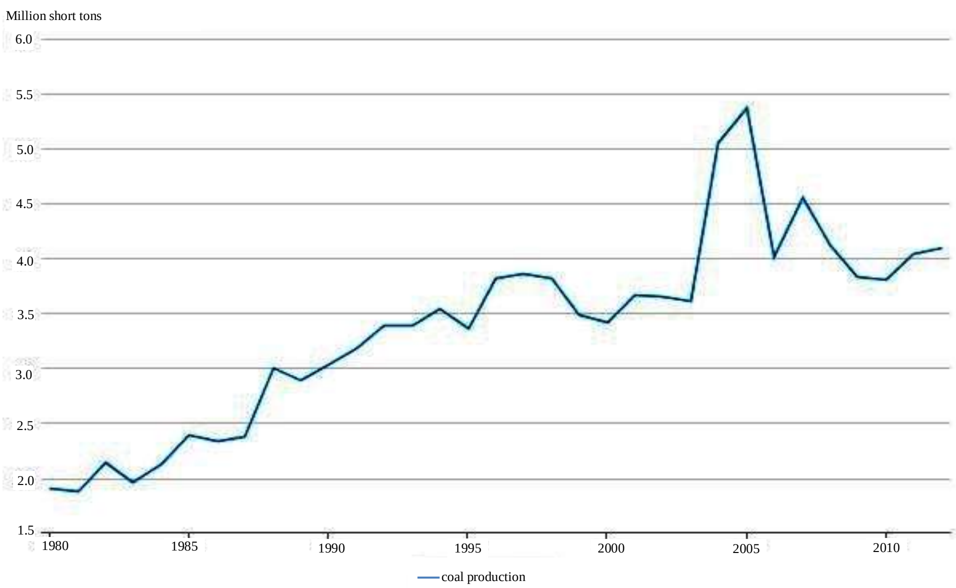
Coal import dependency will decline to 20 percent in 2035 from 67 percent in 2010. Coal production is projected to increase from the current 1.4Mtoe to 9.7Mtoe by 2035, with the expanded production from the Thar coalfield.

Pakistan Coal Consumption (1980–2011)



Source: U.S. Energy Information Administration.

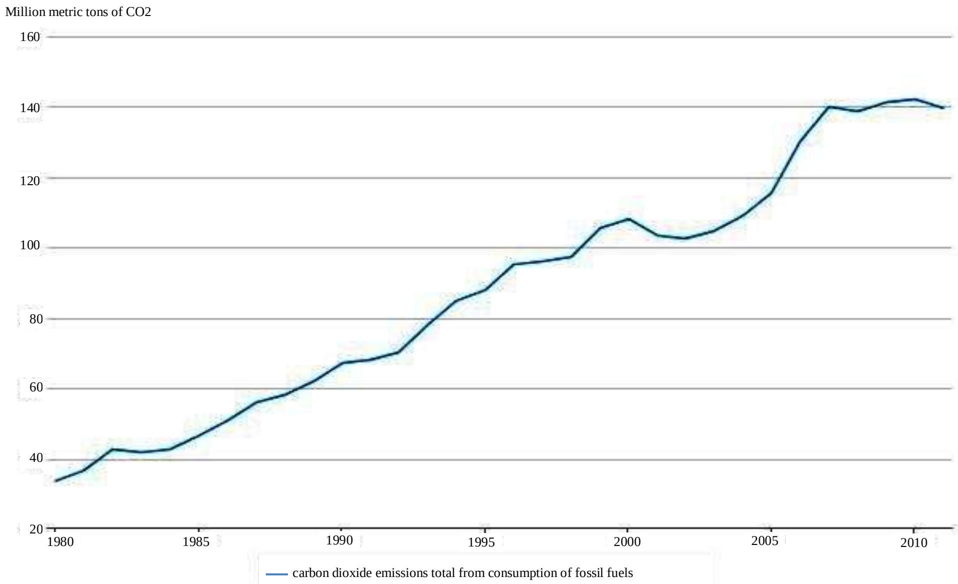
Pakistan Coal Production (1980–2011)



Source: U.S. Energy Information Administration.

Carbon dioxide emissions from consumption of fossil fuels have been increasing during last two decades in Pakistan due to inreasing demand for energy.

Pakistan Carbon Dioxide Emissions Total from Consumption of Fossil Fuels (1980–2011)



Source: U.S. Energy Information Administration.

Pakistan is endowed with potential new and renewable sources such as wind, solar and biomass and their contributions will be important, as well, to diversify the energy sources. To secure energy supply and meet the energy demand in future, the importance of renewable energy becomes even more critical. A rich natural potential of renewable energy resource is already there, the question only lies how to actualise this in practice. Considering geographical and climatic conditions, Pakistan is well placed to exploit more renewable energy sources like Wind, Solar, Biomass. Due to more favourable climatic conditions in Pakistan, solar PV possesses almost infinite potential to generate electricity in Pakistan. Wind energy also has a huge capacity to produce electricity in Pakistan. The other potential source of energy is the Biomass energy.

These rich sources of electricity generation potentially available in the country need special attention and incentives from Government in order to comply with growing energy demands of the country. In this case, Turkey may be a good example for Pakistan to get its experience in this area. Because electricity sector is privatised and all the laws were passed about producing and selling electricity in Turkey. Thus, similar applications can be done wtih private and public sector together by taking economic and social conditions of Pakistan into consideration.

With continued energy demand growth in Pakistan, it will be increasingly difficult to meet demand with domestic sources. Pakistan is faced with constraints in domestic energy supply as well as the need for upgrades and replacement of obsolete energy supply infrastructure, including power plants and transmission and distribution systems.

It is important to note that demand-side efficiency improvements, mainly to reduce electricity demand, will greatly affect Pakistan's overall energy requirements and promote economic growth. As a policy implication, Pakistan government must consider energy efficiency and increasing the share of renewable energy sources (Solar, Wind, Biomass, Hydro…) as a priority items in its energy policy agenda.

4.1. Causes of Electricity Shortages in Pakistan

- Increase in cost of oil
- Number of dams and level of water in rivers
- Power theft (electricity theft)
- Incomplete projects
- Lack of energy conservation programme
- Imprudent and reckless energy policies
- Weak grid infrastructure
- High transmission and distribution losses
- Mismanagement
- Corruption
- Growing energy demand and etc.

4.2. Suggestions to Overcome Energy Crisis in Pakistan

- Privatising distribution is an especially important step.
- the role and share of private sector should be increased.
- There is a need for a strategy to launch a sustainable long-term national energy efficiency programme and most importantly, design effective incentive mechanisms.
- Public's awareness of the importance and substantial social benefits of energy efficiency (saving) should be shared with society by using campaigns.
- Pakistan Energy Council should be constituted/created which should include people from public sector, private sector, professionals and academics.

Prepare SWOT Analysis of Energy

For policy-makers to prepare energy strategy document and give correct decisions on enery policies, Pakistan authorities must prepare a SWOT analysis. It is necessary to see:

- what we have? (current energy supply, Pakistan energy sources)
- what we need? (energy demand)
- energy demand > energy supply= Energy deficit
- how and from where we get the difference?
- the cost of financing energy
- the effects of the sources on economy, society and environment.

Pakistan Needs Energy Strategy Plan

—To overcome energy crisis, Pakistan needs to take the steps in form of:

— **Short Term Plan**

- import electricity from your neighbours.
- strict regulations by government, such as using smart electricity counters instead of mechanical one to reduce the electricit theft and etc.

— **Medium Term Plan**

- developing and installing solar and wind projects in small places like villages.
- announce energy efficiency programme and apply it.
- using energy saving devices (electrical applicances, lighting etc.)
- announce incentive programmes for private sector who can make renewable energy investment.

— **Long Term Plan**

- installing coal based powerhouses.
- build nuclear energy plant.
- increasing number of dams.
- increasing efficient natural gas stations.

5. CONCLUSION AND POLICY IMPLICATIONS

The purpose of this paper is to explore the importance of energy efficiency and renewable energy sources and their roles on reducing energy dependency and promoting energy security. Energy efficiency helps address the "Energy Trilemma" i.e. energy security, environmental sustainability and energy equity. Therefore, improving energy efficiency and using more renewable energy sources will allow energy savings and reduction in the environmental impacts of energy production and use, and reduce the energy dependency of that country. Thus, to achieve sustainable development, energy dependent countries must pay attention to energy security and environment, energy efficiency, and renewable energy sources in order to deal with energy shortages, negative effects on economic growth and climate changes.

As mentioned before, both Pakistan and Turkey are energy importing (energy dependent) countries. Turkey is both natural gas and oil importing country while Pakistan is oil importing country. Thus, any problem in energy supply will directly affect the economic growth of these countries.

In this case, the importance of energy efficiency and renewable energy sources become more critical for these countries. Renewable energy sources and energy efficiency should be supported for the following reasons:

- for energy supply security and diversification of energy sources,
- reducing dependence on energy imports,
- to fight against climate change, reducing carbon dioxide emissions, creation of new jobs, contributing to local and regional development (contributing to economic and social cohesion).

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Gustav Ranis Lecture

Electricity Economics and Integrated Resource Strategic Planning

ZHAOGUANG HU

Electricity supply economics and electricity demand economics are the two major components of electricity economics. This paper discusses the production functions with electricity, a core principle of electricity demand economics. In this paper, production functions with electricity are introduced at the firm level, sectoral level, industrial level, and national level. This paper also discusses integrated resource strategic planning (IRSP). As a part of electricity supply economics, it is a useful tool for policy study on low-carbon electricity. During the national economic development, low-carbon electricity can be recognised as the IRSP and the implementation of smart grid. The low-carbon electricity would be a great roadmap to Pakistan's economic development. Pakistan's economy is in an early phase of industrialisation. China's economy is in the late phase of industrialisation. Experiences and lessons from China's economic development would provide references to Pakistan.

Keywords: Electricity Economics, Production Functions with Electricity, Integrated Resource Strategic Planning (IRSP), Low-carbon Electricity, Pakistan, China

1. INTRODUCTION

What is electricity economics? This is a popular topic that receives global attention from all quarters. Electricity economics consists of two parts: electricity supply and electricity demand [Hu and Hu (2013)]. On the electricity supply side, it studies the economic issues in the electric power sector, including topics of: economic operation of power system, economic analysis of power plant construction and operation, power sector regulation and deregulation, power generation expansion planning, electricity tariff, economic analysis of power transmission and distribution. It is based on the fundamentals of economics to study and solve the electric engineering problems on power supply side. For example, generation expansion planning is to optimise the power resources such as hydro power, nuclear power, coal-fired power, gas/oil power, wind power, solar power and etc. to get the best profits or least cost from technical and economic perspectives [Yuan, Kang, and Hu (2008)]. It investigates optimal allocation of resources and electric power supply [Stoft (2002)]. How to improve productivity of power system is also discussed by many economists and researchers [Rothwell and Goméz (2003)], which is called electricity supply economics [Zhang and Shen (2005)], or electric power (system) economics.

Zhaoguang Hu <zghu@public3.bta.net.cn> is Vice President and Chief Energy Specialist, State Grid Energy Research Institute, SGCC, China.

The electricity demand part investigates the economic and business issues based on electricity consumption. Electricity consumption is positively correlated with production output. On the level of firm production, it studies the output such as product quantity, product sale, value added, and production profit by analysing electricity consumption for any production line and other economic activities. For commercial service, it helps managers to analyse revenue, value added, profits, and other business issues based on electricity consumption. On sector level, it studies the production on the basis of electricity consumption. On national level, it reviews macroeconomic developments by analysing electricity consumption on the industrial and state levels.

Production functions with electricity are principles of electricity demand economics. Since increasing volume of products are being produced and increasing amount of electricity is consumed, the product quantity can be mathematically expressed as a function of electricity consumption. Production functions with electricity can be used with electricity consumption as input production function which can be studied on firm level, sectoral level and national level [Hu and Hu (2013)].

Electricity demand economics can be helpful to review, study, observe and analyse economic operation, the trend of economic growth, and the characteristics of the economy's dynamics. For firm production function with electricity, the *e-q* function can show the relationship between electricity consumption *e* and product quantity *q*, *e-re* function studies the relationship between electricity consumption and revenue *re*, *e-v* function demonstrates the relationship between *e* and value added *v*, and *e-pf* function shows the relationship between *e* and profit *pf*. Similarly, there are *Es-Q* function, *Es-Re* function, *Es-V* function, and *Es-Pf* function on sectoral level. For three industries (primary industry, secondary industry, and tertiary industry), there are E_1-V_1 function, E_2-V_2 function, and E_3-V_3 function to study the electricity consumption and value added for the three industries respectively. For state, there is *E-GDP* function to study the relationship between GDP (gross domestic product) and electricity consumption *E* to exhibit the inherent character of the national economy. Electricity demand economics is a new area which has not been explored broadly. Details are discussed in the book "Electricity Economics: Production Functions with Electricity" Springer (2013).

Why do we investigate electricity demand economics? Electric energy, as an important production factor, has been widely used in almost all economic activities (except transportation by gas/oil vehicles and etc.). The characteristics of electricity data of being accurate, accessible and representative of production factors are key elements for electricity demand economics. With the development of electrification, it is also essential in our residential life. In the modern society, commercial business and manufacturing activities are closely associated with electricity consumption. An electric pump can help farmers to irrigate agricultural land; machines and electric equipment require electric power to drive production line in manufacturing; shops, hotels, and restaurants must use electricity to do their daily businesses and services. With the improvement of electric vehicle technologies, transportation will also use more and more electric energy in the near future.

Electricity economics is used to study the issues in the electric power sector based on the principals of economics, which is now being recognised as electricity supply economics. On the other hand, electricity consumption reflects the economic issues of the electricity, which is now recognised as electricity demand economics.

Therefore, electricity economics consists both electricity supply economics and electricity demand economics, i.e. [Hu and Hu (2013)].

Electricity economics = electricity supply economics + electricity demand economics

2. CHARACTERISTICS OF ELECTRICITY DATA

Since electricity is very difficult to be massively stored, it is required that the electric power generation and electricity consumption must be balanced simultaneously. Any unbalance between power supply and demand will make the power system operation unstable, and then power outage could happen at large scale. If the electricity supply is interrupted, not only the production of various industries, but also the people's life would be disrupted. Power system consists of generators, transformers, power lines, power users, etc. In order to guarantee a stable power system operation, the following equation has to hold:

Power generation = line loss + power consumption … … … (1)

Electricity data can be collected and measured by electric meters. With the development of metering technologies, it is easy to access electricity data. For example, China's official electricity data of the month is published in the middle of the next month. It has only two weeks of lag period on monthly basis. However, the GDP data is published quarterly during the year. Furthermore, electricity data obtained from meters contains the features of highly comprehensive, reliable, accurate, and timely data, not merely in China but also in Pakistan as well as many other countries in the world.

With technology innovation, smart grid will highly integrate the system of power grid beyond the boundaries of countries. Smart meters will secure electricity data classification to be more detailed. It is possible to get the data after each 15 minutes. Thus, smart grid and related improvements of technologies will provide more detailed and reliable data on electricity consumption at any time interval. Based on the rule of power system operation, electricity data is more accurate than any other economic data.

National electricity consumption (referred to as total electricity consumption), is the sum of primary industry electricity consumption, secondary industry electricity consumption, tertiary industry electricity consumption, and the residential electricity consumption. Electricity consumption from the three industries can produce value added, which is called productive electricity consumption. To summarise: the productive electricity consumption has four characteristics as follows [Hu and Hu (2013)]:

(1) Necessity—almost any production must use electricity.
(2) Accuracy—the data of electricity consumption can be collected by reading meters. It is objective and unbiased, and it can also be checked by formula (1).
(3) Accessibility—it is very easy to get the reading of electricity consumption from a smart meter per hour (or per 15 minutes).
(4) Representativeness—as a production input, electricity consumption is in proportion to the other production inputs. Electricity consumption can be the representative of all other production factors.

3. PRODUCTION FUNCTIONS WITH ELECTRICITY [Hu and Hu (2013)]

Production function is the relationship between the input and output. What is production function with electricity? The characteristics of electricity data are useful to production function with electricity, i.e. electricity as an input to set up a production function. The characteristic of necessity makes it possible to set up production function for almost all production lines in industries. Representativeness makes it possible to set up the production function with only one production factor, electricity. Therefore, the production function will be very simple and accurate.

The enterprise production function with electricity can reflect both the technology level and management level of the production. If the quantity of product in a firm increases/decreases, it means that the contribution of other production factors also increases/decreases, then, electricity consumption will increase/decrease accordingly as well. The change in electricity consumption is the result of the changes in the other production inputs. Therefore, electricity consumption *e* will vary accordingly with respect to the change in other production inputs (*l*,*m*,…*w*). Relationship between the production inputs (*l*, *m*,…, *w*) and electricity consumption *e* can be seen as a mapping *f* [Hu and Hu (2013)]. It is the positive correlation between *e* and (*l*, *m*,…, *w*). The production function with electricity can be expressed as follows [Hu and Hu (2013)]:

$$y = F(e) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

The output *y* is the function of input *e*. In fact, the data history and data samples have shown that the formula (2) is a linear function, it can be expressed as follows [Hu and Hu (2013)].

$$y = ae + b \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

where *a* is the slope of the linear function and *b* is the intercept of the function.

As introduced in [Hu and Hu (2013)], the average output of electricity *ay* for enterprise is equal to total quantity of the output *y* divided by the electricity consumption *e*. Marginal output of electricity *my* is the increase in total quantity of the output Δy that results from one-unit increase in electricity consumption Δe.

We can see that the slope of the linear function (3) is the marginal output of electricity.

The output *y* can be total quantity of the product *tq*, revenue *re*, value added *v*, and profits *pf*. for the firm. As discussed in the book "Electricity Economics: Production Functions with Electricity" Springer (2013), we can have the following four production functions with electricity :

e-*q* function: $tq = a_1 e + b_1 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (4)$

e-*re* function: $re = a_2 e + b_2 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (5)$

e-*v* function: $v = a_3 e + b_3 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (6)$

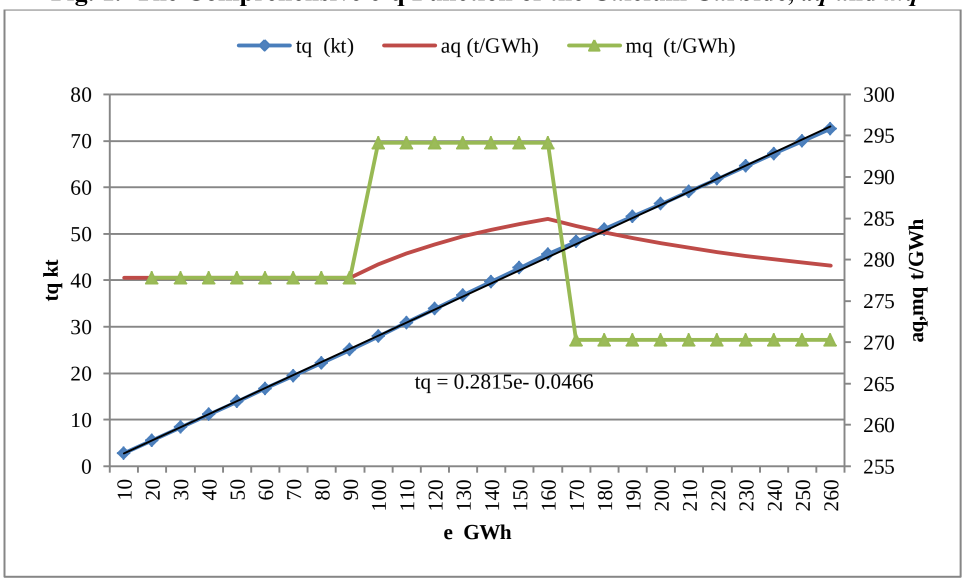
e-*pf* function: $pf = a_4 e + b_4 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (7)$

A case study is shown in Figure 1 [Hu and Hu (2013)], an enterprise has three types of production lines (calcium carbide furnaces) to produce calcium carbide, the electricity consumption is about 3600kWh per ton of producing calcium carbide with little difference between the three kinds of production lines. The comprehensive *e-q* function for this enterprise is a linear function as follows:

$$tq = 0.2815e - 0.0466 \quad 10 \le e \le 260 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

Figure 1 also shows the curves of the production function with electricity *e-tq*, average quantity of electricity *aq* and marginal quantity of electricity *mq* for the product calcium carbide in this enterprise. The marginal product of electricity varies at electricity consumption 90 GWh and 160 GWh since the three production lines switched one by one. The highest *mq* is 294 ton/GWh, the lowest one is 270 ton/GWh, and the comprehensive *mq* of the three production lines is 281.5 ton/GWh. The *aq* increases from 277.7 ton/GWh to 284.92ton/GWh, and then falls to 279.3 ton/GWh. It increases generally since the intercept of the linear *e-q* function (8) is negative.

Fig. 1. The Comprehensive e-q Function of the Calcium Carbide, *aq* and *mq*



Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. p. 41 Springer.

Now we look at the sectoral production functions with electricity, a sector consists of many firms producing the same kinds of product. If we take *Q* as the total quantity of all firms produced product, *Re* as the sectoral revenue, *V* as the value added of the sector, *Pf* as the profit, and *Es* as electricity consumption of all firms, then, sectoral production functions with electricity are as follows:

Es-Q function: $Q = A_1 Es + B_1 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$

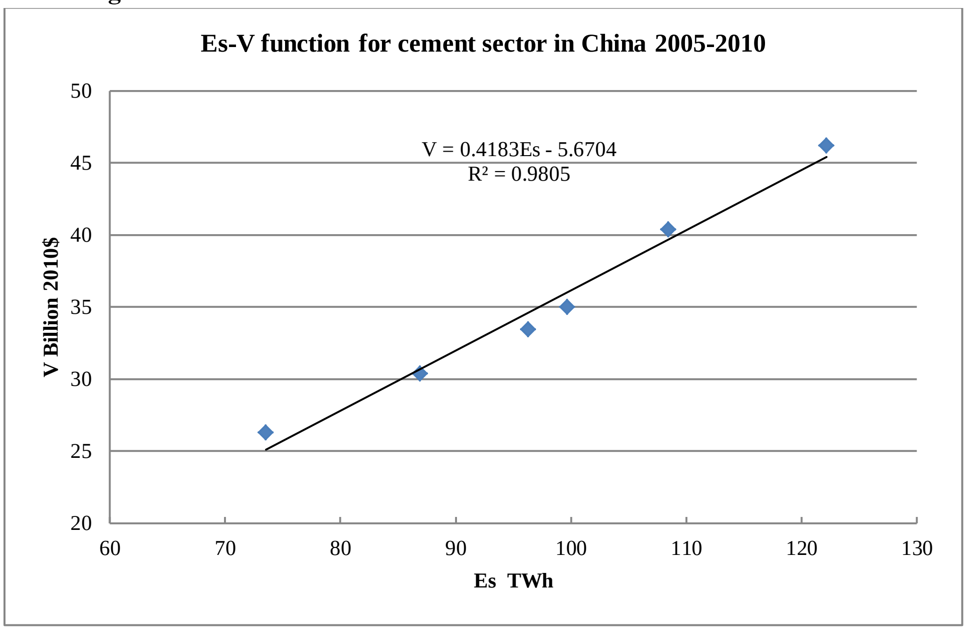
Es-Re function: $\mathrm{Re} = A_2 Es + B_2 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$

Es-*V* function: $V = A_3 Es + B_3$ … … … … … (11)

Es-*Pf* function: $Pf = A_4 Es + B_4$ … … … … … (12)

Figure 2 shows the *Es*-*V* Function for the cement sector in China during 2005–2010. It is a linear function with the slope as 0.4183 and intercept as –5.6704. It shows that the marginal value added of electricity in the sector is 0.4183$/kWh (in constant 2010 USD) while the average value added of electricity is increasing with the growth of electricity consumption in the cement production.

Fig. 2. *Es*-*V* Function for the Cement Sector in China from 2005 -2010



Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. [M] p. 73 Springer.

An industry consists of many sectors, and there are three industries as primary industry (agriculture), secondary industry (industry) and tertiary industry (commercial). The electricity consumption for the three industries can be expressed as E_1, E_2 and E_3, and the value added as V_1, V_2 and V_3 respectively. Then, the production functions with electricity at industrial level can be expressed as follows:

E_1-V_1 function: $V_1 = A_1 E_1 + B_1$ … … … … … (13)

E_2-V_2 function: $V_2 = A_2 E_2 + B_2$ … … … … … (14)

E_3-V_3 function: $V_3 = A_3 E_3 + B_3$ … … … … … (15)

As an example for China, the E_1 was 23.815TWh and the V_1 was 1110.79 billion RMB (in constant 2010 RMB) in 1986. In 2010, they were 97.6TWh and 4053.36 billion RMB respectively. the E_1–V_1 function is a linear function as:

$$V_1(E) = 36.42E_1 + 272.5 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (16)$$

It shows the marginal value added of electricity in agriculture is 36.42RMB/kWh, and the average value added of electricity is decreasing with increasing electricity consumption.

For secondary industry in China in 1986-2010, the E_2 was 364.19TWh and V_2 was 1198.495 billion RMB in 1986. In 2010, the E_2 was 3145TWh and V_2 was 12567.44 billion RMB. We can see that the growth of E_2 was higher during the period since China's economy is in the different stages of the industrialisation. The E_2–V_2 function is a linear function as follows:

$$V_2(E) = 6.09E_2 - 21.81 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (17)$$

Its slope is 6.09, and its intercept is -21.81. The marginal value added of electricity of China's secondary industry is 6.09 RMB/kWh, which is lower than that of agriculture. The average value added of electricity is increasing with the growth of electricity consumption since the intercept of the function is negative.

For tertiary industry in China, the E_3 was 31.75TWh and V_3 was 1192.045 billion RMB in 1986. In 2010 the E_3 reached at 447.TWh and $V_3(S)$ was 17308.7 billion RMB. The E_3-V_3 is shown as:

$$V_3(E) = 39.48E_3 - 186.1 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (18)$$

The slope is 39.48, i.e. MV_3 is 39.48 RMB/kWh. It is higher than MV_2 and MV_1. The AV_3 is increasing with the growth of electricity consumption since the intercept is negative.

On the national level, the production function with electricity is *E-GDP* function as shown below:

$$GDP = AE + B \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (19)$$

The average GDP per unit of electricity is:

$$AGDP = \frac{GDP}{E} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (20)$$

It is also the electricity intensity of GDP. The marginal GDP per unit change in electricity is:

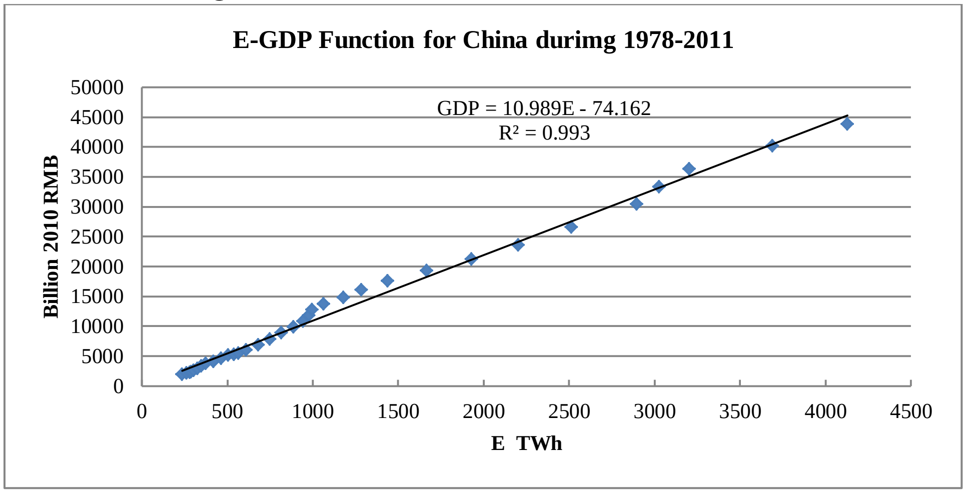
$$MGDP = \frac{\Delta GDP}{\Delta E} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (21)$$

China is the second biggest economy in the world. As the biggest developing county, its experience of the economic operation would be useful for other developing countries. What is the relationship between *E* and *GDP*? China's *E-GDP* function is (see Figure 3):

$$GDP = 10.989E - 74.162 \qquad 300<E<4000 \quad \dots \quad \dots \quad \dots \quad \dots \quad (22)$$

It shows the marginal GDP of electricity in China is 10.989RMB/kWh, and the average GDP of electricity is increasing with the growth of electricity consumption.

Fig. 3. *E-GDP* Function in China from 1978 to 2011



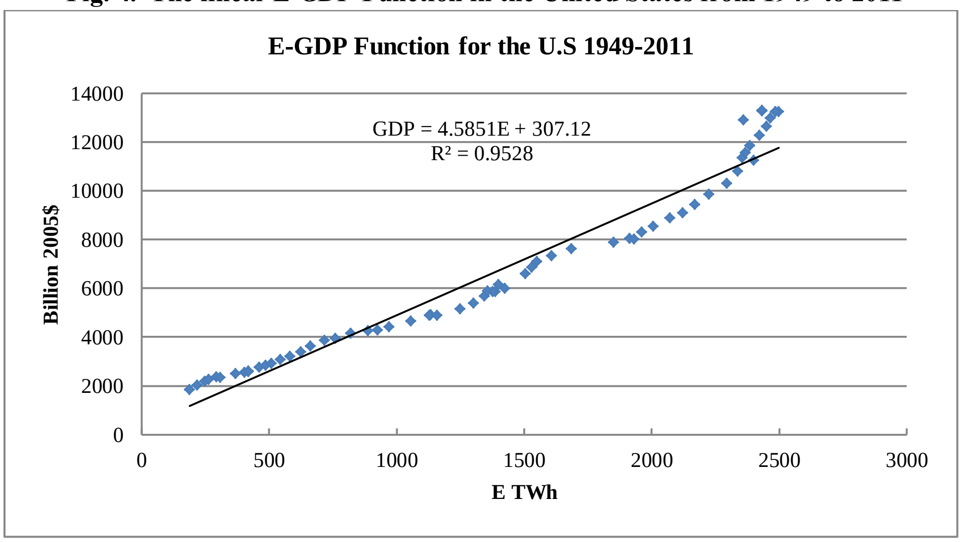
Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. [M] p. 144 Springer.

What about the U.S.? The U.S is the biggest economy and the biggest developed country in the world. The *E-GDP* function for the U.S. during 1949-2011 is shown in Figure 4 as:

$$GDP = 4.5851E + 307.12 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (23)$$

The slope of the function is 4.5851, i.e. the marginal GDP of electricity is 4.5851$/kWh in constant 2005$. The intercept is positive , it means the average GDP of electricity is decreasing with the growth of electricity consumption.

Fig. 4. The linear *E-GDP* Function in the United States from 1949 to 2011



Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. [M] p. 157 Springer.

Why the R^2 is only 0.9528 in Figure 4? In the past 50 years, the technologies have been greatly improved in the U.S. It has made some changes for the slope and intercept of the *E-GDP* function. The technology innovation has also divided the economic development period. As studied in the paper "Production Function with Electricity Consumption and Its Application" Energy Economics 39(2013) p. 317, there are four periods as 1949-1975, 1975-1987, 1987-1994, and 1994-2011 in the U.S. The *E-GDP* functions for the four periods are as follows:

1949-1975:

$$GDP = 3.1945E + 1342.6 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (24)$$

1975-1987:

$$GDP = 5.762E - 2018.7 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (25)$$

1987-1994:

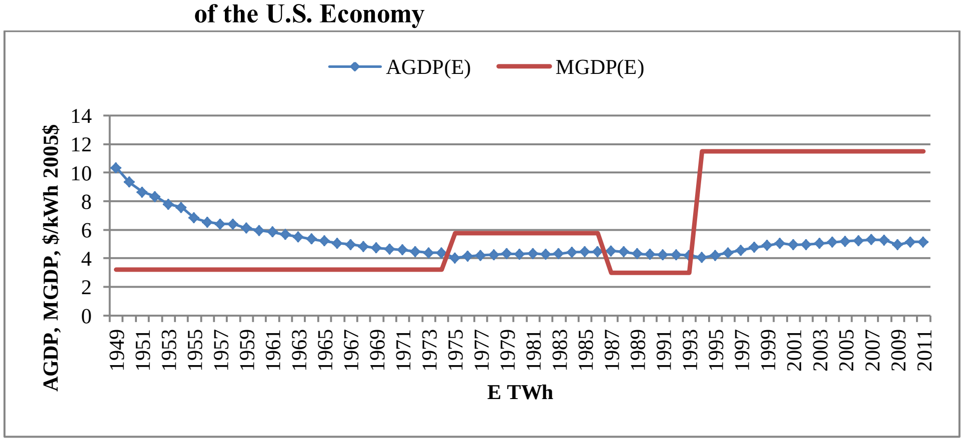
$$GDP = 2.9765E + 2477.2 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (26)$$

1994-2011:

$$GDP = 11.492E - 15438 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (27)$$

We can see that the slope of the *E-GDP* function has changed in the periods. It was 3.1945 during 1949-1975 increased to 5.762 in 1975-1987, and decreased to 2.9765 in 1987-1994, then, it increased to 11.492 in 1994-2011. The intercept also changed accordingly with the change of the slope. It was 1342.6 in the period of 1949-1975, and decreased to –2018.7 with the increase of the slope in 1975-1987, and increased to 2477.2 with decrease of the slope in 1987-1994, and then decreased to 15438 with the slope increase sharply in 1994-2011. Figure 5 shows that if the intercept is positive, then, the marginal GDP of electricity will be less than average GDP of electricity, and the AGDP is decreasing with the rise of electricity. On the other hand, if the intercept is negative, then, the marginal GDP of electricity will be bigger than average GDP of electricity, and the AGDP is increasing with the rise of electricity.

Fig. 5. *AGDP* and *MGDP* with the Improvements of Technologies of the U.S. Economy



Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. [M] p. 190 Springer.

Japan as the third biggest economy and second biggest developed country in the world, could show the way of industrialisation and post-industrialisation process during 1965-2010. Japan's *E-GDP* function is:

$$GDP = 689.4E + 21546 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

Its marginal GDP of electricity is 689.4 yen/kWh due to the low value of the yen currency. The average GDP of electricity is decreasing with the growth of electricity consumption. In fact, we can see the slope and intercept behave differently in different periods due to the technology innovation. Detail discussion can be found in the book "Electricity Economics: Production Functions with Electricity" in chapter 6 published by Springer (2013).

4. CASE STUDY FOR PAKISTAN

The economist Hollis B. Chenery had studied the characteristics of per-capita income during the different economic stages as shown in Table 1. Per-capita GDP was 783.3 USD (in constant 2005 USD) in 2011 in Pakistan (see Figure 6) [www.worldbank.org]. Accordingly, Pakistan is a developing country in the primary products phase based on Table 1.

Table 1

The Division Standard of Economic Development Phases (Chenery's Model)

Development Phase		Per Capita Income (in 1982 US Dollars)	Per Capita Income (in 2008 US Dollars) [Jiahai, *et al.* (2008)]
Primary Products Stage		260—364	
		364—728	710-1420
Industrialisation Stage	Early	728—1456	1420-2841
	Middle	1456—2912	2841-5682
	Late	2912—5460	5682-10654
Developed Economy Stage		5460—8736	10654-17046
		8736—13104	17046-25569

Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. [M] p. 228 Springer.

Based on the GDP, the value of per capita income must be transferred to a particular year's value, and also to USD with exchange rate or purchasing power parity. It will produce some errors. Electricity consumption per capita can show the economic development. Since electricity consumption has positive correlation with GDP, per capita electricity consumption can be taken as a rule for judging the stages of economic development. Therefore, electricity consumption per capita and residential electricity consumption per capita can be used to show the economic development stages (Table 2).

Table 2

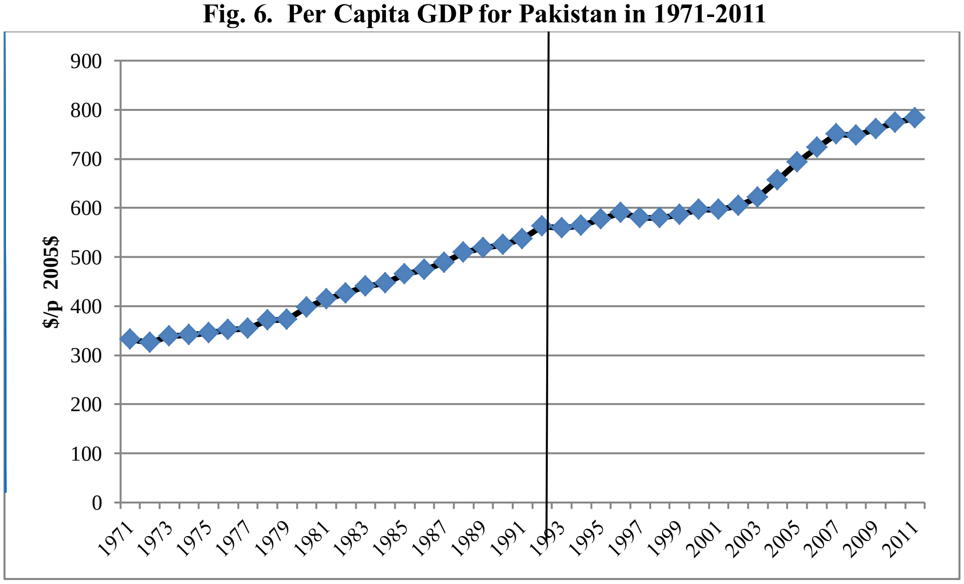
Electricity Consumption Features in Different Economic Development Phases (Unit: kWh/Person)

Development Phase		Per Capita Electricity Consumption	Per Capita Residential Electricity Consumption
Stage of Primary Commodity		<300	<20
Industrialisation Stage	Early	300—1000	20—80
	Middle	1000—2400	80—240
	Late	2400—4500	240—810
Stage of Industrialisation Completion		4500—5000	810—900
Developed Economic Stage	Early	5000—6000	900—1500
	Middle	6000—8000	1500—2400
	Late	>8000	>2400

Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. [M] p. 232 Springer.

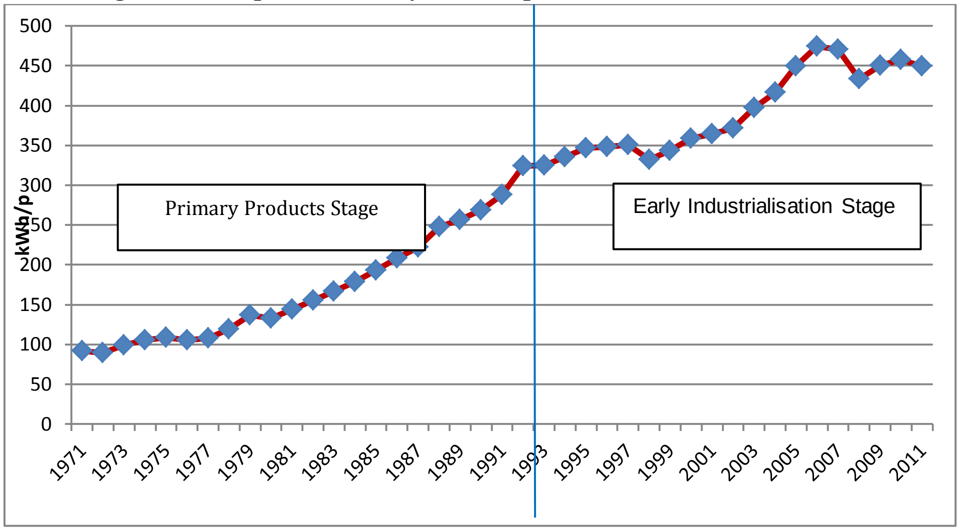
The per capita electricity consumption was less than 300kWh before 1992 (see Figure 7), and then, it was in the interval [300,500]. Since it is difficult to get the data of residential electricity consumption, the per capita electricity consumption would be only index in our study. Based on Table 2, the economy of Pakistan was in the primary product stage before 1992, and then, it entered into the early stage of the industrialisation.

Fig. 6. Per Capita GDP for Pakistan in 1971-2011



Data Source: http://www.worldbank.org.

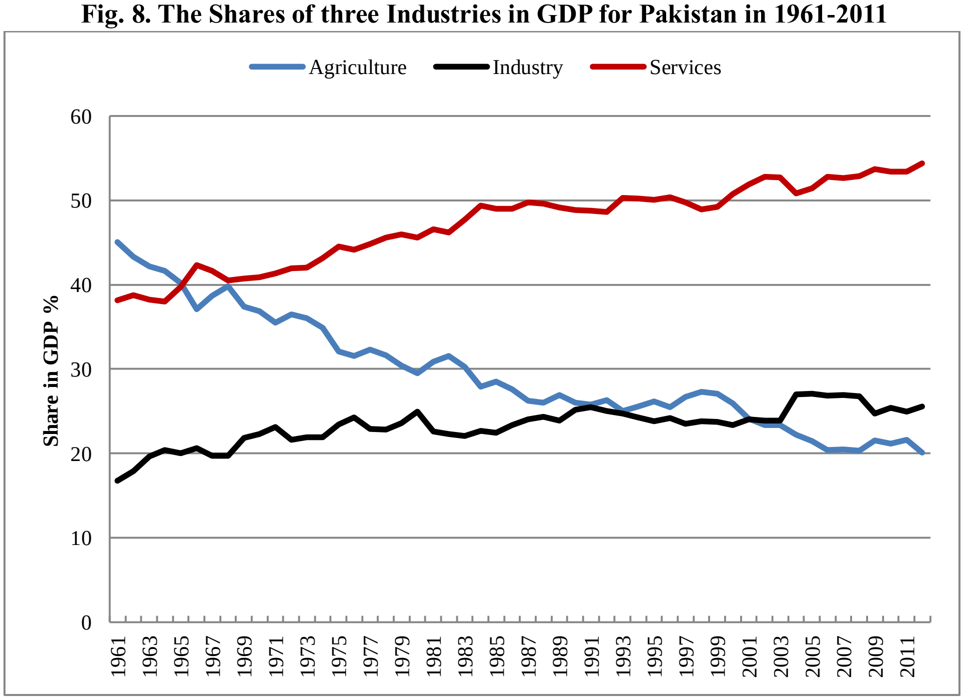
Fig. 7. Per Capita Electricity Consumption for Pakistan in 1971-2011



Data Source: http://www.worldbank.org.

At the early stage of industrialisation, the share of tertiary industry in GDP would be higher than that of secondary industry, and the share of secondary industry would be higher than that of primary industry. It can be shown in Figure 8 that the share of secondary industry is close to that of primary industry in 1991.

Fig. 8. The Shares of three Industries in GDP for Pakistan in 1961-2011



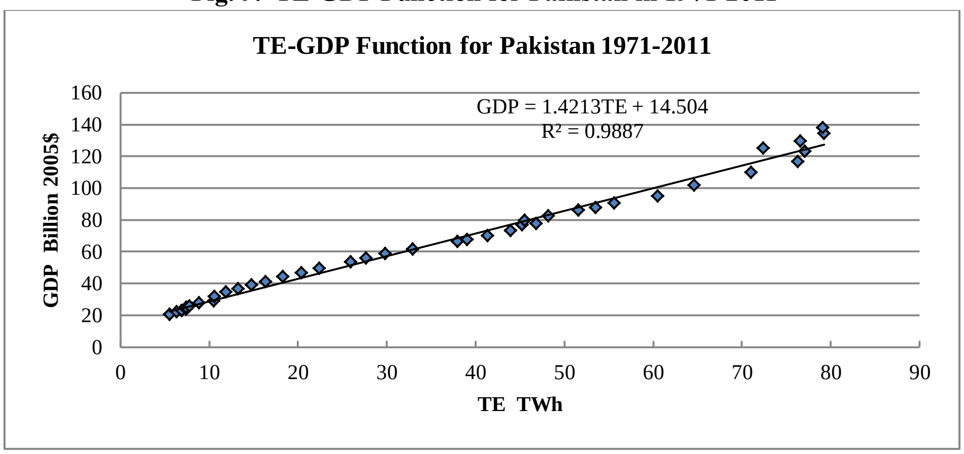
Data Source: http://www.worldbank.org.

Since there is no data on residential electricity consumption, the total electricity consumption is used to set up production function with electricity as *TE-GDP* function. the *TE-GDP* function of Pakistan as shown in Figure 14 is as follows.

$$GDP = 1.4213TE + 14.504 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (29)$$

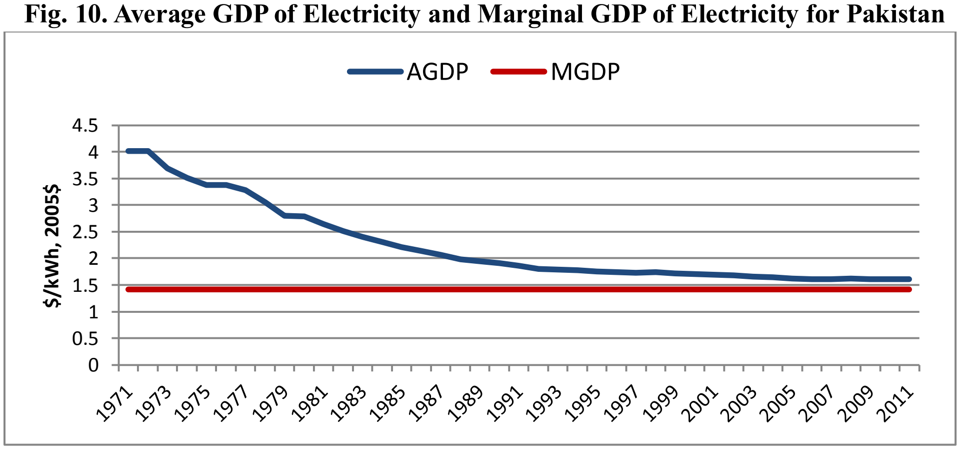
The intercept is 14.504 $/kWh in constant 2005$. The positive sign of the intercept would make the average GDP of electricity greater than marginal GDP of electricity and the AGDP will decline. We can see from Figure 10 that the AGDP (1.6046 $/kWh) was very close to MGDP (1.4213 $/kWh) in 2011. May be the *TE-GDP* function will have a change (mutation) that the slope would increase and the intercept would have negative value. In this case, the average GDP will rise with the more electricity demand in the near future. Some factors will push it such as the secondary industry growth, the drop in the share of primary industry and the technology innovation and improvement. Therefore, we find that there is a great opportunity for the development of Pakistan's economy in the near future to enter the middle stage of the industrialisation.

Fig. 9. TE-GDP Function for Pakistan in 1971-2011



Data Source: http://www.worldbank.org.

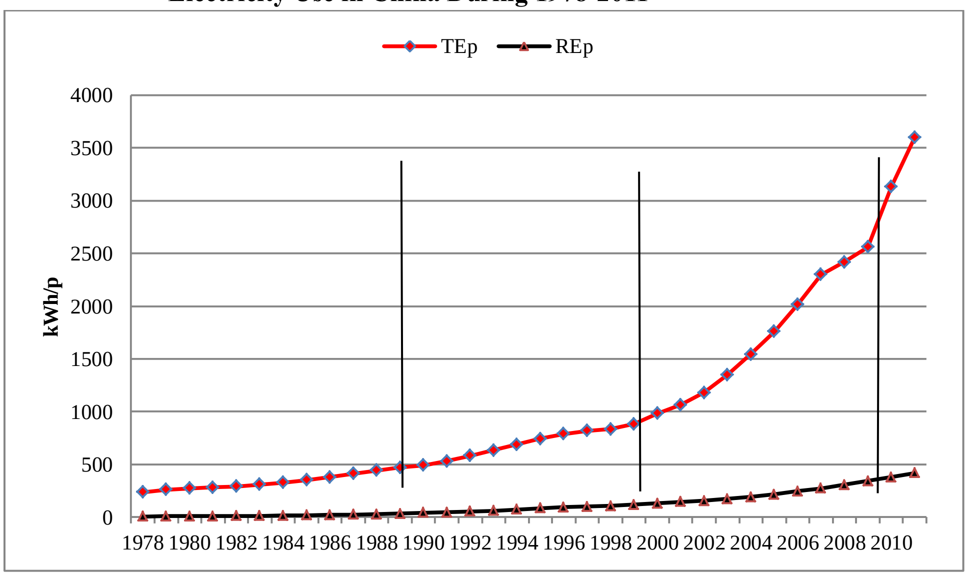
Fig. 10. Average GDP of Electricity and Marginal GDP of Electricity for Pakistan



In order to capture the opportunity of the economic development in Pakistan, what economic growth rate will be in the next 20 years? And what electricity demand will be to meet the economic growth? The forecast of the economic development and electricity demand is very hard since there will be so many uncertainties in the future. However, it is very important to do that since the construction of power plant will take many years. In this paper, the China's experience in the middle stage of the industrialisation will be considered.

The per capita electricity consumption (*TEp*) was 469kWh in 1989 in China, and it was higher than 1000 kWh in 2000 when China entered into the middle stage of the industrialisation. From 2009, China entered into the late stage of the industrialisation since the *TEp* was higher than 2400kWh. The *TEp* growth was 6.53 percent per annum in 1989-1999, and it was 11.23 percent per annum in 1999-2009 in China. The growth rate of *TEp* in the middle stage was higher than that of early stage of the industrialisation (see Figure 11).

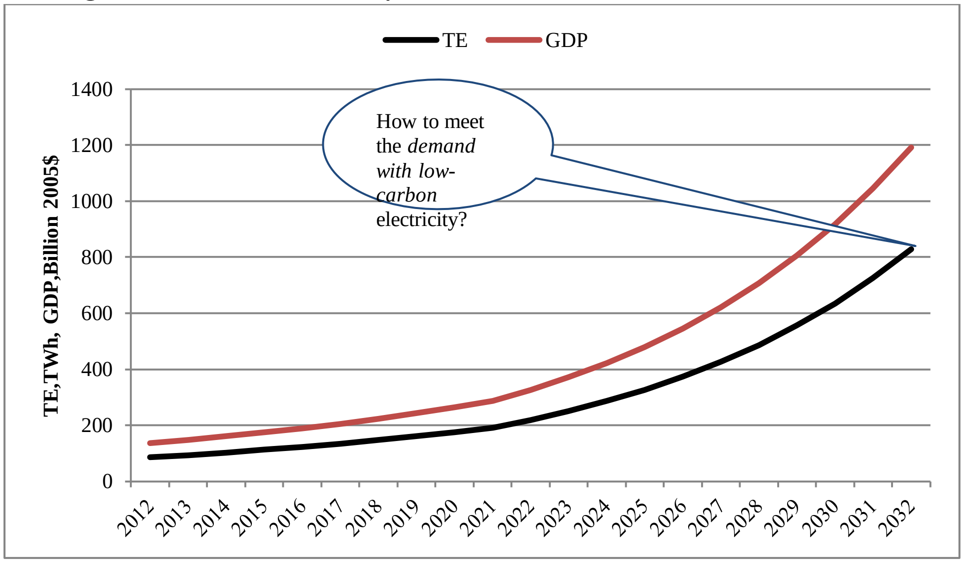
Fig. 11. Per Capita Electricity Consumption and Per Capita Residential Electricity Use in China During 1978-2011



Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity.* [M] p. 244 Springer.

Per capita electricity consumption was 450 kWh in Pakistan in 2011. It was the case of China in 1989. Suppose growth of *TEp* in Pakistan in 2012-2022 will be similar to Chinese' growth of *TEp* at 6.53 percent in 1989-1999, and it will be 11.23 percent in 2022-2032. And also suppose the growth of population in Pakistan will be 2.7625 percent annually until 2032, which is same growth as in 1961-2012. Then, the *TE* will be 219.39 TWh and GDP will be $362.32 billion (in constant 2005$) in 2022. In 2032, the *TE* will be 827.9 TWh and GDP will be $1191.19 billion in Pakistan (see Figure 11). How to meet the electricity demand with low-carbon electricity? The power planning method will be important in the model of low-carbon electricity.

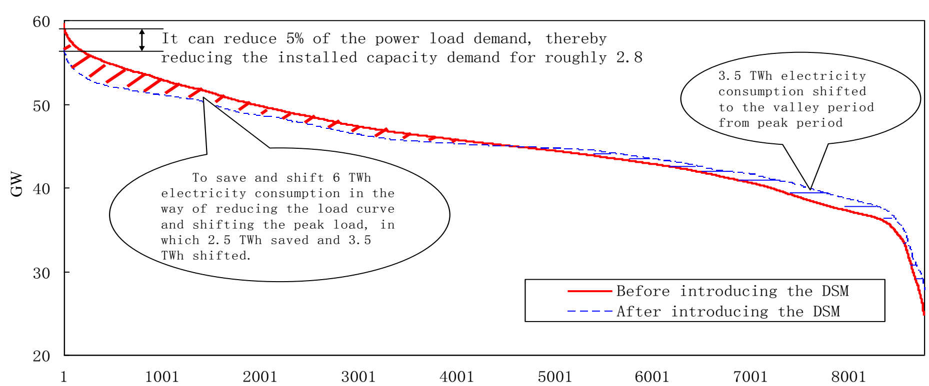
Fig. 12. Outlook of Electricity Demand and GDP for Pakistan in 2012-2032



5. INTEGRATED RESOURCE STRATEGIC PLANNING (IRSP)

Power generation expansion planning should meet the long term electricity demand for economic growth. However, since the energy resource is limited and the issue of climate change motivates increasing level of energy efficiency. Power demand side management (DSM) is one of the most important measures in the world. The key of DSM is to design various kinds of business management programmes for different power customers to affect their behaviour on electricity use. DSM is a useful tool for shifting peak load and saving energy. There is a case study of DSM in Figure 13. The peak load is 58 GW as shown in Figure 13. By designing some DSM projects, the peak load can be reduced by 5 percent, which is 2.8 GW. DSM projects also move 3.5 TWh from peak hours to off peak hours and it could save 2.5 TWh.

Fig. 13. The Energy Saving and Peak Load Shifting by DSM

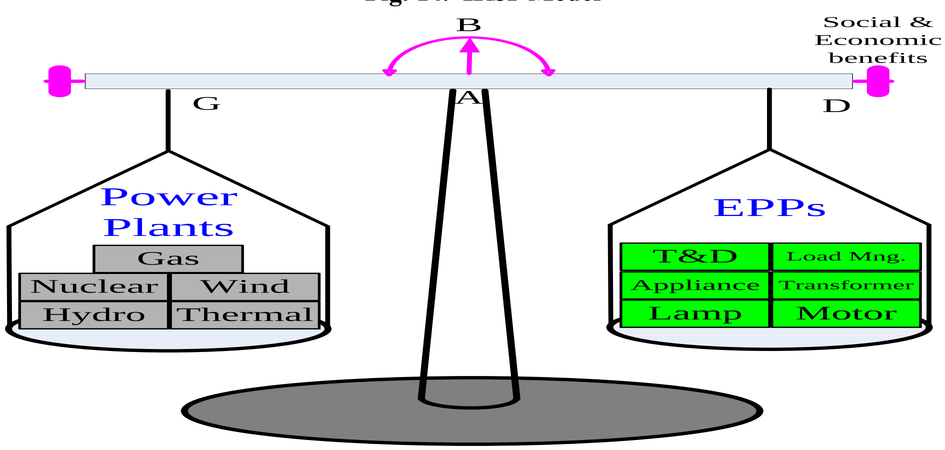


Source: Hu, Zhaoguang and Zheng Hu (2013) *Electricity Economics: Production Functions with Electricity*. [M] p. 18 Springer.

In order to involve DSM in power planning, it has to play the same role as a power plant in the planning model, and hence Efficient Power Plant (EPP) has been studied [Hu, Han, and Wen (2013)]. Lighting EPP is a lot of high efficiency lamps to reduce the load and save electricity. For example, one 10W of high efficiency lamp is the same with 50W ordinary lamp, thus, it saved 40W to replace the ordinary lamp by efficiency lamp. What about 1 billion high efficiency lamps? It will save 4GW. Therefore, 1 billion 10W efficiency lamp is same as a 4GW power plant. It is a 4GW EPP. And also there are motor EPP, transformer EPP and so on.

Integrated Resource Strategy Planning (IRSP) is a power planning model to meet the electricity demand by building all kinds of power plants such as coal-fired power plant, hydro power plant, nuclear power plant, wind power plant, gas power plant, solar power plant, and EPPs (see Figure 14). The goal of the IRSP model is to maximise social and economic benefits including lower investment and lower emissions. The government can design policy incentives to promote EPP and renewable power generation by formulating some rebate and incentive policies. Thus, the IRSP model is also a useful tool for policy study in the power planning.

Fig. 14. IRSP Model



Source: Zhaoguang Hu, Quan Wen, Jianhui Wang, Xiandong Tan, Hameed Nezhad, Baoguo Shan, Xinyang Han: Integrated Resource Strategic Planning in China, [J] *Energy Policy* 38(2010), p. 4636.

In order to show the impact of IRSP model, a case study for China can be an example since there is no data for Pakistan. In 2012, the total power generation capacity was 1167.75 GW as shown in Table 3, and the electricity consumption was 4959 TWh. It is forecasted that the electricity demand will be 7734 TWh in 2020 [Hu, Tan, and Xu (2013)]. In order to meet the demand and promote EPP, the power plants and EPPs have been studied by IRSP model as shown in Table 3. In 2020, the total power generation capacity will be 1805.94 GW. The coal-fired power plant is only project to increase 165.77 GW, while solar power will increase 146.72 GW and wind power will increase 159.17 GW in the next 8 years. EPPs will share 197.65 GW in 2020. Total electricity saving will be 388.3 TWh, more than 1280.79 million tons of coal equivalent will be saved. The CO_2 emission will be reduced more than 3163.63 million tons.

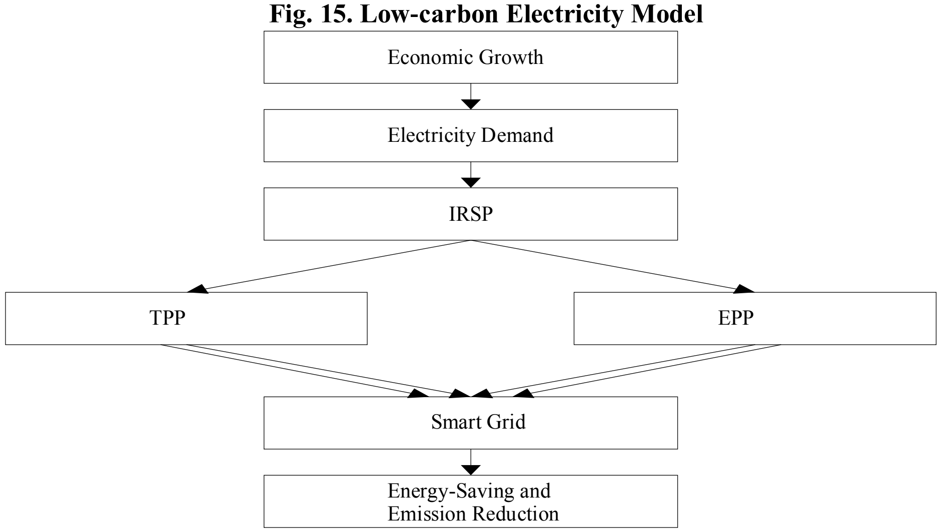
Table 3

Power Plants and EPP by IRSP for China in 2020

Generation Capacity (GW)	2020	2012
Generation Capacity	**1805.94**	**1167.75**
Hydro	**350**	248.90
Coal-fired	**975.94**	819.17
Nuclear	**60**	12.57
Wind	**200**	60.83
Gas	**70**	23.00
Solar	**150**	3.28
Epps	**197.65**	
Lamp	**37.65**	
Motor	**30**	
Transformer	**30**	
Frequency	**20**	
Appliance	**20**	
Interrupt Load	**60**	
Electricity Saving (TWh)	**388.3**	
Coal Saving （Mtec)	**1280.79**	
CO2 Saving (Mt)	**3163.63**	

The scenario of low-carbon electricity can be shown in the Figure 15. With the growing economy, the electricity demand will also experience a high growth. There are two ways to meet the electricity demand. One is to build more power plants and another way is to build more EPP. It is clear that EPP will be the first priority to meet the electricity demand. It can be achieved by providing policy incentives to promote EPP.

Fig. 15. Low-carbon Electricity Model



Source: Hu, Zhaoguang, Jiahai Yuan, Zheng Hu (2011) Study on China's Low Carbon Development in an Economy-Energy-Electricity-Environment Framework. [J] *Energy Policy* 39, p. 2602.

On the other hand, Pakistan is facing power shortage. It will harm the economic growth. However, DSM will play an important role to mitigate the power shortage in peak hours. Load management, demand response, the tariff at time of use, and many other technologies are useful to reduce/shift the peak load. For example, there were power shortages around 30GW-50WG in China in 2003-2006, DSM has been used in China then, and it did not harm the economic growth badly.

6. CONCLUSIONS

Based on the above discussions, this paper has the following conclusions;

(1) Electricity economics consists of electricity supply economics and electricity demand economics. Production functions with electricity are the principles of electricity demand economics. Integrated resource strategic planning is a part of electricity supply economics. Low-carbon electricity can be recognised as the planning of IRSP and the implementation of smart grid in the economic development.
(2) Pakistan's economy is in the early phase of industrialisation according to the per capita electricity consumption. China's economy is in the late phase of the industrialisation. Experiences and lessons from China's economic development would provide references to Pakistan.
(3) Low-carbon electricity will be an important economic development model in the near future. It is suggested to study how to make economic development with low-carbon electricity in Pakistan to avoid the mistakes from other countries.
(4) DSM and IRSP will not only play an important role in low-carbon electricity, but also will be important and useful measures to deal with power shortage in Pakistan.

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Comments

First of all, I congratulate the speaker for presenting such an interesting paper on a topic of utmost importance for Pakistan. Chinese economy has grown at a wonderfully high rate for past several decades and has successfully surmounted the associated challenge of providing energy resources needed to support this growth. As Pakistan aspires to attain high growth rate in future, and at the same time, is facing an acute energy crisis, our policy makers and researchers stand to learn a great deal from Chinese experience.

Economics is a vast subject but it can be summarised in two simple words, 'demand' and 'supply'. It is in this light that the paper examines various aspects of electricity economics. The paper presents various production functions that express output as a linear function of electricity alone. As indicated in the paper, this approach has several advantages. While it is extremely difficult to obtain reliable and accurate data on various inputs and the output in a short period of time, electricity data can be read almost instantaneously from an electricity meter.

It needs to be stressed that this remarkable simplification of the production function comes at a cost. One of the assumptions needed for this simplification, that electricity is used in every production process, seems harmless given the state of technology today. However, a more stringent assumption is also required to give electricity its 'representativeness', hence enabling us to express output as a function of just electricity. We need to assume that all other inputs are used in a fixed proportion to electricity. This, nonetheless, leaves no room for substitutability between inputs. If this assumption is close to reality, it does no harm to the estimation of the production function. Instead of counting the number of steel toed shoes used by the workers, we are counting pairs of shoes, and in doing so we are along the expansion path. Whether this is actually the case in the real world is a question that needs to be decided empirically.

If output is a linear function of electricity, then simple mathematics shows that marginal output is a horizontal straight line, whereas average output per unit of electricity is a rectangular hyperbola. This can be seen from relevant equations in the paper as well. Therefore, some further elaboration is needed to explain why some figures in the paper do not show strict conformity to these geometric forms.

The worthy speaker has very imaginatively used his approach of expressing national income as a function of electricity to redefine Chenery's stages of economic development. Chenery expresses these stages in terms of per-capita income. Using Dr Hu's electricity production function, the per-capita income figures can be readily translated into per-capita electricity consumption figures. Now we don't have to go through the trouble of deciding on the base year, converting figures into U.S dollar equivalent, worrying about the purchasing power parity issues and finally waiting for at least a quarter to get GDP figure. Determining a country's stage of development is now just an electricity meter away. But these are not the only reasons I like this new measure. One more reason for my liking for Dr Hu's measure is that whereas Chenery's measure puts Pakistan in the primary products phase, the lowest stage of economic development, Dr Hu's measure puts us in the early stage of industrialisation.

Najam us Saqib

Pakistan Institute of Development Economics,
Islamabad.

Comments

Let me first thank Dr Musleh ud Din and Dr Durr-e-Nayab for extending an invitation to be a discussant for this paper. I would also like to take this opportunity to congratulate PSDE for organising a conference on ‘energy’, an important issue facing Pakistan.

At the outset, let me make it clear that my comments are not a criticism of the research presented in this paper but to share my thoughts to further expand this research.

It is an interesting paper, presenting a theoretical application of ‘electricity economics’ and its empirical application. I commend Dr Zhaoguang and Dr Zheng to combine economics, ecology and engineering in one paper. The main contribution of this paper is to develop a simple production function including electricity as an input and analysing its impact on economic growth using data from China and Pakistan. While the paper is comprehensive, it is relatively weak in economic theory and modelling. The paper uses a simple linear production function. Its empirical part, analysis on China is quite strong but not so for Pakistan. This is perhaps due to non-availability of data in case of Pakistan.

The use of energy as an input in the production function is not new in economics literature. The debate on whether energy should be used as an input in the production function goes back to Neo-classical and classical economists such as Adam Smith, David Ricardo, John McGulloch, John Stuart Mill, and so on. Nicholas Gorgeson-Roegen (1972, 1976) was perhaps the first one to identify the absence of energy in economic theory in a formal way which later led to the development of ecological economics.[1] Economics literature identifies two channels through which energy (or electricity) enters the production function. One, primary converting activities (PCAs) which convert energy from natural resources (such as solar, heat, light, wind, running water, tide, minerals, fossil fuels, gravitation, and chemicals) into forms that will eventually be used to produce goods and services. Second, secondary converting activities (SCAs) which do not make any direct contribution of energy to the economy. The paper focuses mainly on PCAs. I believe that authors may carefully look into the following issues to further improve this paper.

- The paper uses a simple linear model (a Cobb-Douglas production function). There are better ways to formulate production function such as CES, etc. Authors may want to explore these.
- The paper uses electricity as exogenous. Literature suggests that electricity is determined by energy consumption and other variables. This may have an impact on the results obtained in this paper. Electricity can also be taken as a function of capital use. The paper correctly differentiates between different sectors but still assumes electricity as exogenous.

[1]Please also see Zaeske (2012), Chaudhry (2010) and Filippini and Pashauri (2002) for more details in the context of Pakistan and India.

– The above leads to another question—whether capital and electricity are substitutes or compliments. As discussed in some papers at this conference; it seems appropriate to consider the two as compliments in case of Pakistan. The literature, however, is indecisive on this issue. This also depends on 'rebound effect', which means that the improvement in technical efficiency of energy use is expected to reduce energy consumption. For example, engineering literature shows that a 20 percent improvement in fuel efficiency for passenger cars could lead to a 20 percent reduction in motor fuel consumption per personal automotive. This is also consistent with some results presented in this paper.

I would also like to make some suggestion for designing and implementing policies to conserve energy. This could be achieved through the cooperation and coordination of public and private sector in Pakistan should focus:

- Governance is the main issue in energy problems in Pakistan. This should be the priority in our policy planning.
- As stated by Abid Sulari (a guest speaker at this conference), we need to control and minimise electricity waste. In a country facing severe energy shortage, we should maximise our use of natural energy. Businesses should operate during daylight. I strongly feel that market should operate between 8am to 8pm.
- We should find ways (as used in many countries) to preserve water (preserve rain water by having rain water tanks) and use alternative ways of electricity generation such as solar.
- Research and development (R&D) to improve the efficiency of electricity use.
- The paper talks about carbon tax. But this is a major political issue even in developed countries.

Finally, let me suggest that the paper presented by Dr Zhaoguang offers an interesting research agenda. I believe with the expertise of Dr Zahoguang and the level of economic expertise available at PIDE, this could result in broader research collaboration between the two institutions under the guidance of Dr Zhaoguang.

Thank you very much.

Ahmed M. Khalid

Bond University,
Australia.

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The Impact and Cost of Power Load Shedding to Domestic Consumers

HAFIZ A. PASHA and WASIM SALEEM

1. INTRODUCTION

The widespread and growing phenomenon of power load shedding has emerged as one of the principal supply-side constraints to growth of the economy of Pakistan. Not only has this led to significant losses of output, employment and exports but also during periods of high outages there have been large-scale protests, particularly in Punjab and KPK.

Households have faced severe disruptions due to the high and growing incidence of load shedding. These have led to mass protests on streets resulting in disruption of other economic activities. As such, the economic return of reducing outages and of facilitating the process of adjustment to these outages is likely to be high.

This paper provides an approach and methodology for quantifying cost of load shedding to households in Pakistan. It is organised as follows: Section 2 highlights some key trends in the power sector of Pakistan. Section 3 will present a detailed literature review on the methodology used for quantification of costs due to outages. Section 4 describes the methodology used for qualification of costs due to outages and for estimation of willingness to pay. Section 5 presents estimates of the cost of load shedding in the domestic sector of Pakistan. Finally, Section 6 highlights the major policy implications emerging from the research.

2. THE POWER SECTOR

The growth in installed capacity and generation of electricity in Pakistan is presented in Table 1 since 1970-71. The growth in installed capacity has been more than doubling every decade up to 2000-01, with annual growth rate of over 7 percent. It is only during the last decade that the rate of expansion in capacity has substantially slowed down to less than 3 percent per annum. In the initial years of the decade there was significant excess capacity, due to the hump in investment by the IPPs in the mid-to late-90s. But adequate provisions were not made to cater for the future growth in demand.

Hafiz A. Pasha <hafiz-pasha@gmail.com> is Dean and Professor of Economics, Beaconhouse National University, Lahore. Wasim Saleem <wasimsaleem3344@yahoo.com> is Lecturer, Beaconhouse National University, Lahore.

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Table 1

Long-Term Trend in Capacity and Generation of Electricity in Pakistan 1970-71 to 2011-12

	Installed Capacity (MW)	Annual Growth Rate (%)	Electricity Generation (GWH)	Annual Growth Rate (%)	Index of Capacity Utilisation (%)
1970-71	1862		7202		81
1980-81	4105	8.2	16062	8.4	82
1990-91	8356	7.4	41042	9.8	102
2000-01	17498	7.7	68117	5.2	81
2011-12	23358	2.7	98664	3.4	88

Source: Handbook of Statistics, SBP, and *Pakistan Economic Survey*, MOF, Government of Pakistan.

The growth in electricity generation was rapid in the 70s and 80s. In particular, the commissioning of the Tarbela Dam in the early 80s enabled a quantum jump in supplies at low cost. During the 90s as the growth rate of the economy slowed down, demand for electricity was not so buoyant and the rate of increase annually in power generation declined to 5 percent. During the last decade, this has fallen further to only 3 percent.

An index of capacity utilisation[1] is constructed in Table 1. The rate of capacity utilisation exceeded 100 percent by 1990-91 and the load shedding which occurred in a significant way in the mid-to-late-80s can be attributed to a shortage of capacity. It was during this period that the first study in Pakistan on costs of load shedding was undertaken by Pasha, Ghaus and Malik (1989). As opposed to this, the upsurge in load shedding once again since 2007-08 can be attributed primarily to a lack of full capacity utilisation arising from lack of adequate maintenance of older plants and liquidity problems due to the ballooning of circular debt and the slow expansion in capacity.

The growth in electricity consumption by type of consumer during the last decade is presented in Table 2. The analysis is broken up into two sub-periods, the years prior to commencement of significant load shedding in 2007-08 and the years thereafter. In the latter period, the overall level of power consumption has declined with marginal growth only in the case of industrial consumers.

Table 2

Growth in Electricity Consumption from 2000-01 to 2011-12

(GWH)

	Domestic	Industrial	Commercial	Agricultural	Others*	Total
2000-01	22765	14349	1774	4924	3773	48585
2007-08	33704	20129	5572	8472	4923	73400
2011-12	33138	21334	5526	8290	4760	73084
Growth Rate (%)						
2000-01 to 2007-08	5.8	5.4	10.5	8.1	6.7	6.1
2007-08 to 2010-11	2.1	0.8	0.5	1.9	2.2	1.6
2001-01 to 2011-12	-0.4	1.5	-0.2	-0.5	-0.7	-0.2

Source: PES.

* mostly government, street lights and traction.

[1]300 days operation with 16 hours daily.

The surplus/deficit between demand and supply during system peak hours for National Transmission and Despatch Company (NTDC) and Karachi Electric Supply Corporation (KESC) combined is given in Table 3. The supply gap was 1912 MW in 2007 which has risen to 6518 MW, equivalent to 29 percent of demand. It is important to note that in 2011-12 National Electric Power Regulatory Authority (NEPRA) reports the generation capability as less than 70 percent of the installed capacity.

Table 3

Surplus/Deficit in Demand and Supply during System *Peak Hours*

	Generation Capacity	Demand	Supply-Gap	%
2007	15575	17487	–1912	11
2008	14707	19281	–4574	24
2009	16050	20304	–4254	26
2012	16104	22622	–6518	29

Source: NEPRA, State of Industry Report.

*NTDC and KESC combined.

According to NEPRA, the highest incidence of outages regionally is in the area served by Multan Electric Power Company, Peshawar Electric Supply Company and Lahore Electric Supply Company. The least outages are in areas served by Islamabad Electric Supply Company. Most areas of Punjab and Khyber-Pakhtunkhwa are more vulnerable to load shedding.

Incidence of Load Shedding

The costs of load shedding, to a large extent, depend on the frequency and duration of outages. The incidence of load shedding is given in Table 4.

Table 4

Incidence of Load Shedding

	No. of Times there is a Load Shedding in a Day	Annual Hours of Outages
By Province		
Punjab	6	1683
Sindh	3	1123
KPK	4	1216
Balochistan	4	1069
By Income Group		
Upto 15000	5	1498
15001-35000	4	1394
35001-70000	5	1430
70001 +	5	1702
Total	**5**	**1453**

Overall, on an average outages occurred 5 times a day in Pakistan in 2012, highest being in Punjab, 6 times. Households, on an average did not have electricity supply from power distribution companies for 1453 hours in 2012. The highest load shedding has occurred in Punjab at 1683, followed by KPK, 1216. Clearly, the average incidence is lower in Sindh and Balochistan.

3. LITERATURE REVIEW

Various approaches have been developed in the literature for quantification of the cost incurred by different types of consumers as a result of power outages. These approaches vary greatly in terms of data requirements and level of complexity. This section starts with the simple value added approach and ends with the full-blown survey based and contingent valuation approaches.

The Simple Value Added Approach

A relatively high estimate of the cost of load shedding is as follows:

V_i = Value added by sector *i* in absence of load shedding
E_i = Electricity consumption in the absence of load shedding

Then the cost C_i, of load shedding is given by

$$C_i = \frac{V_i}{E_i} l_i \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where l_i is the quantum of electricity not supplied due to outages. Summing across sectors, the total cost of load shedding is given by

$$C = \sum_{i=1}^{n} \frac{V_i}{E_i} l_i \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where *n* is the number of sectors.

This approach can be applied on the production sectors of the economy, viz, agriculture, industry and commerce, but not to domestic consumption of electricity.

The reasons why this approach leads to a high estimate of the cost of Load shedding are as follows:

(i) It does not distinguish between the average and marginal productivity of the electricity input, that is, there could be some economies of scale in the use of energy.
(ii) It assumes that output lost is proportional to the extent of electricity not supplied and the firms do not make adjustments to recover at least part of the output.

As opposed to the above, an approach that yields a low estimate is one which focuses only on the wage cost, on the assumption that the idle factor during outages is labour. As such, in this case

$$C_i = \frac{W_i}{E_i} l_i \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Where W_i is the wage bill.

The Adjusted Value Added Approach

This approach postulates the marginal cost of unsupplied electricity is different from the average cost as given in (1) above. Accordingly,

$$\frac{\partial V_i}{\partial E_i} = \beta \frac{V_i}{E_i} \quad \beta > 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

β is estimated on the basis of the historical relationship between value added and electricity consumption. Generally, it is observed that $\beta < 1$.

However, the value added approaches suffer from the defect that they do not allow for spoilage costs arising from damage to materials that takes place at the time when the outage occurs, especially if there is no prior notice.

Marginal Cost of Unsupplied Electricity

It has been argued by Bental (1982) that by observing firms' behaviour with respect to the acquisition of own generating power, the marginal cost of unsupplied electric energy may be inferred. A competitive risk-neutral firm equates, at the margin, the cost of generating a kwh on its own to the expected gain due to that kwh. This expected gain is also the expected loss from the marginal kwh which is not supplied by the utility. Therefore, the marginal cost of generating its own power may serve as an estimate of the marginal outage cost.

The cost to a firm of generating its own power consists of the two elements. The first part is the yearly capacity cost of the generator. This can be represented as follows:

$K(c)$ = annual capital cost (depreciation + interest cost) of a generator with capacity in kva

In addition,

VC = variable cost per Kwh, consisting mainly of fuel cost
l = hours of outages

The marginal cost, MC of self-generation per Kwh is given by

$$MC = \frac{\partial K(c)}{\partial c} + vc \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

On the assumption that the *MC* is constant, the total cost, *TC*, of Load Shedding is given by

$$TC = MC.l \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

This approach may not lead to proper estimates in the following cases:

(i) Presence of economies/ diseconomies of scale in the capital cost of generators such that $\frac{\partial K(c)}{\partial c}$ is not constant.

(ii) Imperfections in the capital market whereby firms, especially the smaller ones, are unable to borrow for acquisition of a generator.

(iii) In Pakistan previous surveys of firms, for example by the Institute of Public Policy (2009), indicated that not all units have self-generation. This implies that the marginal cost of outages is lower than the marginal cost of a generator. For such units, this method cannot, therefore be applied.

The Value of Leisure Approach

Munasinghe (1980) has proposed a novel approach for evaluating the cost of outages to residential consumers, as the value of leisure foregone. According to this approach, the principal outage cost imposed on a household is the loss of leisure during the evening hours when electricity is essential. During the day time there is sufficient slack in the execution of household activities that are interrupted by the outage, such as cooking or cleaning, to permit rescheduling of these activities without causing much inconvenience.

As such, the monetary value of this lost leisure is equal to income earning rate on the basis of consumers' labour–leisure choice. Munasinghe accordingly computes the cost per Kwh of unsupplied electricity as

$$C = \frac{y}{k} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (6)$$

Where *y* is the hourly income and *k* the normal level of electricity consumed per hour in the absence of outages. Therefore, the total cost of outages to residential consumer is, *C*, where

$$C = \frac{y}{k} . l \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (7)$$

A principal practical advantage of this method of estimating outage costs for residential consumers is that it relies on the relatively easy-to-obtain data. But for proper application of this method it is essential to have the levels of electricity consumption by households at different income levels.

Other problems with this approach include the following:

(i) It assumes that the income earner in the household has flexible working hours so that he/she can effectively exercise his/her labour-leisure choice. This may be true in the case of self-employed persons. But for wage earners who work fixed hours, the marginal value of leisure is unlikely to be equal to the income rate per hour. As such, some authors have preferred to apply this approach by assuming that the value of leisure is only a fraction of income.

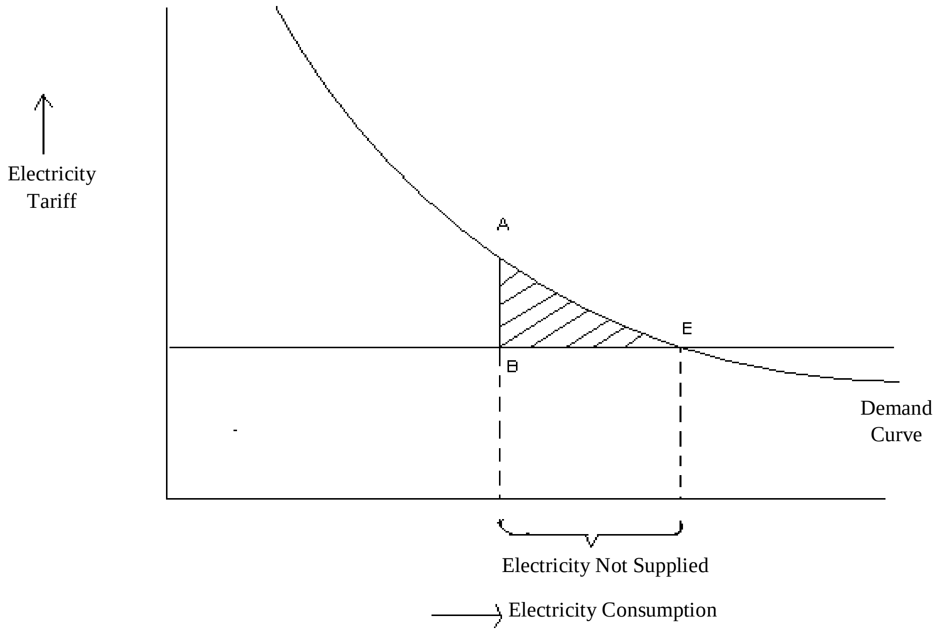
(ii) It ignores the presence of household economic activities like cottage industry or sewing/embroidery work by women, especially in lower income households. This is sometimes the case in Pakistan. Such, activities may not readily be rescheduled in the presence of outages, especially if they are of long durations. As such, in these cases the cost of outages must include the value of lost output.

(iii) Outages, especially when accompanied with voltage fluctuations, can damage home-based appliances like TV, refrigerator, air-conditioner, freezer, etc. Cost has to be incurred to repair the damage. These are equivalent to spoilage costs and should be included in the cost of load shedding.

The Consumer Surplus Approach

This is relatively popular approach and has been applied by Sanghvi (1982). The demand curve for electricity captures the willingness to pay for the service and the consumer surplus of electricity supply is represented by the area between the demand and supply curves. The loss of consumer surplus due to supply interruptions is represented by the shaded area, **ABE,** in Figure 1 below.

Fig. 1. Loss of Consumer Surplus Due to Outages



The prime magnitude required for application of this approach is the price elasticity of demand, which is not possible to measure in the presence of outages. Also, given a non-linear schedule of power tariffs, as is the case with residential consumers in Pakistan, the magnitude of the consumer surplus lost due to outages becomes difficult to quantify. Further, if AB is large then the consumer may be able to reduce the loss by investing in self-generation. This becomes more attractive the larger the amount of electricity not supplied.

The Contingent Valuation (WTP) Approach

This approach involves asking consumers their willingness to pay for more reliable supplies of power. For example, the question could be as follows:

If the incidence of outages is reduced to half its present level, how much more would you be willing to pay on your monthly electricity bill?

An alternative approach is to ask the following question:

If level of outages were to double, what reduction in your monthly electricity bill would you consider to be fair?

The contingent valuation approach is prone to giving biased estimates as it is based on subjective responses. It is likely that in response to the first question the consumer understates his willingness to pay for improved service, while he may overstate the compensation that he would like to receive for deterioration in the reliability of supply.

The Survey Based Approach

The most comprehensive approach to quantify the cost of outages is to undertake a random survey of affected consumers. This enables explicit and direct determination of different components of outage costs including the spoilage cost, idle factor cost and adjustment cots.

However, the survey based approach is more costly than approaches which rely largely on secondary data. Also, the possibility of a bias cannot be ruled out by the respondents who may exaggerate the costs in order to attract greater attention to the problem of load shedding.

We apply each of the above approaches to quantification of outage costs to domestic consumers in light of the data obtained from the survey of 500 households in Pakistan.

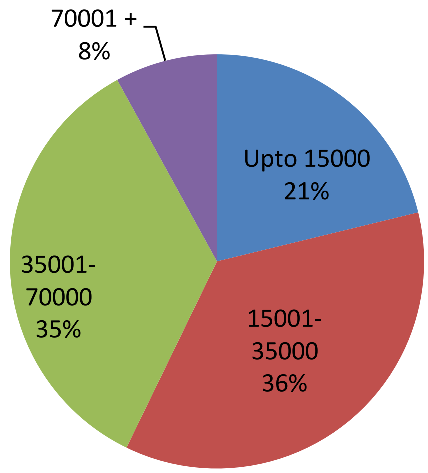
Table 5 gives the sample distribution by city the sample was distributed among cities on the basis of share of city in provincial population. 57 percent of the sample household units are in the province of Punjab while about 22 percent are in Sindh. From the remaining 33 percent, 15 percent are in Khyber Pakhtunkhwa (KPK) and 6 percent in Balochistan.

Table 5

Distribution of Sample by Province and by City

Provinces	Cities	Numbers	Percentage
Punjab	Lahore	96	19
	Faisalabad	51	10
	Sialkot	13	3
	Gujranwala	26	5
	Multan	38	8
	Rawalpindi/Islamabad	61	12
	Total	**285**	**57**
Sindh	Karachi	80	16
	Hyderabad	20	4
	Sukkur	10	2
	Total	**110**	**22**
KPK	Peshawar	50	10
	Mardan	13	3
	Abbotabad/Bannu	12	2
	Total	**75**	**15**
Balochistan	Quetta	30	6
	Total	**30**	**6**
Total		**500**	**100**

Fig. 2. Distribution of Selected Households by Income Group



The distribution of sample households by income group is given in Figure 2. About 21 percent of the households have permanent monthly income, proxied by monthly consumption expenditure, of upto Rs 15000, 36 percent have income between Rs 15000 to Rs 35000, 35 percent have income between Rs 35000 to Rs 70000 while 8 percent have income above 70000 per month. The overall average monthly income of sample households is Rs 38429.

Value of Leisure Approach

Munasinghe (1980) argued that the outage cost corresponds to the value of leisure, which he proxies by income.

The estimated outage cost per kwh for domestic consumers based on this approach is derived from the Survey as Rs 91 per kwh in Table 6. The Munasinghe approach yields very high estimates.

Table 6

*Outage Cost per kwh according to the Value of Leisure Approach**

Group (Rs per Month)	Income** per hour	Electricity Consumption per hour***(kwh)	Outage Cost per kwh (Rs)
0-15000	67.5	0.9	75
15001-35000	144.8	1.5	97
35001-70000	295.5	3.3	90
Above 70000	612.6	5.7	107
Total	**218.3**	**2.4**	**91**

*Y = income per hour worked based on 8 hours a day for 22 days a month.
Kwh = normal power consumption per hour (in public supply).
**Proxied by consumption expenditure, which is assumed to correspond to permanent income.
***On the assumption that electricity is consumed 16 hours a day. The consumption of electricity in the evenings is assumed to be three times the daily average.

There is another way of examining the validity of assumptions made by Munasinghe. Respondents were asked which activities are disrupted most in the household by load shedding. The frequency of different responses is given in Table 7.

Table 7

Activities most Disturbed by Load Shedding

	% of Sample Units
Cooling/heating	24.4
Studies (home work) of children	18.2
Preparation for work/school	17.4
Regular household work (cooking, cleaning, etc.)	14.6
Shortage of water	13.0
Income generating activities (home based)	8.2
Social Activities	2.2
Entertainment, leisure	2.0
Total	**100.0**

Leisure is reported by only two percent of the sample households as the activity most disturbed by load shedding. Other activities are of greater importance to households, including cooling/heating, studies of children and preparation for work/school reported 24 percent, 18 percent and 17 percent respectively as the principal activity affected by outages. Therefore, the Munasinghe hypothesis that leisure is the activity most disrupted is not borne out by the data obtained from households in Pakistan.

It is our view that the Munasinghe approach has a developed country bias. It cannot be applied in the context of low-to-middle income countries like Pakistan. A significant and new finding is the impact of outages on children, either in terms of the ability to undertake studies (homework) or in preparation to go to school.

Generator Cost Approach

This approach is based on the assumption that the principal form of adjustment to outages by households is the acquisition of a generator and/or a UPS (Uninterrupted Power Supply). As such, the cost of self-generation corresponds to the outage cost.

The question that arises is if a household does not have a generator/UPS then is the outage cost zero? Clearly, this is not the case.

It is likely that there are outage costs, especially in terms of the monetised value of the utility lost due to disturbance to some household activities, but these costs may not be large enough to justify the resort to self-generation.

Table 8 gives the percentage of households by level of consumption expenditure with a generator and/or UPS. Overall, 28 percent of the households have a generator and 30 percent have UPS. Poorer households generally are unable to self-generate electricity. However, majority of the households in the upper most income group have made arrangements for alternative sources of power at the time of load shedding.

Given the high percentage of households which do not have self-generation the issue is one of quantifying the cost of outages in the case of such households.

Table 8

Sample Households with Generator and/or UPS

	% of Sample Households	
Level of monthly consumption expenditure (Rs)	**With Generator**	**With UPS**
0-15,000	2	4
15,001-35,000	17	26
35,001-70,000	45	47
70,001 and above	75	43
Total	**28**	**30**

Willingness to Pay

The willingness to pay approach provides the basis for determining the subjective valuation by households of the cost of outages to them. There is, of course, the likelihood of a 'free rider' problem here. A household may understate its willingness to pay on the expectation that other households may reveal a high enough WTP to justify investment in improving the reliability of the power system.

Table 9 indicates the outage cost per hour as implied by the WTP. This can be estimated as follows:

$$SOCKW = \left(\frac{WTP}{100}\right)\frac{AEB}{ENS} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where,

SOCKW = subjective valuation by household of the outage cost per kwh
WTP = % higher tariff that the household is willing to pay for improved reliability of power supply (with minimal outages)
AEB = Annual electricity bill paid to the DISCO/KESC
ENS = electricity not supplied in the outages.

Table 9

Subjective Valuation of the Outage Cost per Hour

Monthly Expenditure Group	Willingness to Pay (extra over tariff)	Annual Electricity Bill	Electricity not Supplied	Subjective Valuation by Household of Outage Cost per Hour
(Rs)	(%)	(Rs)	(kwh)	(Rs per kwh)
0-15000	30.3	15330	479	9.70
15001-35000	28.7	28836	732	11.31
35001-70000	28.3	65094	1599	11.52
70001 and above	31.8	130590	4299	9.66
Total	**29.2**	**46734**	**1289**	**10.59**

It is interesting to note that while the subjective valuation of the outage cost per hour is somewhat low at below Rs 11 per kwh, it is higher for households belonging to the 'middle class'.

4. METHODOLOGY FOR QUANTIFICATION OF OUTAGE COST

The methodology for quantification of outage cost to domestic consumers is qualitatively different from that used in the case of industrial and commercial consumers. The basic reason for this is that there is no notion of 'output' in the case of a household,[2] which is more of a consuming unit. As such, outages impact the level of utility/quality of life of a household.

The exposure to outages daily is given by DLOUT where

$$D = \sum_{i=1}^{n} n_i d_i \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

Where n_i = number of outages of duration d_i , i = 1, …..n.

The normal level of electricity consumption per hour is given

$$e = \frac{(Kwh_1 + Kwh_2)}{8760-365D} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

Where,

Kwh_1 = electricity purchased from the distribution company during summer months
Kwh_2 = electricity purchased from the distribution company during winter months.

The normal consumption of electricity during times when there are no outages depends upon the number of electrical appliances at home. As such,

$$e = \beta_o + \sum_{j=1}^{m} \beta_j A_j \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

Where, β_j *= electricity consumption by appliance j, where j =1,2,3,……..,m.

$A_j =$ number of appliances j
$\beta_o =$ basic electricity consumption (e.g. for lighting).

Depending upon the nature of use of particular appliances the share of electricity consumed in different activities like heating/cooling, household functions, entertainment/leisure is derived. That is

$$\sum_{k=1}^{r} W_k = 1 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

Where W_k= share in electricity consumption of activity k, k=1,2,……,r.

If a sampled household has a generator then

$P_k^1 = 1$ if activity k can be performed during the outage.
$P_k^1 = 0$ if activity k cannot be performed during the outage.

Then the extent of substitution, S, by the generator of public supply during outages is given by S_1 where

$$S_1 = \sum_{k=1}^{r} W_k P_k^1 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (5)$$

[2] With the exception of households which engage in some economic activity at home.

*The β_j is estimated by OLS regression across the sample households with electricity consumption per hour, which varies with ownership of different types of appliances.

Similarly, the extent of substitution by a household which has a UPS can be derived

$$S_2 = \sum_{k=1}^{r} W_k P_k^2 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (6)$$

It may, of course, be noted that in the case of household which has neither a generator nor UPS, S_1=0, S_2=0.

For a household which has a generator the costs of operation have been obtained as

$$G_c = K(i+\delta) + 12f + 4(m+o) - T \quad \dots \quad \dots \quad \dots \quad \dots \quad (7)$$

Where, K = capital cost, I = annual interest rate, δ = annual rate of depreciation, f = monthly fuel cost, m = quarterly maintenance costs, o = quarterly other costs, T = savings in terms of payment to the utility.

Similarly, the cost of a UPS can be derived as G_u. In this case T = 0 because the UPS stores electricity obtained at the time when there are no outages.

There are also other costs arising from the outages, including spoilage cost, SPC, damage to appliances, DAC and miscellaneous costs, MC.

The last part of the methodology relates to the valuation of costs arising from disturbance of activities which cannot be performed or only partially performed during the outages either because of the absence of self-generation or because of only partial substitution by generator/UPS.

These costs are subjective in nature in terms of a loss of utility and are, therefore, not observed. We use the willingness-to-pay (WTP) as a measure of the subjective costs and apply this magnitude to the part of the electricity consumption which is not substituted by self-generation during outages. As such,

$$MUTL = WTP(B_1 + B_2)(1 - S_1 - S_2) \quad \dots \quad \dots \quad \dots \quad \dots \quad (8)$$

Where,

WTP = extent of higher tariff that household is willing to pay for better quality of service (with minimal outages).
B1 = electricity bill of the distribution company during summer months.
B2 = electricity bill of the distribution company during winter months.

The overall outage costs to the household, OTC, is given by

$$OTC = G_c + G_u + SPC + DAC + MC + MUTL \quad \dots \quad \dots \quad \dots \quad (9)$$

In the case of a household with no self-generation capacity

$$OTC = SPC + DAC + MC + MUTL$$

Where, $MUTL = WTP(B_1 + B_2)$

This methodology is new and has not been used yet in other studies.

5. RESULTS

The objective of this section is to present the estimated magnitudes of different types of costs associated with outages. As identified in previous section, these include direct costs which consist of spoilage costs and indirect or adjustments costs which include generator costs and UPS costs.

Total Outage Costs

Table 10 shows that the total outage cost on average to each residential consumer is almost 31,000 Rs per annum. The variation in outage costs is not very large among Provinces, ranging from about Rs 29,200 per consumer in Punjab to Rs 34,100 in K-PK.

Outage costs rise sharply by consumption (income) level of a consumer. For households with monthly consumption expenditure of up to Rs 15000, the outage cost annually is Rs 8800. For the highest expenditure group of households the cost rises to Rs 75200.

Table 10

Total Outage Cost per Residential Consumer

(Rs)

	Monetisation of Utility Loss	Cost of Self-Generation: **Generator Cost**	**UPS Cost**	Other Costs	Total Outage Cost
		By Province			
Punjab	7355	11263	3864	6747	29229
Sindh	7626	17562	2054	6075	33317
KPK	4954	18964	2037	8104	34059
Balochistan	3530	18120	2573	5235	29458
		By Income Group (Rs)			
0 – 15000	3828	290	400	4262	8780
15001 – 35000	5655	6380	2734	6749	21518
35001 – 70000	9544	22370	4831	7053	43798
70001 and above	8193	50900	4550	4549	75192
Total	**6824**	**14215**	**3114**	**6712**	**30865**
Share (%)	**22**	**46**	**10**	**22**	**100**

Overall, for the sample as a whole, the largest component of outage costs is self-generation costs at 56 percent. Monetisation of utility loss and other costs (spoilage costs, income foregone in household economic activity, etc. each account for 22 percent.

For lower income households, the share of monetisation of utility loss is higher at 44 percent because a low proportion of such households have either a generator or an UPS. As opposed to this, the share of self-generation costs for the highest expenditure households is high at 74 percent.

The burden of outage costs as a percentage of total consumption expenditure by a household is given in Table 11. It appears that the highest burden is on the 'middle class' living in the cities of Pakistan. It is 7 percent for such households as compared to 6.2 percent for low income households and 5.8 percent for the richest households.

Table 11

Total Outage Cost as Percentage of Total Household Consumption Expenditure

(000Rs)

	Annual Outage Cost	Annual Consumption Expenditure	Outage Costs % of Consumption Expenditure
0 – 15000	8.8	142.5	6.2
15001 – 35000	21.5	305.9	7.0
35001 – 70000	43.8	627.6	7.0
70001 and above	75.2	1293.9	5.8
Total	**30.9**	**461.1**	**6.7**

Table 12 indicates the total outage cost per kwh for residential consumers on average is close to Rs 24 (25 cents) per Kwh.

Table 12

Total Outage Cost per kwh to Residential Consumers

(Rs)

	Total Outage Costs	Electricity not provided (Kwh)	Outage Cost per Kwh (Rs)
By Location			
Punjab	29229	1655	17.66
Sindh	33317	830	40.14
KPK	34059	865	39.37
Balochistan	29458	1474	20.00
By Income Group			
0 – 15000	8780	479	19.32
15001 – 35000	21518	732	29.40
35001 – 70000	43798	1599	27.39
70001 and above	75192	4299	17.49
Total	**30865**	**1289**	**23.94 (25 c)**

The highest outage cost per Kwh is observed in Sindh at Rs 40 (42 cents) per Kwh, while the lowest cost is in Punjab at Rs 18 (19 cents) per Kwh. The outage cost per Kwh is the highest for the 'middle class' at Rs 27 (28 cents) – Rs 29 (30 cents).

Blowing-up of the sample to arrive at a national estimate requires, first, estimation of the number of urban households in the country. According to the PES the population of Pakistan in 2011-12 is 180.7 million, out of which 37.4 percent is located in the urban areas. The average household size is given in the latest HIES of the PBS at 6.19. This implies that there are 10.9 million urban households in the country.

Second, there is a need to determine the distribution of urban households by level of monthly consumption expenditure. This has also been derived from the HIES and is presented in Table 13. Overall, the total outage cost to residential consumers in the urban areas of Pakistan is Rs 195.8 Billion in 2011-12.

Table 13

National Estimate of Outage Costs to Urban Residential Consumers, 2011-12

Monthly Total Consumption Expenditure Group(Rs)	Number of Households (000s)[a]	Outage Cost per Household (Rs)	Total Outage Cost (Rs billion)
0 – 15000	5014	8780	44.0
15001 – 35000	4360	21518	93.8
35001 – 70000	763	43798	33.4
70001 and above	327	75192	24.6
Total	**10464**[b]		**195.8**

[a] adjusted on the basis of distribution in the HIES, 2010-11.

[b] 10.9 million households in urban areas with 98 percent of households having access to electricity according to PSLSMS, 2010-11.

6. CONCLUSIONS AND POLICY IMPLICATIONS

We have highlighted in the previous section the principal findings on the incidence of outages and cost of load shedding in the residential sector. In this concluding section we derive the key policy implications.

The estimated impact of outages on households is as follows:

(i) Outages on the average occur almost five times a day for 17 percent of the time. The highest incidence is in Punjab at 1683 hours annually, 16 percent above the national average. The lowest incidence is in Sindh at 23 percent below the national average.

(ii) Outages are disruptive most of heating/cooling, household activities, preparation for work/study (especially by children) and any home-based economic activity.

(iii) The outage cost per kwh works out as Rs 24(25c).

Table 14 presents the total cost of electricity consumption to household at different levels of total consumption expenditure (proxy for income). Overall, this is estimated at close to 17 percent. A striking finding is that the cost is the lowest for the upper most income group.

In the pre-load shedding period, in 2005-06, according to the HIES, the share of electricity cost in total consumption expenditure was 5 percent on average for urban households. Following the high levels of load shedding this share has jumped up by over three times.

Table 14

Total Cost of Electricity Consumption Per Residential Consumer

(Rs in 000)

Monthly Expenditure Group(Rs)	Annual Electricity Cost of Public Supply	Annual Electricity Cost Total Outage Cost	Annual Consumption Expenditures	Total Electricity Cost as % 0f Consumption Expenditure
0-15000	15.3	8.8	142.5	16.9
15001- 35000	28.8	21.5	305.9	16.4
35001-70000	65.1	43.8	627.6	17.4
70001 and above	130.6	75.2	1293.9	15.9
Total	**46.7**	**30.9**	**461.1**	**16.8**

It is clear that the high share of expenditure on electricity is cutting into consumption of food, clothing and basic services (like education and health), especially by the low income groups. As, such an indirect impact of the high level of load shedding in the country is the reduction in nutrition levels, particularly of children. Along with impact on preparation for school and homework, the impact of outages on children needs to be more strongly highlighted.

Overall, limits of affordability to power tariffs have been reached by bulk of the households and the scope for further enhancement in tariffs is very limited. The recent increase in tariffs will put a large burden, especially on the middle class.

Table 15

Present Tariff Structure for the Residential Sector

(Rs)

	Actual Per kwh	Proposed Per kwh
Up to 50 units	2.00	2.00
For consumption exceeding 50 units		
1 – 100 units	5.79	5.79
101-200 units	8.11	8.11
201-300 units	8.11	12.09
301 – 700 units	12.33	16.00
Above 700 units	15.07	18.00

The prevalence of self-generation is relatively low among residential consumers. 28 percent have generators and 30 percent have UPS. Resort to self-generation is the highest in Sindh and KPK and among consumers in the highest income category.

The average capacity of generators in use is under 3.5 KVA. The proposal for eliminating the GST on small generators and UPS is justified in this case also, as for commercial consumers.

Based on responses by the sample households, the following proposals are presented for reducing the level of outage costs:

(i) The majority, 65 percent, of respondents prefer, given the total duration of load shedding, shorter though more frequent outages. Higher duration of a typical outage is one of the main reasons why outages costs are higher in Karachi, despite lower incidence of outages.

(ii) Bulk of the load shedding is in the morning from 6:00 am to 9:00 am. This creates disturbance in preparation for work/school and heating during winters. Over 43 percent of sample households report that changing load shedding times to later in the day would be less disruptive, especially to low income households.

(iii) The worst time in year for load shedding is summer and worst day are Sunday, Monday and Friday. To the extent there is scope, the pattern of load shedding needs to be adjusted accordingly.

(iv) There has been a clear vote of no-confidence against the services provided by the power sector. 43 percent rate the quality of services as 'very low' and 35 percent as 'low'. Distribution companies, in particular, will have to work very hard to rehabilitate their image.

(v) A series of recommendations have been made for reducing the costs of load shedding, as follows,

Construct New Dams	43%
Build New Power Plants	27%
Import Electricity	22%
Minimise Electricity Theft	17%
Stop Corruption	17%
Use Coal	14%
Gas Pipeline From Iran	15%
Subsidy	13%
Reduce Price	10%
Solar Energy	8%

Therefore the largest responses relate to enhancement in electricity supply and to improved management of power sector. Overall, power outages have become a major source of inconvenience and cost to domestic consumers in Pakistan.

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What Inspires Electricity Crises at the Micro Level: Empirical Evidence from Electricity Consumption Pattern of Households from Karachi

LUBNA NAZ and MUNIR AHMAD

1. INTRODUCTION

With urbanisation[1] and modernisation of the economy, the use of electrical appliances has increased manifold in Pakistan. Now, household shares in the total electricity use account for 46.5 percent. While other users have lower shares that are industrial 27.5 percent, agriculture 11.6 percent, commercial 7.5 percent and the government 6.2 percent only [Pakistan (2012-13)]. Overtime, the household electricity consumption has also increased because of the increase in electricity consumers[2] and of village electrification.[3] Other important reasons include the use of modern appliances including both locally made and smuggled and increase in the share of urban women in the labour force by 6.5 percent during 2007-08 and 2012-13 [Pakistan (2012-13)]. These reasons are also responsible for enlarging electricity demand and supply gap over the years and have led to the electricity shortage to alarming proportions in March 2012. The electricity gap increased to 57,754 GW from 56,930 GW showing an increase of 1.4 percent from the corresponding period of the last year. The acute electricity shortage has caused long hours of the electricity load shedding in the country. The population living in urban areas bears the direct fall out of the electricity breakdown because of the modern lifestyle and sheer dependence on electricity [Pakistan (2012-13)].

Karachi is the largest city of Pakistan and the fourth largest urban centre of the world. It is located at the elevation of 65 meters above sea levels. It has the largest urban population (20 million) in Pakistan comprising locals, internal migrants and even external migrants mainly from Bangladesh and Afghanistan. Karachi is administratively divided into five districts, eighteen towns and six cantonments. The city's management is run

Lubna Naz <lubnanaz@uok.edu.pk> is PhD scholar, Pakistan Institute of Development Economics, Islamabad. Munir Ahmad <munir@pide.org.pk> is Joint Director, Pakistan Institute of Development Economics, Islamabad.

[1]Urban population increased from 58.78 million in 2008-09 to 69.87 million in 2012-13. It is projected to reach at 122million by 2030 given the current pattern of urbanisation continues [Pakistan (2012-2013)].

[2]On average, electricity consumers in household sector increased at the rate of 20.8 percent per annum during 2007-08 and 2012-13 [Pakistan (2012-13)].

[3]8995 more villages were electrified from June 2012 to March 2013 [Pakistan (2012-13)].

largely by local government .The city has top ranking in almost all social and economic indicators among 110 districts of Pakistan [Haroon and Khan (2007)]. Karachi Electric (K-electric)[4] is responsible for supplying electricity to entire Karachi including its suburbs and some parts of Balochistan. In total, it caters to the electricity demand of 20 million consumers.[5] Now, households in all five districts of Karachi are suffering from power breakdowns due to an acute shortage of electricity, dwindling power distribution and poorly managed transmission lines of the K-Electric.[6] The electricity demand of Karachi increased to 2500 MW in 2013 and surpassed 2700 MW in the peak of summer (Jun 2013) causing load shedding of up to 14 hours daily for residential consumers.[7]

With this background, the present study has set two main objectives:

First**,** to empirically analyse the end use based electricity demand for the residents of Karachi. The study employs Conditional Demand Model (CDM), which is a multivariate econometric technique. It uses information on household's total electricity consumption, electricity pricing, weather and household details on holding of modern appliances stock. The model yields robust end-use estimates for energy consumption of different appliances after accounting for difference in electricity consumption.

Second, to assess economic and social impacts of the electricity crises on the households by gender and the district of residence, and the household's ability to cope with electricity crises in the short run. Also, to analyse the household's views on prevailing electricity crises and its impact on work, medical and other expenses, crimes, participation in ceremonies, etc. For this, the study uses logistic regression and employs a qualitative research method.

Earlier studies [see for example Parti and Parti (1980); Aigner, *et al.* (1984); Lafrance and Perron (1994); Bartels and Fiebig (2000)] used CDM to estimate end use based electricity demand. In the recent past [for example Hsiao, *et al*. (1998); Larsen and Nesbakken (2004); Yun and Steemers (2011)] have used Engineering Model end-use meter data to estimate end use based electricity consumption. A few studies [for example Lafrance and Perron (1994); Bartels and Fiebig (2000)] used various time periods to determine the causes of changes in the pattern of electricity consumption. However, these studies could not use gender-based differences in the analysis of end-use electricity consumption. Thus, it is important to analyse gender specific differences in end-use electricity demand. In addition, the analysis of gender-specific differences in the ownership of electrical appliances and socio-economic characteristics of the head of the households also helps to analyse various implications of electricity shortfall.

The findings of the study suggest electricity demand depends on end-use electricity consumption in Karachi, and income, household size and dwelling type interact with end-use of electricity consumption. Furthermore, households with

[4]K-electric is presently a private limited company established in 1913 under the Indian companies act of 1882. It was privatised in 2005 and renamed on 20th February 2014 as K-electric from KESC. It is also only vertically integrated company that supplies electricity to Karachi and some parts of Balochistan.

[5]www.ke.org.pk

[6]A/c to K-electric the transmission and distribution losses stood at 27.8 percent in 2013, see for details http://www.ke.com.pk

[7]See The Express Tribune, published on May 14, 2013. Available from http://www.tribune.com.pk

inadequate capacities to cope with electricity crises are more vulnerable to electricity crises than households who can afford alternate provisions. Above all, gender, income, district of residence and the electricity saving behaviour of the head of household also determine the vulnerability to electricity crises at the household level.

The next section reviews methods relating to analysis of electricity demand and electricity shortfalls. The methodological framework for end use electricity demand and econometric specification of the determinants of the electricity crises is then outlined. The next section presents results and discussion on household's views about electricity crises, its contributors, its implications and the government's ability to handle the problem. The last section highlights gender-specific differences in coping with electricity crises, followed by the conclusion of the study and suggestions for policy-makers.

2. METHODS

2.1. Review of Research on Electricity Demand

The existing research work on electricity consumption suggests two fundamental demand-side approaches for electricity demand analysis; that is utility maximisation or cost minimisation and end use electricity consumption. The former approach uses cross-section, time series and panel data methods to obtain theoretically consistent estimates of electricity demand [see for example, Kraft and Kraft (1978); Dubin and McFadden (1984); Jumbe (2004); Yoo (2006); Jamil and Ahmad (2010); Ahmad, *et al*. (2011)]. The latter approach employs econometric methods that are CDM and Engineering Model [see for example, Parti and Parti (1980); Lafrance and Perron (1994); Larsen and Nesbakken (2004); Yun and Steemers (2011)].

Moreover, we can distinguish studies based on end-use electricity consumption by two main methods; the first method is called the conditional demand model (CDM) and the second method is termed as the Engineering Model. The earlier studies, for example, Parti and Parti (1980), Aigner, *et al*. (1984), Lafrance and Perron (1994), Fiebig and Steel(1994); Bartels and Fiebig (2000) and Dalen and Larsen (2013) used the former method of electricity demand. The studies based on the former method use household's total electricity consumption, electricity prices, weather, household's ownership of energy appliances and a household's demographic and economic characteristics to model electricity demand. These studies mainly differ in the sample period covered, as some of the studies [for example, Lafrance and Perron (1994); Bartels and Fiebig (2000)] used many periods to analyse patterns of electricity consumption. The studies based on Conditional Demand Model (CDM) have an advantage over the Engineering Model because of complexity of the latter approach to adjust electricity demand mainly for regional differences in income, prices and energy-saving behaviour.

Recent studies, for example, Hsiao, *et al.* (1998), Larsen and Nesbakken (2004), Reiss and White (2005), Firth, *et al.* (2008), Yun and Steemers (2011) used Engineering Model. This method is an improvement on the first in respect of employing end-use metered data on electricity consumption of households and yielding results that are more robust. However, the study based on engineering model uses direct meter data and so imposes a significant cost on the household. Many developing countries like Pakistan have not switched to end-us electricity meters yet. Therefore, researchers cannot use the engineering model to estimate electricity demand.

In Pakistan, the literature on electricity demand can be classified into three groups. The first group comprises studies that estimate electricity by using economic theory[8] and explore its determinants. These studies include: Siddiqui (1999, 2004), Aqeel and Butt (2001), Khan and Qayyum (2008), Khan and Usman (2009), Nasir, *et al*. (2009), Jamil and Ahmad (2010) and Shahbaz and Feridun (2011).[9] A few studies used total electricity consumption in kWh as dependent variable, and electricity prices and per-capita income as main explanatory variables [for example, Aqeel and Butt (2001); Nasir, *et al*. (2009); Alter and Syed (2011)]. Others for example [Jamil and Ahmad (2010); Siddiqui, *et al*. (2004); Shahbaz and Feriden (2011)] have analysed electricity demand at sectoral levels. The studies differ in the use of econometric techniques, sample periods, independent variables and decomposition of electricity demand into commercial, industrial and household.[10] The findings are mostly consistent with economic theory[11] [for example, Jamil and Ahmad (2010)] except for few studies[12] [for example, Khan and Quyaum (2009)] which contradict the theory.

The second group includes research conducted more recently about the causes and consequences of electricity shortages in Pakistan. These studies are addition to the literature as electricity crises deepened in 2007-08 and reached at peak in 2011 when electricity shortfall exceeded 40 percent of national demand [FODP (2010)]. The studies include: FODP (2010), Malik (2012), Asif (2011), Trimble, *et al.* (2011), Nasir and Rehman (2011), Alhadad (2012), Qasim and Kotani (2013) and Pakistan (2013). The research reveals that rapid growth of electricity demand, inadequate electricity generation capacity and lack of alternate energy sources have largely contributed to intensify present electricity shortfall. Other reasons given include inconsistent power policy, issues with governance and circular debt [see for example, FODP (2010); Malik (2012); Alhadad (2012)].

On the other side, commonly noted consequences are fiscal burdening, as 7.6 percent of total government revenue was used for power subsidies in 2007-08, and decline in economic growth and dwindling growth of manufacturing. Besides, increasing trade deficit due to oil imports, delays in export's orders and decline in employment are also fallout of long-standing problem of electricity shortfall [see for example, FODP (2010); Nasir and Rahman (2011); Pakistan (2013)]. A third group of study deals with effects of electricity crises on industry's output, employment and delay in supply orders, and decline in commercial business [see for example, Pasha (2010); Siddiqui, *et al*. (2011)].

Two studies by Iqbal (1983) and Saleem (1992) are different from earlier studies as authors used different methods from the earlier work on electricity demand in Pakistan. Iqbal

[8]Utility maximisation approach is used to derive electricity demand and time series econometric techniques i.e. Cointegration, Autoregressive and Distributed Lag model, Granger Causality etc. are used for estimation of electricity demand.

[9]See table at the end of Section 3 for details.

[10]Aqeel and Butt (2001) analysed relationship among different sources of energy and economic growth, Siddiqui (2004) analysed the relationship between commercial sector electricity demand and economic growth and Jamil and Ahmad (2010) analysed electricity demand at various disaggregations i.e. sectors level.

[11]Electricity demand is price inelastic and income elastic in long run [Jamil and Ahmad (2010)], Electricity demand is price and income inelastic [Khan and Usman (2009)].

[12]Electricity demand is price and income elastic in the short and long run [Khan and Qayyum (2009)].

(1983) estimates fuel demand function conditioned on the stock of energy using appliances and their rate of use. The study showed negative price elasticity of fuel and positive income elasticity of fuel. Saleem (1992) uses cross-sectional data from Karachi on electricity consumption to find out the probability of electricity shortage conditioned on variation in temperature and projected the average and the peak electricity demand (see Table 1). Recently, Chaudhry (2010) analyses the impact of appliance ownership and household income under different tiers of electricity tariff on residential monthly electricity consumption of Lahore[13] for 2003. The study used five tariff tiers, which included Rs 1.675kWh for 50kWh or less, Rs 2.613 for 51kWh -101kWh, Rs 3.53kWh for 101kWh-300 kWh, Rs 5.87 for 301kWh- 1000kWh, Rs 7.047 for more than 1000kWh. The study showed positive relationship between electricity usage and exogenous variables i.e. income and ownership of electrical appliances. The study also showed that total ownership of electrical appliances was distributed across tiers, as households consuming in the fourth tariff tier owned most of air-conditioners, computers, and microwaves. To sum up, the existing research on electricity demand and on causes and implications of electricity shortages mainly differs in the use of methods as shown in Table 1.

This study adds to the existing literature in two ways. First, it estimates end-use based electricity demand for households in Karachi, and analyses household's holding of modern appliances with other characteristics as determinants of electricity crises. Second, it analyses difference in the ownership of electrical appliances by the gender of the head of households and implications of electricity crises at local levels.

2.2. Data Collection

This article is based on the household energy survey. The survey was conducted in all districts of Karachi in the last week of May 2013.[14] The simple random sampling technique was used and 2,500 households of various income groups were selected. A well-structured questionnaire was formed and emailed to more educated households. On the spot interviews were also conducted with uneducated households and with households who failed to return the questionnaire on-line. The questionnaire consisted of eight sections. These are personal information; job information; household's spending; electrical and gas appliances; electricity and gas load shedding; losses due to electricity and gas load shedding; household views about effects of electricity crises. In total, 2,333 filled questionnaires were received of which 110 questionnaires were found with matching cases. Similarly around 220 questionnaires were found with less than 50 percent responses and with responses missing on electricity billing, income, spending and assets. Only 2001 questionnaires were found with a 99.8 percent response rate. All information was collected at the household level. Head of the household was the main respondent, except few cases where the eldest son or daughter took part for the head. Data have also been collected using purposive sampling method. For this, in-depth interviews[15] of households' working members, students and voters[16] were also conducted

[13]The capital of the Punjab Province in Pakistan.

[14]The information on electricity consumption in kWh, electricity expenditures and prices were collected for March, April and May 2013 and on all other variables for May 2013. The Household Energy survey was conducted by the students of Adv. Economics Statistics, Department of Economics, University of Karachi under the supervision of the course in charge Lubna Naz (author).

[15]Open ended, and Close ended question such as yes or no and check were used.

[16]In Pakistan, only 18 years and above are eligible for casting vote in general election.

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Table 1

Summary of the Selected Studies on Electricity Demand and Implications of Electricity Crises

Authors	Period	Variables /Objectives	Methods	Main Results
Parti and Parti (1980)	1975	Household electricity consumption, stock of electrical appliances, household income and electricity price per kWh	Ordinary last square	Negative price elasticity of demand Positive income elasticity of electricity demand
Iqbal (1983)	1960-1981 Annual data	Household fuel consumption and Household Gas and Electric appliances, and temperature	Ordinary Least Square	Negative fuel price elasticity in the long run Positive fuel income elasticity in the long run
Dubin and McFadden (1984)	1975	Electricity consumption, stock of electrical appliances, income, dwelling type, household size	Ordinary Least square or OLS, Reduced form or RF, Instrumental variable or IV and Conditional Expectation Correction or CEC)	Own price elasticity of electricity demand is higher for OLS and IV, income elasticity of electricity is lower for OLS than other methods, and cross -elasticity of electricity demand with respect to gas price is higher in CEC than OLS.
Burney and Akhtar (1990)	1984-85	Household expenditure on energy, household size, income, age etc.	Ordinary Least Square	Rural Household Spend More on Fuel than Urban Households do. Price Inelastic Fuel Demand.
Saleem (1992)	2000	Household electricity consumption, weather, household characteristics	Ordinary Least Square	Changes in household electricity demand are conditioned on changes in temperature in Karachi.
Reiss and White (2001)	1993 and 1997 Two waves	Electricity consumption, electricity price, demographic and economic characteristics of household, energy appliances, heating degree days	Method of Moments	Price of electricity has diverse impact on appliance specific electricity use Income effect on appliance specific electricity use is negligible and statistically insignificant.
Larsen and Nesbakken (2002)	1990	Electricity consumption, ownership of electrical appliances, household characteris-tics, weather related variables, electricity prices etc.	Ordinary Least Square	The estimates of engineering model for space heating, cooking and water heating are higher than the estimates for the same from the conditional demand model.
Siddiqui (2004)	1971-2003	Electricity consumption and per-capita GDP.	Hsiao Granger Causality, ARDL	Lack of uniformity exists in the impact of all constituents of energy demand on Economic Growth. Only Electricity and some petroleum products have high impact on Economic Growth.
Jamil and Ahmad (2010)	1960-2008	Electricity Consumption, Electricity Prices and Income	Johnson cointegration	Growth in GDP causes Electricity Demand Growth in Commercial, Manufacturing and Agriculture sectors causes Economic Growth .
Chaudary (2010)	Panel data of 66 countries for 1991-2009	Electricity Consumption, Electricity Prices and Real GDP	Panel Data Models; Fixed Effects and Pooled Regression	Positive Income Elasticity of Electricity demand. Negative Impact of Electricity Prices on Manufacturing Sector's growth.

Continued—

Table 1—(*Continued*)

Malik (2010)		Causes and Consequences of the Electricity Shortages in Pakistan.	Quantitative Analysis	Poor Governance is the main cause of prevailing electricity crises.
Siddiqui (2011)	1971-1997	Determinants of Energy Demand and Revenue Generating Impact of Changes in Energy Prices.	Regression Analysis	Negative Price Elasticity of Energy Positive Income Elasticity of Energy .
Alter and Syed (2011)	1970-2010	Electricity prices, real GDP, number of Electricity Consumers & Electric Appliances	Johnson cointegration	Long run relationship exists between Electricity Consumption and Prices.
Shahbaz (2011)	1971-2009	Real GDP per capita, real domestic private sector credit, electricity consumption	ARDL	Long run cointegration exists among Financial Development, Electricity Consumption, Labour and Economic Growth.
Shabaz and Feridun (2011)	1971-2008	Electricity Consumption and Per Capita Real GDP.	Autoregressive Distributed Lag Model or ARDL	Economic growth causes Demand for Electricity and not vice versa.
Alhadad (2012)		Introduced integrated Energy Planning & Policy information as tool to resolve Energy Crises	Analytical and Quantitative	Lack of integrated Energy planning or IEP is the main cause of persisting electricity crises.
Pasha, *et al.* (2010)		Impact of Electricity short fall on Industrial Sector.	Analytical and quantitative	Power Shortage in Industrial Sector alone has attributed in the loss to Economy over 2.5 percent of GDP.
Javed and Awan (2012)	1971-2008	Real per capita GDP and Electricity Consumption.	Engle and Granger Two Step Procedure.	Unidirectional causality runs from Electricity Consumption to Economic Growth. Electricity Shortages limits Economic Growth.
Ali, Iqbal and Sharif (2013)	1990-2010	Electricity Consumption and Maximum Temperature Index.	ARIMA Time Series Forecast Model for temperature Index	Maximum Mean temperature and Socio-economic Factors affect positively Electricity Demand.
Dalen and Larsen (2013)	1990,2001,2006	Electricity consumption, ownership of electrical appliances, household characteristics etc.	Ordinary least Square	Year to year changes take place in the Electricity consumption for washing, refrigeration and heating.

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Table 2

Description of Variables

Variables	Meaning and Evaluation
Electricity consumption	Total electricity consumption measured in kWh
Electrical-Appliances	Television, Deep-Freezer, Iron, Washing- Machine, Air- Conditioner, Tube-Lights, Water-Extracting-Motor, Desktop, Dryer, Refrigerator, Air-cooler, Microwave-Oven, Cell-Phone,
Electricity prices	Electricity price per kWh
Electricity expenditure	Monthly household outlays on electricity
Electricity load shedding	Electricity breakdown
Duration of electricity load shedding	No of hours electricity load shedding took place during March-May 2013
Timing of Electricity load shedding	No of hours electricity load shedding occurred in day and night during March-May 2013
Marital status	Married=2,Unmarried=2 Divorced or Divorcee =3, Widow or Widower=4
District	East=1,West=2, South=3, Central=4, Malir=5
Age	Age in years
Education	No-education=1 Primary=2, Matric=3, Intermediate=4, Graduation =5, Post-Graduation =6, Diploma=7
Gender	Male=1, Female=2
Household size	No of household members
No of dependents	Household members who are above 60 years age and below 10 years
Family unit	One person family=1, Two person family=2, Three person family=3, Four or more members family =4
Job status	Private job=1, Own-business=2, Government job=3, No job=4
Real Total expenditure	Sum of food and non-food expenditures deflated by official General Consumer Price Index of base 2007-08 for May 2013
No of lighting spots	No of lighting spots greater than ten =1, no of lighting spots fewer than ten =2
Dwelling type	Two or three room apartment=1, Four or more room apartment or house=2
Hot days	No of days for which maximum temperature >40 in March, April and May, 2013.
Crises Affected household (CAH)	Yes =1, No=2
Worst affected household (WAH)	Yes =1, No=2
Extent of electricity load shedding in last five years	Increase by multiple times=1, Increase=2, Decrease=3, No change=4
Increase in medical expenses	Yes=1, No=2
Government role in last five years	Yes=1, No=2
Street crimes during load shedding	Yes=1, No=2
Saving electricity	Yes=1, No=2
Household reaction to electricity load shedding	Media protest=1, Street protest=2, Passive=3
Impact on voting in general election 2013	Yes=1, No=2
Participation in ceremonies	Yes=1, No=2
Household's coping with Electricity load shedding	None=1, UPS=2, Genrator=3, Both=4
Daily Tasks:	
(a) Reaching office late	Yes=1, No=2
(b) Pick drop of kids to and from school	Yes=1, No=2
(c) Complying with doctor's employment	Yes=1, No=2

in every district. The household's views were gathered[17] about changes in the extent of electricity crises over the years, the role of government in addressing the problem of load shedding and household's reaction to load shedding. Other questions were asked about neighbourhood electricity theft, street crimes during load shedding, expenses on electricity alternatives and missed out important daily tasks (see Table 1). The data on non-heating and heating days were collected from the daily weather reports of the Pakistan Meteorological Department.[18] The information on electricity price per kWh was obtained from K-Electric.

2.3.1. *Methodological Framework for End-use Electricity Consumption*

This paper applies Conditional Demand Model (CDM)[19] on the data from household energy survey[20] to estimate end use based electricity demand. The econometric specification of the Conditional Demand Model (CDM)[21] is as follows

$$xij = \delta j + \sum_{m=1}^{M} \rho jm\left(Cim - \overline{Cjm}\right) + \mu ij \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where x_{ij} refers to end-use electricity consumption for appliance j (j=1,2,…………K) of household i (xi, i=1, N) per period, C_{im} (m=1, 2, M) are economic and demographic variables for example age, household size, income, electricity prices, etc. $\overline{C_{jm}}$ is the mean value of these variables for households possessing appliance j. μ_{ij} is a stochastic error term. The parameter δ_j implies a mean value of electricity for end use j provided the household characteristics (Cim) relevant to end use j are equal for all households or ρ_{jm}=0 $\forall m$. Household characteristics such as education, marital status, gender, age, job type and income of the head vary across households. The second term on the right hand side of Equation (1) represents an adjustment in the end-use electricity consumption for appliance j due to the impact of economics and demographics of households. The Equation (1) can be estimated by the Ordinary Least Square, given the data have been collected on electricity consumption through end use electricity meters. For this article, the data on household electricity consumption in kWh is not based on end use electricity meters. Hence, the basic conditional demand model (CDM) given by Equation (1) cannot be estimated. However, the electricity consumption in kWh can be gathered over all end-use of electricity consumption in Equation (1) to get total electricity consumption in kWh of household i as x_i. As not all households own all types of modern electrical appliances, it is impossible to specify all end-use of electricity consumption. To account for heterogeneity in modern appliance ownership, a dummy variable, D_{ij}, is used to value one if household i own appliance j and value zero if the household does not own appliance j. Of J possible end-uses of electricity consumption, S shows electricity end-use demand that can be estimated separately, i.e. j=1, 2..., S,......., J and $S<J$. The econometric specification of the household conditional electricity demand is

[17]Close ended and open ended questions were used for collection of household's views about electricity load shedding and its impact on well-being of households.

[18]www.pmd.gov.pk

[19]Conditional demand model was estimated because directly metered data on end-use electricity consumption was not available for households of Karachi.

[20]This study uses sample of 2000 households for estimation after data cleaning.

[21]M. D. Hanne, Larsen, and M. Bodil (2013) Residential End-use Electricity Demand—Development Over Time. Statistics Norway, Research Department. (Discussion Paper No.736).

$$x_i \equiv \sum_{j=1}^{S} x_{ij} D_{ij} \equiv \sum_{j=1}^{J} x_{ij} D_{ij} + \sum_{j=S+1}^{J} x_{ij} D_{ij} = \sum_{j=1}^{J} \delta_{ij} D_{ij} + \sum_{j=S+1}^{S} \delta_{ij} D_{ij}$$
$$+\sum_{j=1}^{J}\sum_{m=1}^{M} \rho_{jm}\left(C_{im} - \overline{C_{jm}}\right) D_{ij} + \mu_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where, u_i is a stochastic error term and $u_i \approx$ NID (0, 1), which is given as

$$\sum_{j=1}^{J} \varepsilon_{ij} D_{ij} = u_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

The third term on the right hand side of the Equation (2) denotes economic and demographic variables as C_{im} and their mean values as $\overline{C_{jm}}$. These are interactions with electrical appliances to adjust electricity consumption for appliance *j*. For example interaction between household's dwelling type and number of tube-lights which a household owns captures the effect of household's dwelling type on the lighting consumption of electricity. We calculate interactions as deviations from average values of different household demographic and economic characteristics of households owning appliances for example $\overline{C_{jm}} = \frac{1}{H_j}\sum_{i=1}^{N} C_{im} D_{ij}$. The first term in Equation (2) $\sum_{j=S+1}^{S} \delta_{ij} D_{ij}$ shows unspecified electricity consumption. We assume that such consumption does not vary across households $\sum_{j=S+1}^{S} \delta_{ij} D_{ij} = x_0$. We also apply interactions to all *j* because unspecified end use electricity consumption depends on household demographic and economic characteristics. Further, we assume the coefficients of interactions are not varying across households .The final specification of the econometric model becomes

$$x_i = x_0 + \sum_{j=1}^{S} \delta_{ij} D_{ij} + \sum_{j=1}^{J}\sum_{m=1}^{M} \rho_{jm}\left(C_{im} - \overline{C_{jm}}\right) D_{ij} + \mu_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

x_i is total electricity consumption in kWh conditional on having appliances D_{ij}. It takes the value one if household i owns electric appliance j and zero if household i does not own appliance *j*. x_0 is unspecified household electricity consumption and δ_{ij} is the coefficient of the mean electricity consumption of appliances *j* held by the household *i* and for which D_{ij} has a value equal to one. To calculate estimates of mean electricity consumption for different electrical appliances of the average household, we multiply estimates of mean electricity consumption for each electrical appliance by the proportion of households holding electric appliance. The coefficient ρ_{jm} represents the consistency between interactions $(C_{im} - \overline{C_{jm}})D_{ij}$ and electricity consumption x_i. C_{im} (m=1,2,3……….M) are economic and demographic variables such as household's income;[22] household size; no of dependents; household energy saving behaviour; dwelling type; age, education, marital status and gender of the head of household . Also,

[22] Real total expenditures were used as proxy of income and income quintiles were computed. Real expenditures were computed by deflating total expenditure by the official General CPI for May 2013 and real expenditure was obtained for the base year 2007-08. Data on CPI is available from www.pbs.gov.pk.

days with temperature[23] <40^{C} are included as an explanatory variable (see Table 2), and $\overline{C_{jm}}$ is the mean value of the household demographic and economic characteristics. All variables on the right hand side in the Equation (4) are assumed to be exogenous. It is also assumed that no change has occurred in the stock of electricity using equipment during the survey period.[24] The Equation (4) is estimated by Ordinary Least Square or OLS.[25]

2.3.2. *Calculation of End Use Electricity Model*

The expected end-use electricity consumption for household i of appliance k is obtained from the Equation (5) as

$$E(x_{ik}) = \delta_k D_{ik} + \sum_{m=1}^{M} \rho_{km} \left(C_{im} - \overline{C_{km}} \right) D_{ik} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (5)$$

E is expectation operator. δ_k Shows difference in electricity consumption in kWh between households that own appliance k, $D_{ik} = 1$ or $\delta_k + \sum_{m=1}^{M} \rho_{km} \left(C_{im} - \overline{C_{km}} \right)$ and zero for those that do not own appliance or D_{ik} = 0. We calculate the average electricity consumption for end use k as

$$\hat{x}_k = \hat{\delta}_k \overline{D_k} + \sum_{m=1}^{M} \hat{\rho}_k \left(C_{im} - \overline{C_{km}} \right) \bar{D}_k \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (6)$$

Equation (6) represents estimated parameters. Where $\bar{D}_k = \frac{1}{N} \sum_{i=1}^{N} D_{ik}$ is the mean value of the dummy variable for an appliance D_{ik} which a household owns. We calculate average electricity consumption on appliance k as average electricity consumption for a household that owns appliance k times the share of households in appliance ownership. The final estimated Equation is

$$x^p = \hat{x}_0 + \sum_{j=1}^{S} \hat{\delta}_k \overline{D_k} \qquad \ldots \quad ... \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (7)$$

$\hat{x}_0$ is unspecified estimated electricity consumption, x^p implies predicted mean end use electricity consumption. We also calculate average actual electricity consumption of all households in the survey as follows,

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (8)$$

[23]The information on daily weather was obtained from www.pmd.org.gov for March, April and May 2013.

[24]The data was collected in May 2013; however, the information was collected on electricity consumption in kWh and electricity expenditure for March, April and May 2013.

[25]Ordinary Least square is Classical linear regression, it is based on certain assumptions i.e. homoskedasticity, normality, linearity, exogenity and no multicolinearity.

$\bar{x}$ is average actual electricity consumption. The share for electricity consumption of appliance *k* in total electricity consumption is calculated as follows

$$apl_k = \frac{x_k^p}{\bar{x}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

x_k^p is average electricity consumption for the appliance *k* and $\bar{x}$ is average of total electricity consumption. Finally, the share of unspecified electricity consumption is calculated in Equation (10).

$$S_{un} = 1 - \sum_{j=1}^{k} S_j = \frac{\hat{x}_0}{\bar{x}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

S_j is specified electricity consumption for appliance *j*, where $j = 1,2,\ldots..k$ and S_{un} denotes share of unspecified electricity consumption in the total electricity consumption. We calculate this as a residual of end-use electricity consumption after adjusting for all specified electricity end-uses.

2.4. **Modelling Determinants of Electricity Crises**

Crises affected households or (CAH) is the dependent variable, with either a "yes" or "no" response gathered from each surveyed household. We apply binary logistic model function as follows

$$P(Y = 1 | z_i \ldots\ldots. z_k) = \frac{\exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j)}{1 + \exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j)} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

In Equation (11) P_i shows the probability of getting affected by the electricity crises or $Y_{i=}1$ and ($z_1 \ldots\ldots\ldots, z_k$) are explanatory variable. They include economic, demographic and various dummy variables. The economic variables that affect the likelihood of getting affected from electricity load shedding are real income,[26] electricity prices,[27] ownership of modern appliances, job status and expenses on electricity. The household demographics used are the district; age, marital status and gender of the head; number of the working age household members, household size and number of dependents in the family (see Table 1). We also use dummy variables[28] for neighbour's electricity theft, district, households using alternative supplies during electricity load shedding, household saving electricity, and household protesting against load shedding, and model these dummy variables as independent in Equation (11), (see Table 1). The probability of not getting affected from electricity load shedding or $Y_i = 0$ is as follows

[26]The real expenditure of the households were computed by using data on official consumer price index for May 2013 from http://www.pbs.org.pk .

[27]Most of the electricity consumers (50 percent of the data) consume 300-700 units/kWh per month and hence pay 12.83 per kWh. information on electricity prices is available at http://www.ke.com.pk

[28]It takes value 1 if a condition holds and 0 if condition does not hold.

$$P(Y=0|z_i ....z_k)=1-\frac{\exp(\alpha+\sum_{j=1}^{k}\beta_j Z_j)}{1+\exp(\alpha+\sum_{j=1}^{k}\beta_j Z_j)}=\frac{1}{1+\exp(\alpha+\sum_{j=1}^{k}\beta_j Z_j)} \quad \ldots \quad (12)$$

To estimate parameters from the data set (y_i, z_{1i} ………z_{ki}) and i = 1,2………n, we assume that all or N samples are independent. The joint probability of the observed values (y_1 ……… y_i) is estimated as follows

$$P(y_1..............y_n)=\Pi_{i=1}^{n}P(Y_i=y_i|z_{1i}...........z_{ki}) \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

Now we substitute Equation (12) and Equation (13) in place of each parameter on the right hand side of Equation (14). It gives the probability $P(y_1$ ……… $y_n)$ as an explicit function of known parameters (α, β_1, ……… β_k). The likelihood function for (α, β_1, ……… β_k) given (y_1 ……… y_i) is as follows

$$L(\alpha,\beta_1........\beta_k|y_1........y_n)=\Pi_{i=1}^{n}$$

$$\left\{\left[\frac{\exp(\alpha+\sum_{j=1}^{k}\beta_j Z_j}{1+\exp(\alpha+\sum_{j=1}^{k}\beta_j Z_j}\right]^{yi}\left[\frac{\exp(\alpha+\sum_{j=1}^{k}\beta_j Z_j}{1+\exp\sum_{j=1}^{k}\beta_j Z_j}\right]^{1-y_i}\right. \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

If y_i = 1 it follows that 1 – y_i = 0 and the term in brackets reduces to Equation (1). Conversely, if y_i = 0 it follows that y_i = 1 and term in brackets then reduce to Equation (12). We estimate the Equation (14) to get maximum likelihood estimates of the logistic regression.

3. DESCRIPTIVE ANALYSIS

The summary statistics on household characteristics, ownership of electrical appliances, electricity consumption in kWh, electricity prices and weather conditions are shown in Table 3. The data collected on job status show that 56.40 percent of head of the household or interviewed persons have private jobs where only 5.35 percent are retirees or unemployed. Only 16.70 percent have government jobs while 21.50 percent are running their own business. The survey reveals that around 93 percent of female heads are in the job market and about 65 percent of female heads have private jobs (see Table 3). This infers that almost all interviewed female heads have some job.

The data show that about 36 percent of the household heads interviewed are graduates, and 31 percent of the household heads have a post-graduate qualification. The illiterate heads of the household are only 1.20 percent (see Table 3). The data show that about 86 percent of male heads and 55 percent of the female heads are married. While about 25 percent of the female heads are widowed or divorced and only 1.2 percent of the male heads were widower or divorcee (see Table 3). This implies that a majority of surveyed families are living with dependents.

As shown in Table 3, Almost all households had cell phones, television, iron, washing machine, refrigerator and lighting in Karachi in the survey period. However, a few households surveyed own air cooler, air-conditioners and microwave oven. Analysis

Table 3

Descriptive Statistics of Household Energy Survey 2013

Variables	All	Male	Female
Electricity consumption (kWh in 2nd quarter)	2076	1998	1950
Electrical Appliance Variables (0 or 1)			
Cell phone	0.99	0.99n/s	1.00n/s
Microwave oven	0.37	0.38n/s	0.34n/s
Television	0.98	0.97n/s	0.97n/s
Electric water pump motor	0.66	0.67*	0.56*
Dryer	0.38	0.37*	0.48*
Desktop	0.74	0.73***	0.78**
Washing machine	0.91	0.91**	0.97**
Iron	0.99	0.97	0.97
Refrigerator	0.93	0.93	0.98
Air cooler	0.24	0.21*	0.29*
Air conditioner	0.43	0.44*	0.39*
Electricity price (per kWh)	12.83	12.88	12.83
Deep freezer	0.23	0.24*	0.27*
Tube lights	0.99	0.99	1.00
No of lighting points>10	0.42	0.89*	0.82*
Other Variables (Interactions)			
Age of the head of household	43.9	44.40	40.37
Household size	4.5	4.5	4.0
Married head (0 or 1)	0.82	0.86	0.55
Energy saving household (0 or 1)	0.74	0.74*	0.79*
Two person household	.078	0.07	0.10
Flat ownership (0 or 1)	0.54	0.59*	0.66*
Single person household (0 or 1)	.025	0.03	0.01
At least 1 person over age 60 (0 or 1)	0.17	0.17	0.12
Dependency	0.23	0.22	0.19
Education of the Head of Households			
No education (0 or 1)	0.012	0.011	0.016
Matric (0 or 1)	0.14	0.14	0.10
Inter (0 or 1)	0.18	0.18	0.14
Graduation (0 or 1)	0.36	0.36	0.33
Post-graduation (0 or 1)	0.22	0.20	0.31
Diploma (0 or 1)	0.45	0.04	0.05
Primary (0 or 1)	0.036	0.036	0.034
No of days temperature>40	27	27	27
Job status of the head			
Private	0.56	0.55	0.65
Government	0.16	0.17	0.14
Own business	0.21	0.23	0.12
Retirees/unemployed	0.05	0.05	0.06

of appliance ownership by income groups[29] provides the reason for this disparity. Those in the higher strata of income have 79 percent more electricity using appliances like air-conditioners and microwave ovens. The data also show that household on average consume 688 kWh of electricity per month or 2076 kWh of electricity per quarter.[30] About 93 percent of households use electricity between 300kWh-700kWh per month and hence pay Rs 12.38 per kWh. The data from the daily weather reports show that recorded temperature in 27 days out of 92 days during March-May 2013 have remained more than 40^0C in Karachi.

We also use two-sample mean t-test to analyse the gender specific difference in the holding of electrical appliances and electricity consumption. The differences in the ownership of the stock of energy using appliances by gender of the head of the household are listed in Table 3. The data show no significant gender-specific differences in the pattern of the ownership of TV, electric water pump motor and iron. Similarly, the data show no gender-specific differences in electricity consumption in kWh and electricity charges per kWh a month. Nevertheless, the data show statistically significant differences in the ownership of specific electrical appliances like air-conditioners, desktop, dryer, number of lighting points, washing machine and deep freezer between male-headed and female-headed households. About 79 percent of female-headed households and 74 percent of male-headed households are inclined to electricity saving in Karachi, and gender-specific differences in conserving electricity are statistically significant. The data show that female-headed households own small dwelling size than male-headed households in Karachi as 66 percent female-headed and 59 percent male-headed households own small apartments (see Table 3). Figure 1 displays appliance ownership for all households and Figure 2 presents differences in the stock of modern appliances by gender.

Fig. 1. Average Energy Appliances Holding by Households

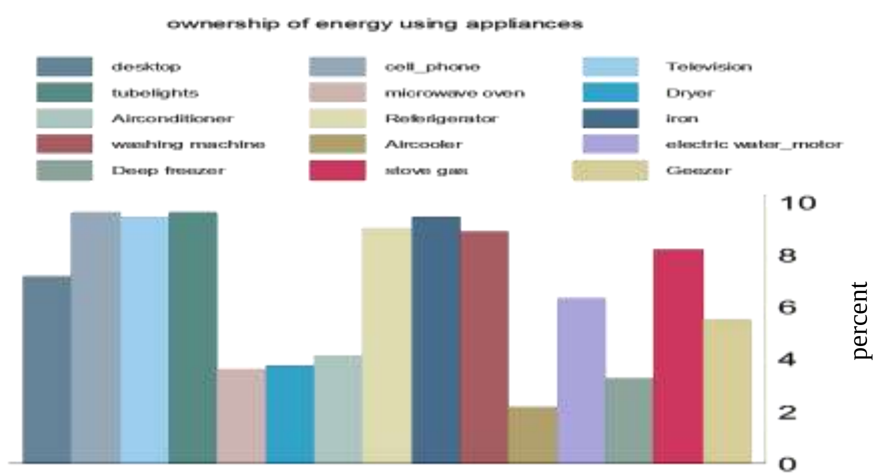
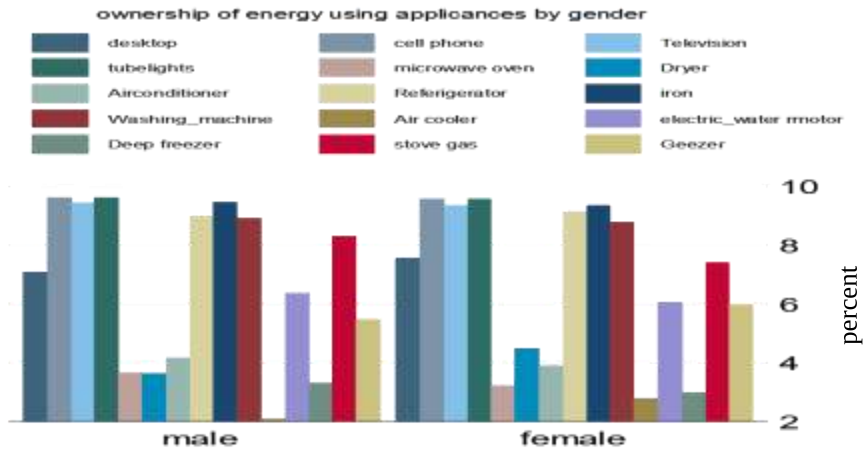


Fig. 2. Average Energy Appliances Holding by Gender

[29]Real total expenditures are used as proxy of income and income quintiles have been computed, results for income quintiles are not reported in Table 3.

[30]For March, April and May 2013.



3.1. Empirical Findings of Conditional Demand Model (CDM)

We use the Equation (4) to estimate end use based electricity demand for residents of Karachi. The estimates of conditional demand model (CDM) are given in Table 4. The quarterly estimate of electricity demand by air-conditioner is 1720 kWh, as 42 percent household own air-conditioners for cooling, this gives only 739 kWh for this cooling electric equipment for the average household. Almost all the households surveyed own iron and washing machine, this gives estimates for households having iron and washing machine, who use 386 kWh and 220 kWh. About 66 percent households use electric water motors for pumping water from pipelines. This indicates that households largely depend on electricity for water consumption in Karachi and electricity breakdown deprives them from water consumption.

The estimate of electricity consumption for more than ten lighting points is greater than the electricity estimate of lighting. The data show that only 42 percent households use more than ten lighting spots and 88 percent of these households belong to larger dwelling size and larger household size. This indicates that the larger family size and larger dwelling type both affect lighting consumption. The estimate of electricity consumption of a microwave oven is 406 kWh, which is even higher than a washing machine and air cooler. Since only 37 percent households own microwaves, the electricity estimate for households having this equipment equals to 150 kWh. Figure 3 illustrates quarterly estimates of electricity consumption for different appliances. The estimates of end-use electricity consumption in kWh for the preceding survey month (April 2013) are shown in Table 5. The electricity estimates for air-conditioner, washing machine and iron show similar patterns of consumption as we have found for these equipment for a quarter. The electricity estimates of lighting spots are higher than lighting and households that use more than 10 lighting points in the data set belong to larger household size and dwelling. The income of households interacts positively with the ownership of air-conditioners while non-heating days show negative interaction with air-conditioners (see Table 5). Only married household category interacts positively with

Table 4

Estimated Electricity Consumption (kWh per Quarter- 2013)

Variables[a]	Coefficient[31]	S/E	Mean-value	Assets Ownership
Intercept	172(2.20)*	78.21	000	000
Television	79 (2.51)*	31.24	77	0.97
Lighting	107(4.2)*	25.76	106	0.99
Desktop	69(2.09)*	33.03	56	0.74
Refrigerator	432(4.7)*	91.19	402	0.93
Deep-freezer	139(2.7)***	51.24	46	0.34
Iron	394(3.7)*	105.08	386	0.98
Air-conditioner	1720(51.60)*	33.33	739	0.42
Air-cooler	226(6.2)**	36.30	50	0.24
Dryer	93(2.9)**	32.68	36	0.38
Washing-machine	239(4.6)*	51.79	220	0.92
Microwave-oven	406(8.2)**	49.18	150	0.37
Electric water pump motor	107(3.5)*	30.87	71	0.66
No of lighting spots>10	219(4.91)*	44.26	92	0.42
Interaction Variables[b]				
High income*air-conditioner	443(4.6)*	96.01		
Household size*deep-freezer	241(4.7)**	51.12		
Household size*lighting	–191(-3.5)**	54.20		
One person household*refrigerator	288(3.8)*	74.78		
Two person household*water-motor	–126(2.06)*	60.08		
Non Heating degree days *AC	–42 (2.07)*	20.21		
Married head*microwave	49 (2.36)*	20.70		
Female headed households*air cooler	167.37(3.9)*	42.57		
Type of dwelling*lighting	–92(2.2)*	41.63		
R^2	0.41			
F-value	316.52(0.000)			
N-obs	2000			

Table 5

Estimated Electricity Consumption in kWh, April 2013

Variable	Coefficient	Standard Error	Mean-value	Assets Ownership
Intercept	63	10.11		
Television	21*	9.8	20	97.80%
Lighting	86*	17.48	86	99.14%
Desktop	26*	11.58	20	74.10%
Refrigerator	49*	20.20	45	93.35%
Deep-freezer	56*	16.97	19	33.90%
Iron	110*	35.26	107	97.90%
Air-conditioner	374**	11.03	159	42.90%
Air-cooler	72***	18.89	17	24.45%
Dryer	27**	11.21	11	38.80%
Washing-machine	76	18.79	70	92.20%
Microwave-oven	29**	10.64	11	37.50%
Electric Water pump motor	54	13.44	35	66.01%
No of lighting spots>10	122*	19.78	51	42.01%
R^2_adj	0.46			
F-value	304.02(0.00)			
N-obs	2000			

[31]*Note:* electricity estimates reported in Table 4 are based on robust regression (corrected for hetrosediasticty in variance); estimation has been carried out in Stata 11.

the use of microwave ovens. The family unit and specially two-person family show negative interaction with electric water pump motor in Karachi, and one-person family interact positively with refrigerator. The study does not find education of the head (any category), a district of the residence of the head, no of dependents, job type and age as statistically significant interacting variables with any of the electrical appliances. Figure 4 displays the mean value of electricity estimates for households.

Fig. 3. Mean Electricity Consumption Estimates in kWh per Quarter for Different Appliances

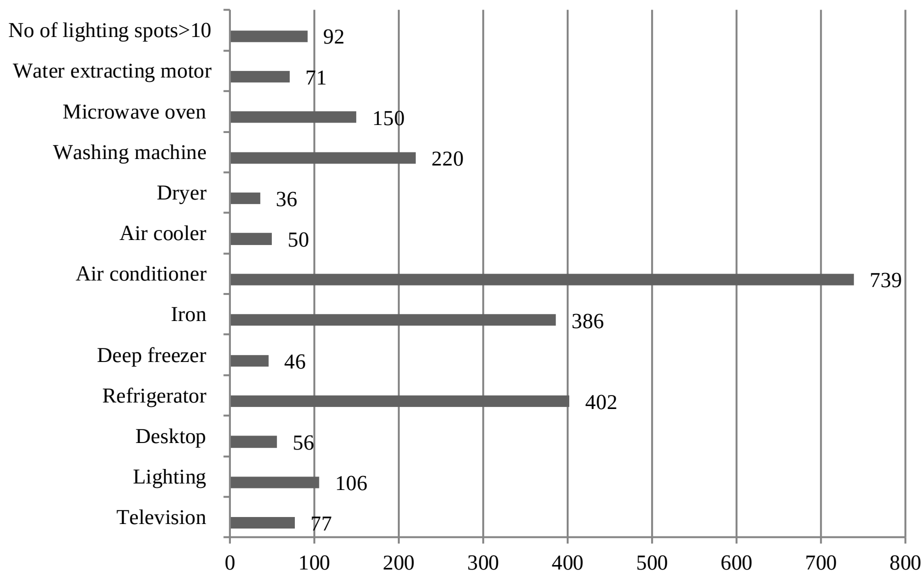
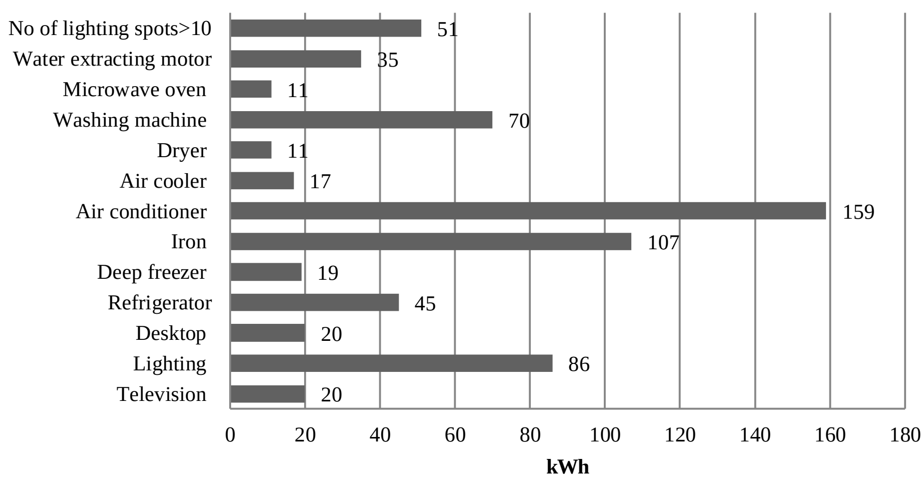


Fig. 4. Mean Electricity Estimates for Different Appliances in kWh for April 2013



3.2. Results of Logistic Model

The results of only those variables, which are statistically significant, are given in Table 6. The log odd ratio or coefficient with negative sign refers to a negative relationship between log odd ratio and likelihood of getting affected by the electricity load shedding. The odds ratio 0.27 for gender of the head of household infers that male-headed households are only 0.27 times the odds of female-headed households to suffer from the electricity crises. A comparative analysis of gender specific capacities to use alternative arrangements during load shedding also supports this finding. About 29 percent female-headed households can use the UPS and only 16 percent can afford generators during electricity load shedding. While 24 percent male-headed households can use generators and 26 percent male heads arrange the UPS during electricity load shedding (see Figure 6). Households who have air-conditioners have odds 1.95 times of the odds of households who do not use air-conditioning. However, the data show that higher income households largely use air-conditioners and these households can arrange alternate provisions during electricity load shedding. The odd of district central implies that households who live in the district central have odds of getting affected by electricity crises twice the odds of households who live in other districts (see Tables 6 and 7). The odds of suffering from electricity crises are 0.22 given household resorts to alternative arrangements during electricity load shedding compared with households with no such provisions. Similarly the odds for a street protest implies that households have odds of 0.46 of getting disposed to electricity crises given they come out on the street and protest compared with households who are passive (see Tables 6 and 9).

Table 6

Estimates of the Determinants of Electricity Crises at Household Level

Variables	Coefficient	Odd Ratios	S/E
Intercept	–2.92		1.39
District (central)	0.71	2.03	0.32
Working age households	0.24	1.27	0.11
Electricity expenditure	–0.63	0.53	0.28
Number of dependents	0.46	1.58	0.18
Damages to electric appliances	1.50	4.48	0.21
Electricity theft	0.53	1.69	0.26
Protest in streets	–0.76	0.46	0.35
Coping strategies	–1.21	0.22	0.34
Energy saving	–0.73	0.48	0.19
Number of household members	1.19	3.28	0.45
Ownership of air-conditioner	0.67	1.95	0.32
Gender	–1.3	0.27	0.19
Log likelihood	–255.66		
LR Chi2(12)	76.29		
Probability >Chi2	0.00		
No. of Obs.	2000		

4. DISCUSSION

We use qualitative research methods such as in-depth interviews from focused groups and household's heads to collect views about problem of load shedding and its impact on their well-being. We use two qualitative variables that are electricity crises affected household (CAH) and worst affected household (WAH), (see Table 2). A binary variable with value 1 implies that representative household has suffered from regular electricity load shedding during March-May 2013. Household is termed electricity crises affected household (CAH). We use qualitative research methods such as in-depth interviews from focused groups and household's heads to collect views about problem of load shedding and its impact on their well-being. We use two qualitative variables that are electricity crises affected household (CAH) and worst affected household (WAH). A binary variable with value 1 implies that representative household has suffered from regular electricity load shedding during March-May 2013. Household is termed electricity crises affected household (CAH). The badly hit districts were the Central and the East and least affected was the South (see Tables 7 and 8). Similarly, distributing data on monthly income[32] across districts showed that about 56 percent of the households in the bottom strata live in the district east and the central. Thus more than half of the population affected by electricity crises in these districts comprises poor households.

Another important finding from the household energy survey is that households were not only electricity crises affected but also endured losses to their electrical appliances. The district wise distribution of the worst affected households and electricity theft in the neighbourhood of the worst affected households are shown in Table 8. The data show that 1340 households or about 67 percent of the households are worst affected. A good majority of the worst affected households live in the Central and the East indicating severity of the electricity load shedding in these two districts (see Table 8). The data on electricity theft in the neighbourhood of worst affected households showed that problem of electricity theft is also rampant in the Central and the East. About 7.20 percent in the Central and 15.43 percent households in the East are involved in electricity theft. The K-Electric also complained that the central and the east districts of Karachi have the highest rate of late electricity payments and electricity theft.[33]

The size of the impact of electricity load shedding also varies by gender of the person, job status and district of residence. Table 9 presents various implications of electricity crises, household's views and household's reaction over prevailing electricity crises. The work impact of load shedding varies by job as the worst affected are private employees which are 42.07 percent following own business 16.29 percent, government 13.60 percent and retirees or unemployed 3.79 percent. The variable "daily tasks" combines responses of the household on three important missed out daily tasks: reaching the office in time, pick and drop of children to and from school and complying with doctor's appointment. The data show that 62.50 percent of households missed all three important tasks at least once during March and May because of electricity load shedding (see Table 9). Only 11.01 percent of households could not do the third task only.

[32]Real expenditure is used as proxy for income of the surveyed household and income deciles were computed.

[33]www.pc.gov.pk

Table 7

Electricity Crises Affected Household by District

Districts	Crises Affected Household	Male Headed (Crises Affected Household)	Female Headed (Crises Affected Household)
Central	31.80	31.40	34.68
East	29.88	29.38	33.58
West	11.65	12.01	8.99
South	8.56	8.71	7.43
Malir	14.81	15.23	11.74
Total	96.70	96.73	96.42

Table 8

The Worst Affected Households from Electricity Crises and Electricity Theft by District

District	Worst Affected Household	Electric Theft in Neighbourhood of Worst Affected
Central	22.45	17.20
East	20.58	15.43
West	8.47	6.60
South	5.49	3.70
Malir	10.20	7.09
Total	67.19	50.03

The data show that 51 percent households experience increases in the expenditure on electricity alternatives that is ups, generator, etc., due to load shedding from the last year[34] (see Table 9). The prolonged load shedding also results in diseases like depression, behaviour disorder and Narcolepsy[35] in the population. Timing of the electricity load shedding badly affect working age men and women as 45.03 percent of working heads find increase in medical payments because of sleeplessness resulting from regular load shedding in the night time (see Table 9). About 60.12 percent of the household members could not do well in their exams—as matric[36] and intermediate exams are held during April and May in Karachi.

The load shedding especially during the night time also contributes to the perpetration of street crimes in Karachi as darkness provides opportunity for criminals to commit crime without exposing their identity. The data show that 55.52 percent of the households strongly agree with this opinion. The study finds that female-headed households are less vocal in reporting electricity theft than male-headed households. About 86.93 percent of the male-headed households find an increase in electricity theft while only 13

[34]Only 20 percent of electricity crises affected households reported expenditure on other alternatives like candles, emergency lights, torches etc.

[35]Severe kind of sleep disorder, see for detail www.webmed.com. Working Households heads were asked to report sleep disorders and their visit to hospital for treatment due to load shedding in past three months, 26 percent of the working households reported severe sleep disorder.

[36]Equivalent to GCE advance level exam.

percent women notice the neighbourhood's involvement in electricity theft. Similarly 88 percent male-headed households and only 12 percent of female-headed households find electricity load shedding as an important influencing factor in their decision to vote in the 2013 general elections. About 31 percent of the households viewed increase in the load shedding by multiple times, 46.60 percent found increase and only 9.25 percent viewed no change over the last five years (see Table 9). About 89 percent of surveyed households hold increase in the electricity prices as a reason for multiplying the problem of load shedding. In their view, more and more poor people have resorted to electricity theft to avoid increasing electricity charges. While 88 percent of the households held past governments responsible for prevailing electricity crises (see Table 9).

Table 9

Implications, Perceptions and Reaction of Electricity Crises Affected Households

Variables	All Households	Male Headed Households	Female Headed Households
Implications			
Work impact	73.13	88.59	11.41
Daily targets	62.50	84.53	15.47
Impact on study	60.12	54.01	8.11
Increase in expenditures on alternatives	51.02	58.52	41.06
Increase in medical expenditure	45.03	47.01	55.99
Participation in ceremonies	77.06	46.06	53.94
Electricity theft by neighbourhood	68.65	86.93	13.07
Street crimes	55.52	86.62	13.38
Voting behaviour in 2013 general elections	77.69	88.11	11.89
Perceptions			
Extent of electricity crises in last five years	89.15	89.43	10.57
Role of the last government	87.83	87.65	12.35
Increase in electricity prices	89.16	78.01	21.99
Electricity crises on Election manifesto, 2013	34.01	31.22	2.85
Reaction			
Passive	78.47	82.16	17.84
Protest in media	13.50	87.82	12.18
Protest in streets	16.63	93.01	6.99

Studies by Pasha (2010) and Asif (2011) also showed that failure by previous governments to react timely to the situation are the main reasons behind persisting electricity crises in Pakistan. The data show that 78 percent of households did not complain against electricity load shedding during survey months, and only 16 percent of households took part in the street protests against the power outages (see Table 9).

4.1. Household's Coping Strategies

Finally, we analyse the Household's capacity in coping with electricity crises (see Table 2). The study finds that about 82 percent of households from upper income deciles use generators and 59 percent resort to the UPS during load shedding. However, about 42.24 percent of households could not afford any alternative supplies during electricity load shedding and therefore bear the brunt of load shedding during March-May 2013 (see Figure 5). The study finds that about 41 percent of male-headed households and 47.36 percent of female-headed households cannot afford any alternate arrangement during electricity load shedding. Only 7 percent female-headed and 8.1 percent male-headed households can use the UPS and generators both during the electricity load shedding (see Figure 6). The data show that about 7.48 percent households can arrange the ups and generators both during electricity load shedding. While a larger proportion or 93 percent households can either use a generator or the ups but not both (see Figure 5).

Fig. 5. Use of Electricity Alternatives during Load Shedding by All Households

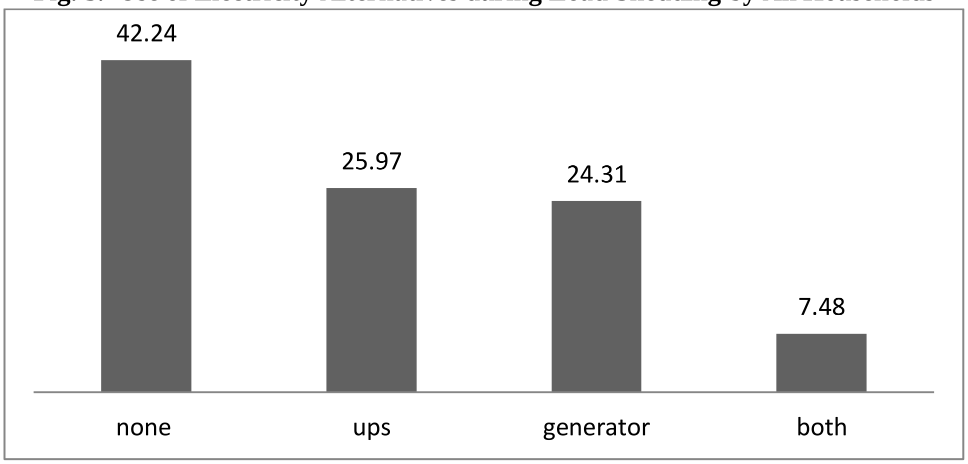
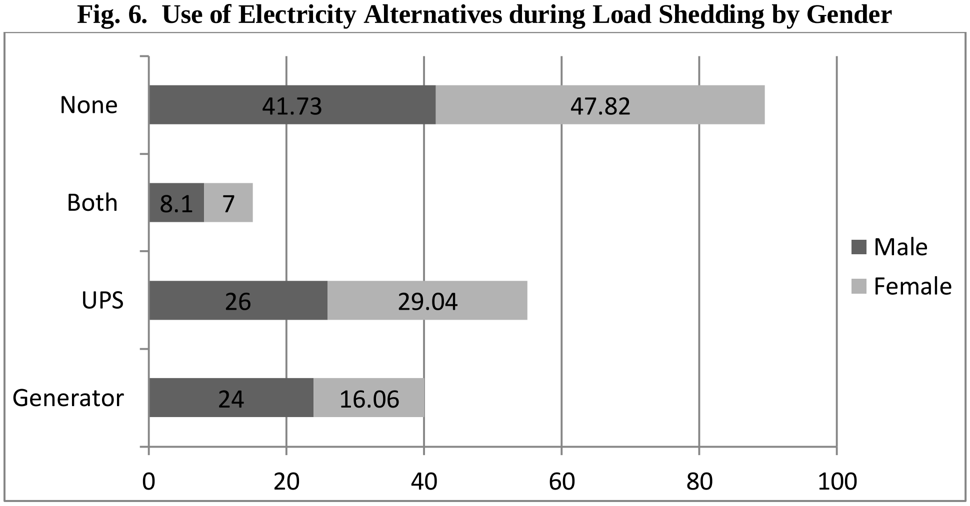


Fig. 6. Use of Electricity Alternatives during Load Shedding by Gender



5. CONCLUSION AND POLICY IMPLICATION

This article analyses the end use based electricity demand and socioeconomic characteristics of households as determinants of prevailing electricity crises in Karachi. The findings of the study suggest that demand for electricity depends on the use of modern electric appliances, and gender specific differences exist in the end uses of electricity consumption. Household's economic and social characteristics interact with end-use electricity consumption. Some effective interactions with end-uses electricity demand are household size, household's income, dwelling type, family unit, gender and marital status of the head of household in Karachi. These variables with electrical appliances also determine the likelihood of suffering from electricity crises for residents of Karachi. Above all, the prevalence of illegal connections, tempering with transmission lines and power theft have compounded the impact of household suffering.

The findings of the conditional demand model (CDM) and logistic model have important theoretical and policy implications. First, analysis of gender specific differences in end-use electricity consumption provides a basis for future research in energy with a gender perspective. Particularly for cities' like Karachi where women comprise majority of the labour force and have sheer dependence on modern appliances. Second findings of logistic model provide useful insight into factors that influence the vulnerability to electricity crises in times of peak demand. Thus, it provides the groundwork for future research in household's vulnerability to electricity failures. Fourth, prospective energy policies in countries like Pakistan should also focus on demand-side-management. Households should be motivated through media campaign; electronic and social media to use all means to conserve energy at the local levels. Fifth, government should encourage investment in the local manufacturing of electricity efficient appliances. Sixth, the most important is the need to legislate law that regards power theft or tampering with electricity meter and transmission lines a criminal offense.

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Comments

With urbanisation and modernisation of the economy, household electricity demand changes.

The present crisis started in 2006-07 with a gradual widening in the demand and supply gap of electricity. Unfortunately, the growth in demand in this decade was clearly not fully anticipated and sufficient investments were not made to accommodate for this increased demand.

This is a well-researched paper based on households' survey to determine household electricity demand and analyse economic and social characteristics of households as determinants of prevailing electricity crises.

(1) The title of the study portrays the energy consumption pattern of urban households from Sindh, but it gives the impression of metropolitan city of Karachi from Sindh province, i.e., literacy 99 percent, household size 4.5, 99 percent refrigerator and cell phone, 91 percent washing machine, 74 percent have desktop computer and 43 percent AC. This is not the urban profile of Sindh province.

(2) While discussing coping strategy during load shedding, 42 percent households reported no alternative of electricity while the rest is using UPS 24 percent, generator 26 percent and both 7.5 percent. It is observed that these 42 percent households uses candles/ lantern/emergency lights as alternative for lighting purposes i.e. studying, other household chores. It is a big share of HH. The study needs some discussion about it, i.e. Pakistan Panel Households Survey-2010 reported 62 percent use traditional strategies (Emergency lights 22, gas lamps/lanterns 40 percent) while only 2.6 percent used UPS, 2.7 percent generator and 35 percent had no alternative in urban Pakistan.

(3) The study did not highlight one of the reason of high demand/energy crises that is use of air conditioner as 43 percent households owned it and average share of energy consumption is 159 KWh which is 25 percent of total consumption.

The paper is a useful contribution in an important area of present high demand of energy.

Rashida Haq

Pakistan Institute of Development Economics,
Islamabad.

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An Investigation of Multidimensional Energy Poverty in Pakistan

REHMAT ULLAH AWAN, FALAK SHER and AKHTAR ABBAS

1. INTRODUCTION

Poverty is an alarming problem all over the world. It is one of the severe challenges today faced by not only the developing nations but by the developed nations also. However, the problem is worst in developing countries [United Nations and IEA (2010)]. All these countries face poverty in different forms such as food poverty, energy poverty, shortage of natural resources, shortage of agricultural products, lack of shelter and clothing among others. It is persuasive to correlate poverty with lack of energy consumption also. Such a correlation identifies that poor use energy very inadequately [Pachauri, *et al.* (2004)]. Energy helps societies to move from one development stage to another. Worldwide energy demand is increasing while supply is decreasing due to increase in the world population, emerging economies and economic development. In current day to day life energy has become an essential requirement. For all of us energy is required for lighting, transportation, cooking, health services, and to fulfill many of our basic needs. Electricity access at household level enhances telecommunication, entertainment, and knowledge via radio, television, and computer etc.

World Economic Forum (2010) defines energy poverty as "the lack of access to sustainable modern energy services and products". The energy poverty is defined as a situation where the absence of sufficient choice of accessing adequate, reliable, affordable, safe and environmentally suitable energy services is found. In simple words, energy poverty is the lack of access to suitable traditional (fire wood, chips, dung cakes etc.) and modern energy services and products (kerosene, liquefied petroleum, gas etc.). For development of any country, energy is the first step. A person is considered to be energy poor if he or she does not have access to at least (a) the equivalent of 35 Kg per capita per year LPG for cooking from liquid and/or gas fuels or from improved supply of solid fuel sources and improved (efficient and clean) cook stoves and (b) 120KWh electricity per capita per year for lighting, access to most basic services (drinking water,

Rehmat Ullah <awanbzu@gmail.com> Department of Economics, University of Sargodha, Pakistan. Falak Sher <muhammadfalak@hotmail.com> Department of Economics, University of Sargodha, Pakistan. Akhtar Abbas <akhtar.bhatti01@gmail.com> is Graduate Student, Department of Economics, University of Sargodha, Pakistan.

communication, improved health services, education improved services and others) plus some added value to local production.

To enhance livelihood opportunities for all, electricity plays a major role. To change the poor's life in a better way, clean and efficient energy resources are required. Firewood collection for cooking consumes a lot of women's time. Clean energy sources for cooking like electricity, and gas etc. mean improvement in living standards and time saving also. The income poor could also be energy poor, however not all of the energy poor are income poor. Energy scarcity and poverty go hand in hand and show a strong relationship. Welfare of masses is affected by the level of energy consumption. There is a negative correlation between access to modern energy services and energy poverty. So in order to alleviate energy poverty, improvement in the access to modern energy services is very essential. Availability of cheaper energy is essential. According to United Nations, lack of electricity and heavy reliance on traditional biomass are hallmarks of poverty in developing countries. Lack of electricity enhances poverty and contributes to its persistence, as it prevents most industrial activities and the job creation. [United Nations and IEA (2010)].

To meet their survival needs in absence of efficient energy using technologies and adequate energy resources, majority of poor depend on biomass energy, animal power and their own labour. To improve the level of satisfaction of basic human needs and living standards of the people and to eradicate poverty energy resources must be improved. For the better health care facilities and education clean energy is required. Achievement of efficient energy resources can lead to the attainment of evenhanded, economically strong and sustainable development. Present study aims to investigate the level of energy poverty in Pakistan and to find the extent of energy poverty in rural and urban areas of Pakistan along with the impact of different variables on energy poverty in Pakistan.

Rest of the study is organised as follows. Section 2 gives review of literature. Section 3 is about methodology and data. Results and discussions are are presented in Section 4. Section 5 concludes the study giving some policy recommendations based on findings.

2. REVIEW OF LITERATURE

Pasternak (2000) found that there is strong relationship between measures of human well-being and consumption of energy and electricity. A roughly constant ratio of primary energy consumption to electric energy consumption was observed for countries with high levels of electricity use and then this ratio was used to estimate global primary energy consumption in the Human Development Scenario. They established positive correlation between Human Development Index (HDI) and annual per capita electricity consumption for 60 populous countries comprising 90 percent of the world's population. Results further showed that HDI reached a maximum value when electricity consumption was about 4,000 KWH per person per year.

Bielecki (2002) by using a measurement of the existing state of oil security pointed out that the threats of supply disruption had not deminished. Outlook of the oil market for coming two decades advocate that there is still need to take more steps for the oil security. It was also found that with rising importance of universal demand and trade of gas, the gas security is also becoming gradually more significant. They claimed that different severe security alarms do exist and will probably strengthen in the future. This indicates that there is no area for gratification on energy security. The present oil crisis measures require extension to cover up energy sources for developing nations and for others.

Clancy, *et al.* (2003) found that Energy security has turned into a central community issue along with concerns with sky-scraping energy prices and the incidence of regional shortage of supply. 2.8 million Households in England are classified as being in fuel poverty in 2007 (13 percent of all households). It is found that the fuel poverty in the UK is not going to be of the same order or intensity as that of sub Saharan Africa. NGOs and practitioners also point at complex processes of energy exclusion and self-exclusion at the community, household and family level, leading to distinct micro cultures of energy use.

Pachauri, *et al.* (2004) measured Energy Poverty for Indian Households using a two-dimensional measure of energy poverty and energy distribution that combine the elements of access to different energy types and quantity of energy consumed. They found that there is significant reduction in the level of energy poverty due to rapid development in India.

Stephen, *et al.* (2004) studied present and future renewable energy potential in Kenya to meet the electrification needs of the poor. They limited the study to solar and hydro technologies owing to technical and socio-economic hurdles. They assessed that present Rural Electrification Fund (REF) in Kenya realises the solar and hydro electrification potential for poor. The results showed that if there is 10 percent increase in Rural Electrification Fund (REF), annual revenue from rural electricity connections increases by 42 percent in Kenya. There exists a relation between access and use of energy and poverty.

Pachauri, *et al.* (2004) presented different approaches for measurement of energy poverty by using Indian household level data. They found positive relation between well-being and use of clean and efficient energy resources. They also concluded that use of access and consumption of clean and efficient energy increases the well-being.

Catherine, *et al.* (2007) examined UK Government's devotions to eradicate fuel poverty among vulnerable families by year 2010 and in the common people by 2016. They explained the relations among this measure of fuel poverty and the governmental objective definition, using an exclusive data set and the Family Expenditure Survey. They recognised the link between two measures. They investigated the characteristics of households in each group, and how each measure is interrelated with different household issues.

Tennakoon (2009) analysed energy poverty status of Sri Lanka. Two approaches namely Quantitative approach and Pricing approach of measuring energy poverty were used. Results of Pricing approach showed that Sri Lanka is facing high level of energy poverty (83 percent energy poverty) while results of Quantitative approach revealed that energy poverty in terms of cooking is very high due to high inefficiencies of cooking stoves.

Barness, *et al.* (2010) explored the welfare impacts of household and energy use in rural Bangladesh using cross sectional data. The result showed that although modern and traditional sources improved energy consumption of rural Bangladesh households but the impacts of modern energy sources were high as compared to traditional energy services. 58 percent households in rural Bangladesh are facing energy poverty.

Shahidur, *et al.* (2010) studied energy poverty of urban and rural areas of India. The estimates showed that in rural area of India, 57 percent households are energy poor and only 22 percent households are income poor while in urban areas of India, energy poverty is 28 percent and income poverty is 20 percent. The persons in energy poverty were also facing income poverty.

Marcio, *et al.* (2010) analysed the impact of energy poverty on inequality for Brazilian Economy using Lorenz Curve, Poverty Gap, Gini coefficient and Sen Index. It is concluded that rural electrification leads to improvement in energy equity.

Jain (2010) explored the problems related to energy consumption faced by Indian rural and urban households. The results showed that energy poverty in rural areas of India is about 89 percent and 24 percent in urban areas of India. It was also concluded that 56 percent households in India has access to electricity facilities. Poor persons spend almost 12 percent of their total income only on the energy. Energy poverty disturbs all aspects of human welfare like agricultural productivity, access to water, education, health care and job creation etc. Energy poor persons have no access to clean water and electricity and they spend a large portion of their income and time to get energy fuel. This consumption pattern of the poor persons on energy leads to the income poverty.

Mirza and Szirmai (2010) discussed the consequences and characteristics of the use of different energy services using Energy Poverty Survey (EPS) data from 2008 to 2009. They outlined that the rural population of Pakistan uses variety of energy services like firewood, plant waste, kerosene oil and animal waste. Despite these sources of energy, the population of Pakistan has to face the energy crises or energy poverty. Estimates show that 96.6 percent of rural households have to face energy short fall. In Punjab province of Pakistan, 91.7 percent of rural households of the total rural population are facing severe energy poverty.

Nussbaumer, *et al.* (2011) reviewed appropriate literature and talked about sufficiency and applicability of existing methods for measurement of energy poverty for several African countries. They proposed a new composite index, Multidimensional Energy Poverty Index (MEPI). It captures the incidence and intensity of energy poverty and focuses on the deprivation of access to modern energy services. Based on MEPI for Africa, the countries are categorised according to the level of energy poverty, ranging from sensitive energy poverty (MEPI>0.9; e.g. Ethiopia) to modest energy poverty (MEPI<0.6; Angola, Egypt, Morocco, Namibia, Senegal). It was concluded that the MEPI will only form one tool in monitoring improvement and designing and executing good quality policy in the area of energy poverty.

3. DATA AND METHODOLOGY

The study uses Pakistan Social and Living Standards Measurement (PSLM) Survey (2007-08) as latest available data set. This data set includes sample of 15512 households consisting of 1113 sample community/enumeration blocks. A two-stage stratified sample design has been adopted for this survey. Villages and enumeration blocks in urban and rural areas, respectively have been taken as Primary Sampling Units (PSUs). Sample PSUs have been selected from strata/sub-strata with Probability Proportional to Size (PPS) method of sampling technique. Households within sample PSUs have been taken as Secondary Sampling Units (SSUs). A specified number of households i.e. 16 and 12 from each sample PSU of rural and urban area have been selected, respectively using systematic sampling technique with a random start.

3.1. Methodology

For the analysis and for the measurement of energy poverty in Pakistan, study uses Multidimensional Energy Poverty Index (MEPI), proposed by Nussbaumer, *et al*. (2011). The MEPI is created by Oxford Poverty and Human Development Initiative (OPHI) with association of United Nations Development Programme (UNDP**)**. The technique utilised is derived from the literature on multidimensional poverty measures, from the Oxford Poverty and Human Development Initiative (OPHI) [Alkire and Foster (2007); Alkire and Foster (2009); Alkire and Santos (2010)], which is improved by Amartya Sen's contribution to the debate of deprivations and potential. Fundamentally, MEPI takes into account the set of energy deprivation that may have an effect on an individual. It captures five dimensions of basic energy services with five indicators. An individual or a household is considered as energy poor if the combinations of the deprivations that are faced by an individual surpass a pre-defined threshold. The Multidimensional Energy Poverty Index is the result of a headcount ratio (share of people recognised as energy poor) and the average intensity of deprivation of the energy poor.

Multidimensional Energy Poverty Index (MEPI) merges two features of energy poverty. On one side is the incidence of poverty defined as the percentage of people who are energy poor, or the headcount ratio (H) and the other is the intensity of poverty defined as the average percentage of dimensions in which energy poor people are deprived (A).

Let $M^{n,d}$ indicate the set of all $n\times d$ matrices, and $y \in M^{n,d}$ stand for an achievement matrix of n people in d different dimensions. For every $i = 1, 2, \ldots, n$ and $j=1, 2, \ldots, d$, the typical entry y_{ij} of y is individual i's achievement in dimension j. The row vector $y_i = (y_{i1}, y_{i2}, \ldots, y_{id})$ lists individual i's achievements and the column vector $y_j = (y_{1j}, y_{2j}, \ldots, y_{nj})$ gives the distribution of achievements in dimension j across individuals. Let $z_j > 0$ represent the cutoff below which a person is considered to be deprived in dimension j and z represent the row vector of dimension specific cutoffs. Following Alkire and Foster's (2007)'s notations, any vector or matrix v,$|v|$ denotes the sum of all its elements, whereas $\mu(v)$ is the mean of v.

Alkire and Foster (2007) suggest that it is useful to express the data in terms of deprivations rather than achievements. For any matrix y, it is possible to define a matrix of deprivations $g^0 = \left[g_{ij}^0\right]$, whose typical element g_{ij}^0 is defined by $g_{ij}^0 = 1$ when $y_{ij} < z_j$, and $g_{ij}^0 = 0$ when $y_{ij} \geq z_j$. g^0 is an $n\times d$ *matrix* whose ij^{th} entry is equal to 1 when person i is deprived in jth dimension, and 0 when person is not. g_i^0 is the i^{th} row vector of g^0 which represent person i's deprivation vector. From g^o matrix, define a column vector of deprivation counts, whose i^{th} entry $c_i = \left|g_i^0\right|$ represents the number of deprivations suffered by person i. If the variables in y are only ordinal significant, g^o and c are still well defined. If the variables in y are cardinal then we have to define a matrix of normalised gaps g.[1] For any y, let $g^1 = \left[g_{ij}^1 \right]$ be the matrix of normalised gaps, where the typical element is defined by $g_{ij}^1 = (z_j - y_{ij}) / z_j$ when $y_{ij} < z_j$, and $g_{ij}^1 = 0$ otherwise. The entries of this matrix are non-negative numbers less than or equal to 1, with g_{ij}^1 being a measure of the extent to which person i is deprived in dimension j. This matrix can be generalised to $g^\alpha = \left[g_{ij}^\alpha \right]$, with $\alpha > 0$, whose typical element g_{ij}^α is normalised poverty gap raised to α power.

A sensible start is to recognise who is poor and who is not? The majority of identification techniques recommended in the literature in general pursue the union/ intersection approach. A person is considered poor according to union approach, if that person is deprived in only one dimension. While according to intersection approach an individual i is considered to be poor if that individual is deprived in all dimensions. If the equal weights are given to all dimensions the technique to recognise the multidimensionally poor suggested by Alkire and Foster deprivations are compared with a cutoff level k. where k= 1,2,…,d. Now we describe the recognition method ρ_k such that $\rho_k(y_i, z) = 1$ when $c_i \geq k$, and $\rho_k(y_i, z) = 0$ when $c_i < k$. This shows that an individual is known as multidimensionally poor if that individual has deprivation level at least in k dimensions. This is called dual cutoff method because ρ_k depends upon z_j within dimension and across dimensions cutoff k. This identification principle describes the set of the multidimensionally poor people as $Z_k = \{i : \rho_k(y_i; z) = 1\}$. A censored matrix $g^0(k)$ is obtained from g^0 by replacing the ith row with a vector of zeros whenever $\rho_k(y_i, z) = 0$. An analogous matrix $g^\alpha(k)$ is obtained for $\alpha > 0$, with the ijth element $g_{ij}^\propto(k) = g_{ij}^\propto$ if $c_i \geq k$ and $g_{ij}^\propto(k) = 0$ if $c_i < k$.

On the basis of this identification method, Alkire and Foster define the following poverty measures. The first natural measure is the percentage of individuals that are multidimensionally poor: the multidimensional Headcount Ratio $H = H(y; z)$ is defined by $H = q/n$, where $q = q(y,z)$ is the number of people in set Z_k. This is entirely analogous to the income headcount ratio. This method has the advantage of being easily comprehensible and estimable and this can be applied using ordinal data.

4. RESULTS AND DISCUSSION

Table 1 shows different Dimensions, Indicators and the Cut-offs. From a human development point of view, a poverty indicator must be significantly and eventually measurable at the individual, household, or community level. It must allow a classifying of these demographic units as more or less poor. Present study uses five main dimensions and their relevant indicators for the measurement of Multidimensional Energy Poverty Index (MEPI) based upon the availability of nationwide data. All the five dimensions are weighted equally. Figure 1 shows the results of Multidimensional Energy Poverty head count for overall Pakistan at dual cutoff equal to 2 i.e. K=2. The empirical results show that in Pakistan almost 54.6 percent and 45.4 percent of households are multidimensional energy poor and energy non poor, respectively.

Table 1

Selected Indicators and their Cutoffs

Dimension/Indicator	Indicator	Variable	Cutoff (Situation of Deprivation)
Cooking	Modern cooking fuel	Type of cooking fuel	A household considered poor/deprived if using any fuel beside electricity, liquefied Petroleum Gas (LPG), kerosene oil, natural gas, or biogas for cooking purposes.
Indoor Pollution	Indoor pollution	Food cooked on stove or open fire if using any fuel beside electricity, LPG, natural gas, or biogas	A household considered poor/deprived if not using modern cook stove or use three stone cook stove or if using any fuel for cooking beside electricity, liquefied Petroleum Gas (LPG), natural gas, or biogas.
Lighting	Electricity access	Has access to electricity	There is no proper data for lighting; therefore for the purpose we use electricity access. A household considered poor/deprived if the household has no electricity connection or access to electricity facilities.
Services provided by means of Household Appliances	Household appliance Ownership	Has a fridge/ Electric fan	This dimension deals with ownership of household appliances. A household considered poor/ deprived if the household has not a fridge or electric fan.
Entertainment/ Education	Entertainment/ education appliance ownership	Has a radio/ television	This dimension deals with ownership of Entertainment/education appliance. A household considered poor/deprived if the household has not Radio or Television or Computer.

Fig. 1. Results of Multidimensional Energy Poverty Headcount for Overall Pakistan at K=2

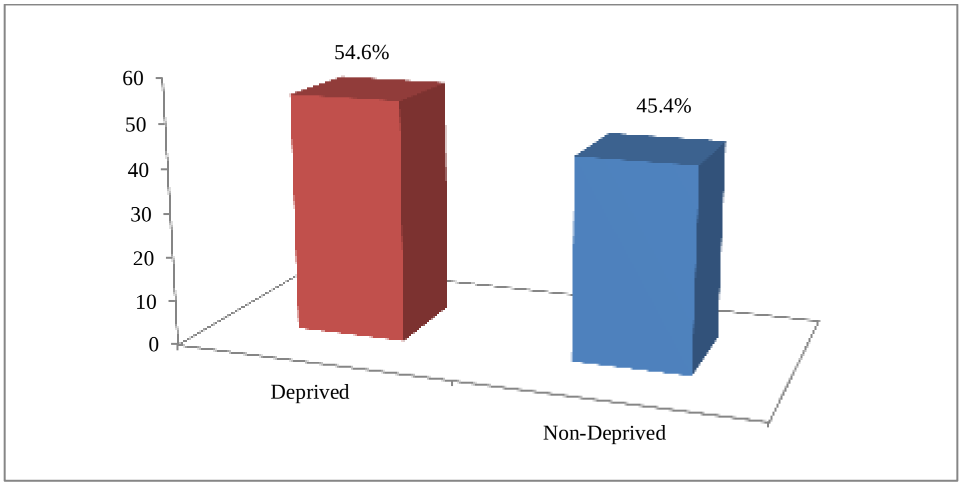


Figure 2 shows the results of Multidimensional Energy Poverty head count for urban Pakistan. It is clear from figure that only 29 percent of the households are multidimensional energy poor in urban areas of Pakistan, while remaining 71 percent of the households in urban areas are energy non-poor.

Fig. 2. Results of Multidimensional Energy Poverty Headcount for Urban Pakistan at K=2

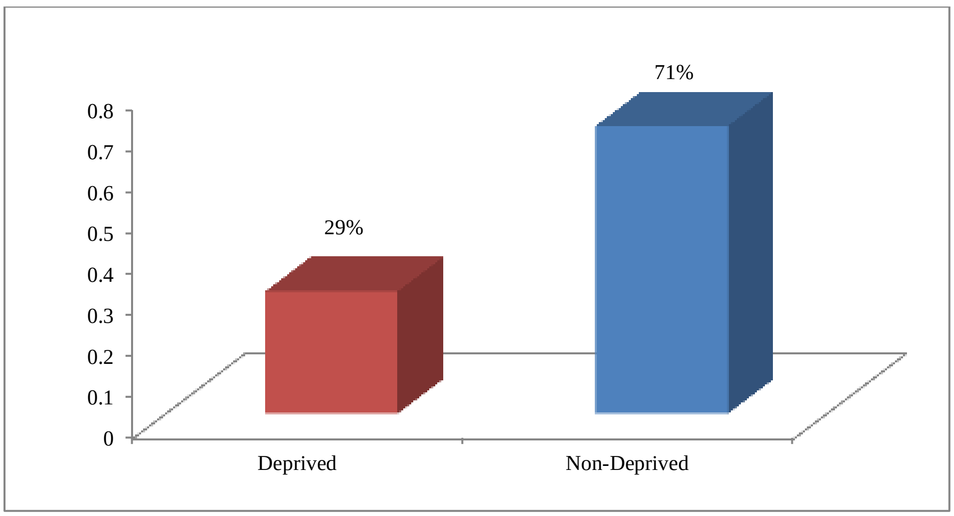
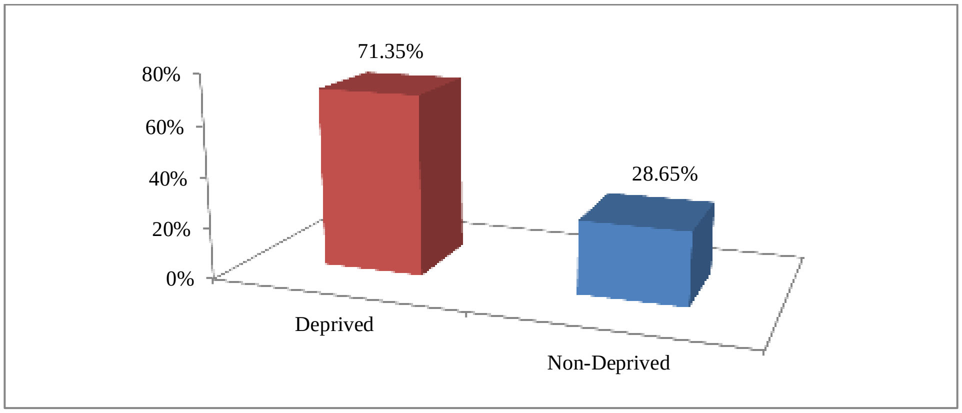


Figure 3 depicts the results of Multidimensional Energy Poverty headcount for rural areas of Pakistan. The incidence and severity of energy poverty is significant in rural areas of Pakistan. Results show that Multidimensional Energy Poverty headcount for rural Pakistan is 71.4 percent and 28.6 percent of the households residing in rural areas of Pakistan are energy non-poor.

Fig. 3. Results of Multidimensional Energy Poverty Headcount for Rural Pakistan at K=2



The analysis of breakdown of energy poverty by dimension for overall Pakistan is shown in Figure 4. Results show that households of Pakistan are most deprived in cooking fuel dimension (55 percent), while deprivation is the least in dimension of home appliances ownership (15 percent). Results further show that 52 percent, 33 percent and 19 percent of the households in Pakistan are deprived in terms of indoor pollution, entertainment appliances and electricity, respectively.

Fig.4. Dimension-wise Breakdown of Energy Poverty for Overall Pakistan

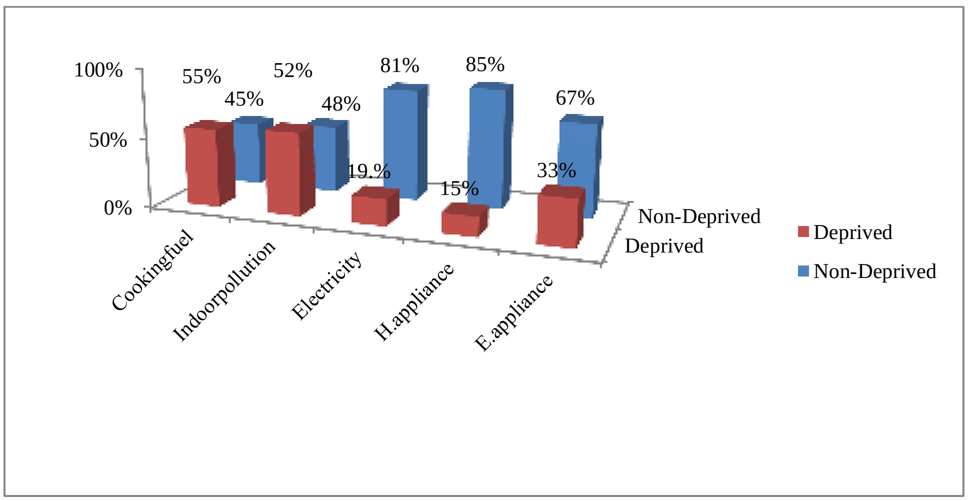


Figure 5 shows the breakdown of energy poverty by dimension for urban Pakistan. The empirical results show that in urban areas of Pakistan households are more deprived in dimension of cooking fuels (23 percent) followed by indoor pollution (19 percent). In urban areas of Pakistan only 3 percent households are deprived in dimension of home appliances ownership. In dimensions of entertainment appliances and electricity households are deprived by 18 percent and 7 percent, respectively.

Fig.5. Dimension-wise Breakdown of Energy Poverty for Urban Pakistan

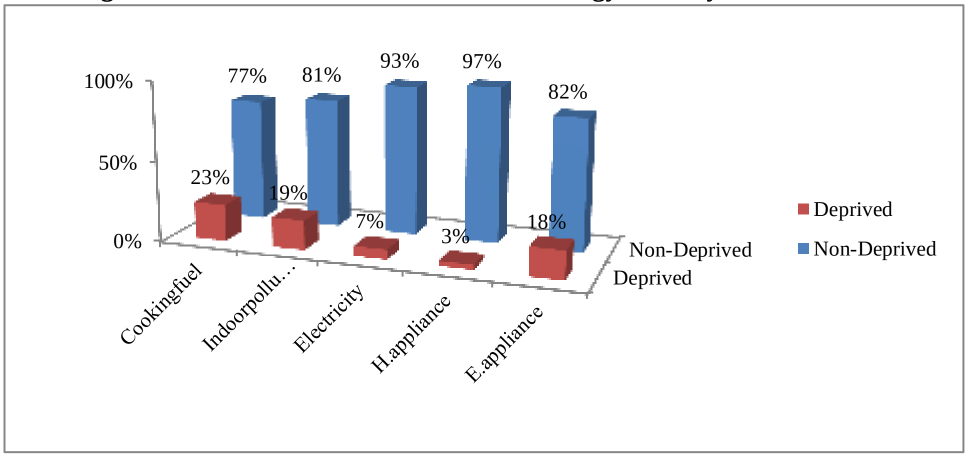


Figure 6 shows the breakdown of energy poverty by dimension for rural Pakistan. Almost one third households of rural Pakistan are deprived in dimension of indoor pollution (69 percent). As shown in Figure 6, 58 percent households are deprived in cooking fuels dimension in rural areas of Pakistan. Situation is also critical in entertainment appliances in the same region. Households' deprivation in terms of entertainment appliances, electricity and home appliances are 44 percent, 29 percent and 22 percent, respectively.

Fig.6. Dimension wise Breakdown of Energy Poverty for Rural Pakistan

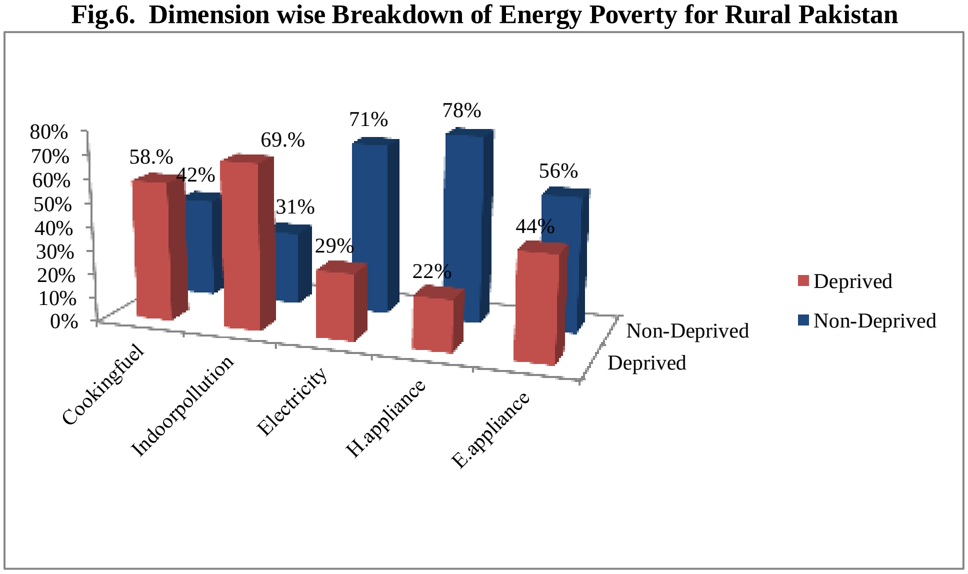


Figure 7 shows the contribution of urban and rural deprived households to Multidimensional Energy Poverty headcount for overall Pakistan. Contribution of rural and urban deprived households to multidimensional energy poverty in Pakistan is 71 percent and 29 percent, respectively.

Fig.7. Results of Contribution of Region-wise Deprived Households to Multidimensional Energy Poverty Headcount for Overall Pakistan

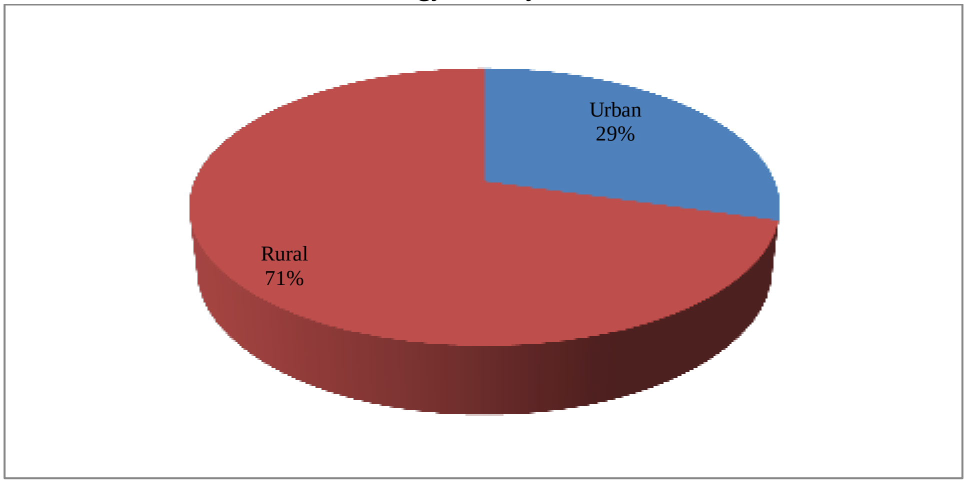


Figure 8 shows contribution of selected dimensions in multidimensional energy poverty headcount. In the paradigm of multidimensional energy poverty in Pakistan contribution of indoor pollution (32 percent) is the highest followed by the cooking fuels dimension (31 percent). Collectively these two dimensions contribute up to 63 percent in overall Multidimensional Energy Poverty headcount for Pakistan. While electricity, home appliances and entertainment appliances contribute to overall Multidimensional Energy Poverty headcount for Pakistan 11 percent, 8 percent and 18 percent, respectively.

Fig.8. Results of Dimension-wise Contribution to Multidimensional Energy Poverty Headcount for Pakistan

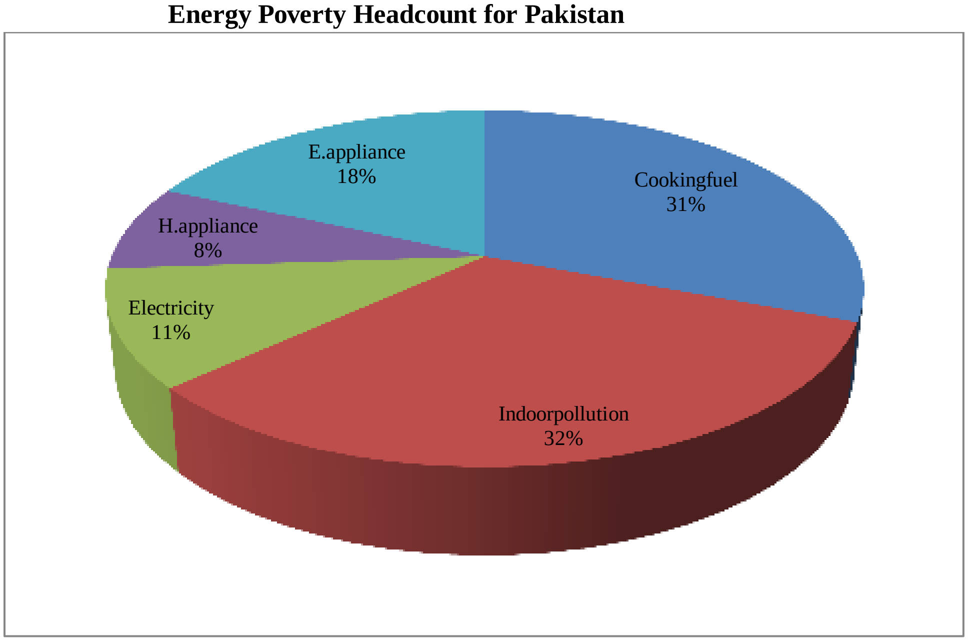
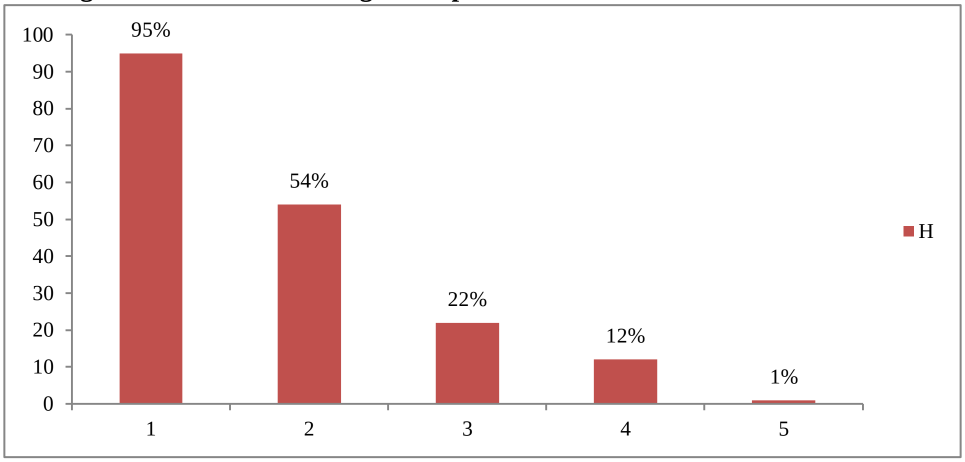


Figure 9 shows percentage of households deprived in exact number of deprivations in overall Pakistan. In overall Pakistan, 95 percent households are deprived when we set k=1. Households deprivation in energy decreases with the increase in value of cut offs.

Fig. 9. Results of Percentage of Deprived Households at Different Cut Offs



5. CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

Based on results, the study concludes that there is significant and higher incidence and severity of energy poverty in rural areas as compared to urban areas, in overall Pakistan. Value of MEP Headcount for rural Pakistan is 71 percent as compared to 29 percent in urban areas of Pakistan. Results show that Multidimensional Energy Poverty headcount for rural Pakistan is 71.4 percent and 28.6 percent of the households residing in rural areas of Pakistan are energy non-poor. Households of Pakistan are most deprived in cooking fuel dimension (55 percent), while deprivation is the least in dimension of home appliances ownership (15 percent). In urban areas of Pakistan households are more deprived in dimension of cooking fuels (23 percent) followed by indoor pollution (19 percent). Almost one third households of rural Pakistan are deprived in dimension of indoor pollution (69 percent). Contribution of rural and urban deprived households to multidimensional energy poverty in Pakistan is 71 percent and 29 percent, respectively. Contribution of indoor pollution (32 percent) to multidimensional energy poverty headcount in Pakistan is the highest followed by the cooking fuels dimension (31 percent) and collectively these two dimensions contribute up to 63 percent in overall Multidimensional Energy Poverty head count for Pakistan. Study further concludes that households deprivation in energy decreases with the increase in value of cut-offs. Overall indoor pollution, cooking fuel and Entertainment appliances are the three major contributors, to overall MEP Headcount not only as a whole but region wise also.

Based on above findings, the study suggests taking special initiatives to combat Energy Poverty in most deprived areas particularly the rural areas on priority basis by allocating more funds to them. Indoor pollution and cooking fuel being the major contributors to overall multidimensional energy poverty in overall Pakistan and regions also, energy poverty in these dimensions should be individually addressed in order to reduce overall multidimensional energy poverty. Provision of subsidised solar panels, bio-gas plants and modern cooking stoves can help a lot in this regard.

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Comments

This paper is a pioneer research in the arena of energy poverty representing overall Pakistan with national representing data of PSLM 2007-08. The paper explores energy poverty in urban and rural areas with tabulation and graphical representation. A high deprivation in energy is seen in rural areas in all provinces.

My major concern with this paper is:

(1) The study uses 2007-08 data although new data set 2010-11 is also available which will give latest estimates of energy poverty.

(2) The study uses equal weights or simple averages with reference to Alkire and Foster, (2009). This can be appropriate when the dimensions have been chosen to be of relatively equal importance as seen in Alkire and Foster (2007) taking income, health, schooling and health insurance. But in your methodology it is mentioned that the study uses Multidimensional Energy Poverty Index (MEPI), proposed by Nussbaumer, *et al*. (2011). This study had used weights on the bases of degree of importance of variables from .13 to .2 for its different indictors. It would be appropriate if the study uses appropriate weights because access to electricity for lighting, access to gas/LPG for cooking had more importance versus ownership of fridge or TV for entertainment.

(3) In Table 1 for indicator 4 and 5 some clarification is needed. For indicator 4 fridge is used as variable but when you go for cutoff points you mentioned both fridge or electric fan. Same with indicator 5, radio/TV is used as variable but in cutoff point you also added computer.

(4) Finally, you had computed incidence of energy poverty by using 5 variables but not severity of energy poverty. These estimates are only for urban/ rural break down but not at provincial level but you had mentioned all in your conclusion.

Finally, I would say that the provision of modern energy services is recognised as a critical foundation for sustainable development, and is central to the everyday lives of people. Effective policies to dramatically expand modern energy access need to be grounded in a robust information-base.

Rashida Haq

Pakistan Institute of Development Economics,
Islamabad.

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Interprovincial Differences in Power Sector Subsidies and Implications for the NFC Award

UMBREEN FATIMA and ANJUM NASIM

1. INTRODUCTION

Power sector subsidies constituted 83 percent of the federal government's total subsidies of PRs 558 billion in 2012. The tariff differential subsidy (TDS) amounted to PRs 464 billion (including arrears of PRs 312.8 billion from previous years). The TDS is provided to distribution companies (DISCOs) to cover the difference between the tariff schedules approved by the National Electric Power Regulatory Authority (NEPRA) (which can differ across DISCOs) and the uniform tariff schedule (by consumer group) notified by the Ministry of Water and Power (MoWP) for all regions of the country.

The NEPRA-approved tariff takes account of DISCOs' revenue requirements and various elements of cost. In calculating the average tariff, NEPRA also takes into account companies' transmission and distribution (T&D) losses. Both revenue requirements and T&D losses differ across DISCOs, which are duly reflected in NEPRA-approved tariffs.

The fact that NEPRA approves different tariffs across DISCOs while the MoWP sets uniform tariffs (by consumer group) implies that each DISCO receives a different TDS from the federal government. This translates into different subsidies for each province. By aggregating the TDS by consumer group across all DISCOs, we can also calculate the aggregate subsidy by consumer group.

In this paper, we calculate the subsidies provided to each of the country's ten DISCOs,[1] to individual consumer groups, and to the provinces. The TDS effectively reduce the federal government's share in the divisible pool of taxes compared with the 42.5 percent share approved under the 7th National Finance Commission (NFC) award. We also calculate the share of the four provinces in the divisible pool by factoring in provincial TDS shares for the financial year (FY) 2011/12.[2]

Umbreen Fatima <umbreen.fatima@ideaspak.org> is Research Associate at the Institute of Development and Economic Alternatives (IDEAS), Lahore. Anjum Nasim <anjum.nasim@ideaspak.org> is Senior Research Fellow at the Institute of Development and Economic Alternatives (IDEAS), Lahore.

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[1]These include the nine DISCOs, which are government-owned companies, and the Karachi Electric Supply Company (KESC), which is a privately owned company. Although the Tribal Electric Supply Company (TESCO) was also created as a DISCO, it has not yet been licensed [see Pakistan (2013)] and is therefore not included in our calculations.

[2]The Pakistan government's financial year starts on 1 July and ends on 30 June of the following year.

Section 2 outlines the electricity tariff determination process. Section 3 reports on the TDS by DISCO, by consumer group, and by province. Section 4 considers changes in the federal/provincial shares of the federal divisible tax revenue, if the TDS were to be distributed among the provinces as part of the revenue-sharing arrangement under the NFC award (treated as a revenue transfer in the divisible pool). Section 5 provides concluding remarks.

2. TARIFF DETERMINATION PROCESS

The tariff-setting process involves the following steps:

DISCOs send their tariff proposals to NEPRA, justifying their costs and revenue requirements.

NEPRA sets tariffs for various consumer categories for each DISCO based on its own assessment of costs and revenue requirements, which can differ from those provided by the DISCOs. It then communicates these to the MoWP, recommending that the tariff be notified.

The MoWP notifies a tariff schedule for various consumer categories, which are common across all DISCOs [Pakistan (2013)].

Typically, the MoWP notifies a minimum tariff for each consumer category across all DISCOs while NEPRA sets tariffs that take into account the various cost components of each DISCO. These components are explained below:

Power Purchase Price (PPP). This is the projected cost at which a DISCO will purchase power. It comprises the generation cost and the cost of transmission by the National Transmission and Distribution Company (NTDC) of the total power that a DISCO is projected to purchase during the year.

Net Distribution Margin. This is the difference between the gross distribution margin and a DISCO's 'other income'. The gross margin consists of operation and maintenance costs, depreciation, and return on assets (ROA) base. 'Other income' includes the amortisation of deferred credit, meter and rental income, late payment surcharges, profit on bank deposits, the sale of scrap, income from nonutility operations, the commission on PTV fees, and miscellaneous incomes. This allows a normal ROA.

Prior Year Adjustment (PYA). Each year, an adjustment for the previous year is built into the current year's tariffs. The 'shortfall' between the projected and regulator-approved actual costs in year *t*-1 is recovered by including it in the tariff for period *t*. This adjustment accounts for the difference between (i) the projected and actual electricity units purchased by DISCOs from the NTDC at the notified tariffs, (ii) the projected and actual distribution margins, (iii) the actual and notified previous year's adjustment,[3] (iv) projected and actual 'other income', and (v) the

[3]To gauge this, consider three time periods, *t* = 1, 2, and 3. Suppose, in year 1, a DISCO's total cost plus normal profits were PRs 10,000 and its projected sales were 1,000 units, which equalled its purchases from the NTDC (assuming zero line losses). NEPRA would then set the tariff at PRs 10 per unit in period 1 to allow the DISCO to recover its costs and earn normal profits. If actual sales/purchases in period 1 were 900 units, then at the notified tariff the DISCO would have suffered a loss of PRs 1,000 because of the difference in actual and projected units purchased/sold. To recover this loss, the tariff in period 2 would include a component on account of PYA. Thus, suppose in year 2, total costs were again PRs 10,000 and projected sales were 1,000 units. Without PYA, the tariff would be set at PRs10 per unit, but if a PYA of PRs 1,000 was allowed, then the tariff would increase by PRs1 from PRs 10 per unit to PRs 11 per unit. If actual sales in period 2 were again 900 units, then the DISCO's losses would be PRs 1,100 of which PRs 100 would be on account of the difference between the notified PYA (PRs 1 x 1,000 = PRs 1000) and actual PYA (PRs 1 x 900 = PRs 900). In setting the tariff for year 3, the PYA would be taken into account and one of the components of the PYA adjustment would be the difference between the notified PYA (PRs 1,000) and actual PYA (PRs 900).

projected and actual consumption mix.[4]

NEPRA determines an average tariff after including all the cost components and dividing the sum by projected sales. The projected sales figure also takes into account DISCOs' T&D losses. Thus, in the case of the Lahore Electric Supply Company (LESCO), NEPRA projected its power purchase and sales in FY2011/12 to be 17,547 GWh and 15,441 GWh, respectively, allowing 12 percent as T&D losses. The total cost was estimated at PRs 170,585 million. The average tariff was PRs 11.05/kWh, which was obtained by dividing PRs 170,585 million by 15,441 GWh. This implies that differences in line losses translate into differences in NEPRA-determined tariffs across DISCOs. The differences in line losses across DISCOs are shown in Table 1.

Table 1

Line Losses Across DISCOs in 2011/12 (Percent)

DISCO	NEPRA-Allowed Line Losses	Actual Line Losses
IESCO	9.50	9.52
LESCO	12.00	13.51
GEPCO	10.50	11.24
FESCO	10.83	10.91
MEPCO	15.00	17.94
HESCO	22.00	27.73
SEPCO	28.00	39.51
PESCO	28.00	35.97
QESCO	18.00	20.87

Source: NEPRA (Various Issues).

As shown in Table 1, NEPRA-allowed line losses vary between 9.5 percent in the case of the Islamabad Electric Supply Company (IESCO) and 28 percent in the case of the Peshawar Electric Supply Company (PESCO) and Sukkur Electric Power Company (SEPCO). We note that the actual line losses are higher than the NEPRA-allowed line losses. The consequent loss of revenue for the DISCOs carries over into the next year and is reflected in the tariffs for that year. Line losses occur on account of technical losses and 'nontechnical' or 'commercial' losses, the latter being a euphemism for pilferage and other corrupt practices.

Differential line losses do not necessarily imply differences in the efficiency of these DISCOs. Table 2 shows that coverage varies across DISCOs, which can also explain differences in technical losses, e.g. LESCO's service area is 16,400 km^2 compared to the Multan Electric Power Company (MEPCO), which has a service area of 105,505 km^2.

DISCOs also differ in their collection of utility bills from consumers. Table 3 shows the differences in collection as a percent of billing across the provinces. Such differences in collection add to the liabilities of the DISCOs and, therefore, of the government, but these are not taken into account at the time of NEPRA's tariff determination. NEPRA assumes a collection rate of 100 percent in its tariff assessment for DISCOs.

[4]The tariff schedules assume a sales mix within the various categories and subcategories of consumers. The actual sales mix may be different from the assumed sales mix and this can also upset the total revenue of the DISCOs. Accordingly, an adjustment is also made on this account.

Table 2

Distribution of Service Areas

DISCO	Service Area (km^2)	Service Area
PESCO	74,521	Province of Khyber Pakhtunkhwa, except tribal areas
TESCO		Khyber, Bajaur, Mohmand, Orakzai, Kurram, North Waziristan, South Waziristan, Frontier Region Peshawar, Frontier Region Kohat, Frontier Region Bannu, Frontier Region Tank, Frontier Region Lakki Marwat, Frontier Region Dera Ismail Khan
IESCO	45,000	Islamabad, Rawalpindi, Attock, Jhelum, Chakwal
GEPCO		Gujranwala, Sialkot, Mandi Bahauddin, Hafizabad, Narowal, Gujrat
LESCO	16,400	Lahore, Sheikhupura, Kasur, Okara, Nankana
FESCO		Faisalabad, Sargodha, Khushab, Jhang, Toba Tek Singh, Bhalwal, Mianwali, Bhakkar
MEPCO	105,505	Multan, Rahimyar Khan, Khanewal, Sahiwal, Pakpattan, Vehari, Muzaffargarh, Dera Ghazi Khan, Leiah, Rajanpur, Bahawalpur, Lodhran, Bahawalnagar
HESCO	70,458	Hyderabad, Jamshoro, Shaheed Benazirabad, Sanghar, Matiari, Badin, Mirpur Khas, Umerkot, Tharparkar, Tando Muhammad Khan, Tando Allahyar, Thatta
SEPCO	56,300	Sukkur, Khairpur, Kashmore, Kandhkot, Jacobabad, Shikarpur, Larkana, Kambar, Shahdadkot, Dadu, Naushehro Feroze, Ghotki, Mirpur Methelo, Rahimyar Khan
QESCO	34,800	Province of Balochistan, except Lasbela where KESC is responsible for power distribution
KESC	3,530	All of Karachi, including Lasbela

Source: NEPRA (2012).

Table 3

Collection as a Percent of Billing, 2011/12

Province	Collection as a Percent of Billing
Punjab	97.03
Sindh	60.38
KP	67.90
Balochistan	36.15

Source: NEPRA (2012).

NEPRA approves different tariff schedules for different categories of consumers: residential, commercial, industrial and agricultural. Additionally, there are consumers who buy power in bulk for further distribution. Each category is also distinguished by its load requirement and offered separate rates. Rates also vary by time of use (peak and off-peak).

The tariffs determined by NEPRA are reference tariffs and subject to monthly and quarterly adjustments, which allow for variations in actual PPP costs from those projected at the time of tariff setting. Variations in fuel cost are reflected in monthly adjustments and a number of other PPP-related costs are reflected in quarterly adjustments. These adjustments are then passed-on and reflected in consumers' monthly bills.[5]

The process of tariff determination begins towards the end of the financial year and continues throughout the year. Table 4 shows that NEPRA admitted tariff petitions for FY2011/12 as late as 28 November 2011. The approval process takes several months and there are further delays in notification by the MoWP. In FY2011/12, the ministry notified a common tariff schedule around mid-May 2012, when the fiscal year was coming to a close.

There have been some recent developments in the tariff determination process. On 5 August 2013, the MoWP notified consumer tariffs after receiving NEPRA's tariff recommendations but later notified another tariff schedule on 30 September 2013, with higher tariffs than those announced in August. The Supreme Court took suo moto notice and questioned whether the ministry was empowered to notify tariffs without NEPRA's involvement. As a result, the MoWP withdrew its notification and referred the matter to NEPRA. Since the new tariffs set by the MoWP were below those recommended by NEPRA, the latter did not revise its tariffs and, instead, notified its old tariffs together with consumer tariffs incorporating the new TDS, effectively notifying the consumer tariffs of 30 September 2013.

Table 4

Dates of Tariff Petition Admission, Approval and Notification, FY2011/12

DISCO	NEPRA Petition Acceptance Date	NEPRA Approval Date	Government Notification Date
KESC	–	–	16 May 2012
FESCO	1 November 2011	15 March 2012	16 May 2012
HESCO	27 September 2011	8 March 2012	16 May 2012
GEPCO	6 June 2011	13 December 2011	16 May 2012
IESCO	24 August 2011	19 January 2012	16 May 2012
MEPCO	28 June 2011	2 January 2012	16 May 2012
LESCO	14 July 2011	10 January 2012	16 May 2012
PESCO	22 July 2011	20 January, 2012	16 May 2012
QESCO	12 August 2011	10 January 2012	16 May 2012
SEPCO	28 November 2011	30 March 2012	16 May 2012

Source: NEPRA (Various Issues) and MoWP (2012a–2012j).

3. TDS BY DISCOS, CONSUMER GROUPS, AND PROVINCES

As mentioned earlier, the tariff schedule notified by the MoWP is common to all DISCOs although NEPRA approves different tariff schedules for each DISCO. The difference between the NEPRA-approved tariff and the tariff notified by the ministry is the TDS.

In this section, we calculate the TDS for each DISCO and consumer group for FY2011/12 by taking the difference between the NEPRA-approved tariffs and

[5]The monthly and quarterly adjustments are pass-through items (see http://nepra.org.pk/Tariff/DISCOs/LESCO/2012/TRF-176 %20LESCO%2010-01-2012%20227-29.PDF, p. 7) but from time to time consumers have approached the courts to obtain stay orders and succeeded in postponing the impact of these adjustments.

corresponding tariffs notified by the MoWP for FY2011/12 and multiplying the difference by the sales mix projected by NEPRA. Since the MoWP notifies tariffs towards the end of the financial year (see Table 4), which then remain effective for most or all of the following financial year, this method involves calculating the TDS as the difference between the NEPRA-approved tariff for a particular financial year and the tariff charged by a DISCO the following year. The subsidy so calculated has budgetary implications for FY2012/13 but we refer to this as TDS for 2011/12.

NEPRA (2012) provides data on the Karachi Electric Supply Company's (KESC's)[6] consumer mix for broad categories of consumer groups, but unlike for other DISCOs, the breakdown of the consumption mix within each consumer group is not available. We approximate this consumption mix for the KESC by assuming that the distribution within each consumer group (e.g. industrial consumers) is the same as that of LESCO.[7]

3.1. TDS Received by DISCOs

The TDS for each DISCO in FY2011/12 is calculated in three steps: (i) the TDS per unit for each consumer category is calculated as the difference between the NEPRA-approved tariff and the government-notified tariff,[8] (ii) the difference in the tariffs is multiplied by the sales mix projected by NEPRA for FY2011/12 to obtain the TDS for each consumer category, and (iii) the TDS for each consumer category is then aggregated over all consumer categories.

Residential consumers face electricity tariff slabs that increase with rising consumption. Since FY2010/11, NEPRA has recommended giving the benefit of lower tariffs to domestic consumers for only one previous slab, but the government has allowed them the benefit of lower tariffs on all previous consumption.[9] This could have an impact on TDS calculations for residential consumers because the sales mix projected by NEPRA (which assumes the benefit of one previous slab) will be different from projected sales if the benefit of all previous lower slabs is allowed.[10] In order to address this issue, we refer to the sales mix ratios for 2009/10, when there was no difference between the two assessments. Using these sales mix ratios and the projected total sales to residential

[6]In January, 2014 the KESC was renamed as K-Electric.

[7]If, within LESCO, industrial consumption under the B-1(a) tariff was 5.73 percent in FY2011/12, then we assume that, of the KESC's total industrial consumption of 3,342 GWh in FY2011/12, the B-1(a) tariff applies to 5.73 percent of its total industrial consumption.

[8]We have taken the NEPRA-approved tariff to be its reference tariff. Monthly and quarterly revisions are passed through to consumers and therefore ignored in our TDS calculations [Pakistan (2013), p. 13]. See also http://nepra.org.pk/Tariff/DISCOs/LESCO/2012/TRF-176%20LESCO%2010-01-2012%20227-29.PDF, p. 7.

[9]Thus, for domestic consumers who consume 800 units of electricity and fall in the tariff slab of 700+ units, NEPRA recommends that, for the first 700 units, they be charged the tariff applicable to consumers in the 301–700 unit slab; for the remaining 100 units, they are charged the tariff applicable to consumers in the 700+ unit slab. The government, on the other hand, has allowed progressively higher rates to be charged for consumption units that fall in the 0–100, 101–300, 301–700 and 700+ slabs, respectively.

[10]If NEPRA recommends that the benefit of one previous tariff slab be passed onto domestic consumers, then a consumer projected to consume 800 units (see footnote 8) would correspond to a consumer mix of 700 units in the 301–700 slab and 100 units in the 700+ slab. If government policy were followed, then the consumer mix would be 100 units in the 0–100 slab, 200 units in the 101–300 slab, 400 units in the 301–700 slab and 100 units in the 700+ slab. NEPRA's projected consumer sales mix for each DISCO is known but that of the government is not.

consumers in 2011/12, we calculate the TDS for residential consumers. This substitution of the 2009/10 sales mix for 2011/12 is necessary only for residential consumers and not other consumer categories. The decision to give the benefit of only one previous slab was made by NEPRA in 2010/11.[11]

Table 5 gives the TDS by DISCO; Appendix 1 calculates this subsidy for LESCO.

Table 5

TDS by DISCO, 2011/12

DISCO	Subsidy (PRs Billion)	No. of Consumption Units (GWh)	Subsidy per Unit (PRs/kWh)
IESCO	8.31	7,940	1.05
SEPCO	14.03	3,097	4.53
HESCO	15.64	3,725	4.20
QESCO	19.55	4,336	4.51
GEPCO	19.33	6,754	2.86
FESCO	22.96	8,921	2.57
LESCO	27.60	15,437	1.79
MEPCO	36.92	10,947	3.37
PESCO	41.59	8,229	5.01
KESC	45.27 a	10,279	4.40
Total	**251.21**	**79,735**	

Sources: NEPRA (Various Issues) and authors' calculations.

Although NEPRA (2012) provides data on the aggregate units sold to each consumption subcategory for KESC, there is no information on the number of units sold to consumer subcategories. Therefore, we have projected the units consumed by each KESC consumer subcategory by using LESCO as a reference case to allocate units to each consumer subcategory. The projected units thus calculated are used to calculate the TDS.

The variation across DISCOs in terms of subsidy per unit (kWh) is quite striking, with IESCO receiving PRs 1.05 per kWh and PESCO receiving PRs 5.01 per kWh. As discussed earlier, tariff differentials do not necessarily imply that some DISCOs are more efficient than others. One factor that might explain differences in cost is the difference in customers' geographical concentration, the resulting difference in T&D networks and their associated overheads and maintenance costs and line losses. An analysis of these issues is, however, beyond the scope of this paper.

3.2. TDS by Consumer Group

NEPRA distinguishes between different categories of consumers: residential, industrial, agricultural, commercial and bulk purchasers, etc. (see Appendix 1 for details). Within each category are further subcategories, e.g. residential consumers are subdivided into those with a sanctioned load of less than 5 kW and those with a sanctioned load above 5 kW; within the first category, consumers are further distinguished by the number

[11]See http://www.nepra.org.pk/Tariff/DISCOs/LESCO/2010/TRF-155%20LESCO%20IST%20QUARTER%20JULY-SEPTEMBER%202010%20-%202011.PDF, p. 30.

of units consumed (up to 50 units, 1–100, 101–300, 301–700 and 700+). For each subcategory, there is a NEPRA-approved tariff and an MoWP-notified tariff. Aggregating the TDS for all subcategories within a consumer group and across all DISCOs gives the aggregate subsidy for the consumer group (Table 6).

Table 6 gives two sets of calculations: one set excludes KESC and the other includes KESC. This is because, as explained above, the subsidies by consumer group for the KESC are based on an approximation; separating these allows us to see the per-unit subsidies by consumer group for DISCOs whose consumption mix is based on NEPRA projections and not on an approximation involving the consumption mix of another DISCO (in this case, LESCO).

We observe that all consumer groups receive a subsidy. Residential consumers, however, receive the largest subsidy, both in absolute terms and per-unit terms.

Table 6

TDS by Consumer Category, 2011/12

Consumer Category	Excluding KESC: Subsidy (PRs Billion)	Excluding KESC: No. of Consumption Units (GWh)	Excluding KESC: Subsidy per Unit (PRs/kWh)	Including KESC: Subsidy (PRs Billion)	Including KESC: No. of Consumption Units (GWh)	Including KESC: Subsidy per Unit (PRs/kWh)
Residential	126.84	31,891	3.98	150.23	36,455	4.12
Agricultural	28.65	9,332	3.07	29.04	9,466	3.07
Commercial	12.38	4,994	2.48	17.15	6,122	2.80
Bulk Supply	4.19	2,224	1.89	6.86	3,030	2.27
Industrial	36.01	19,022	1.89	49.19	22,364	2.20
Other	–2.14	1,993	–1.07	–1.25	2,298	–0.55
Total	**205.94**	**69,456**		**251.21**	**79,735**	

Sources: NEPRA (Various Issues) and authors' calculations.

3.3. TDS by Province

We calculate the provincial TDS using the subsidy estimates given in Table 5: the DISCOs are all categorised by province and their respective subsidies summed over each province. IESCO provides electricity to consumers in the federal capital, Islamabad, as well as four districts of Punjab (Rawalpindi, Jhelum, Chakwal and Attock). The other DISCOs in Punjab are LESCO, MEPCO, the Gujranwala Electric Power Company (GEPCO) and Faisalabad Electric Supply Company (FESCO). Those in Sindh are the KESC, the Hyderabad Electric Supply Company (HESCO) and SEPCO. Those in KP and Balochistan are, respectively, PESCO and the Quetta Electric Supply Company (QESCO). The subsidies by province are given in Table 7. Due to data limitations, our aggregation does not account for the fact that Lasbela is provided electricity by KESC and that some portions of Rahimyar Khan are supplied by SEPCO [NEPRA (2012)].

In absolute terms, Punjab is the largest recipient of TDS but the per-unit subsidy it receives is about half that of Sindh and Balochistan and about 46 percent that of Khyber Pakhtunkhwa (KP). Punjab's overall TDS is about 46 percent of the total TDS, which is considerably less than its share of the population (56 percent) and the provincial divisible pool of tax revenues (51.74 percent) under the 7th NFC Award.

Table 7

TDS by Province, FY2011/12

Province	Subsidy (PRs Billion)	No. of Consumption Units (GWh)	Subsidy per Unit (PRs/kWh)
Punjab	115.12	49,999	2.30
Sindh	74.95	17,101	4.38
KP	41.59	8,299	5.01
Balochistan	19.55	4,336	4.51
Total	**251.21**	**79,735**	

Sources: NEPRA (Various Issues) and authors' calculations.

4. THE TDS AND THE NFC AWARD

NFC awards are constituted every five years under Article 160 of the Constitution of Pakistan as a revenue-sharing arrangement between the federal and provincial governments. The transfer of resources from the federal government to the provinces under this award covers not only transfers from the divisible pool of taxes but also straight transfers such as royalties on crude oil and natural gas, gas development surcharges, excise duty on natural gas and general sales tax on telecom and other services. For the purposes of this analysis, we compare TDS across the provinces based on the tax revenue-sharing arrangement under the 7th NFC Award.

The NFC tax revenue-sharing involves two steps. The first step involves a distribution of tax revenues between the centre and provinces (vertical distribution). The second step involves distribution of the provincial tax revenue-share among all four provinces (horizontal distribution).

Under the 7th NFC award, the provincial share in vertical revenue distribution was increased to 56 percent in FY2010/11, and to 57.5 percent from FY2011/12 till the end of the award. This left 44 percent of the divisible pool of taxes for the federal government in 2010/11 and 42.5 percent in each subsequent year of the five-year award.

Horizontal distribution shares under the 7th NFC Award for Punjab, Sindh, KP and Balochistan were, respectively, 51.74 percent, 24.55 percent, 14.62 percent and 9.09 percent. Additionally, KP receives 1 percent of the divisible pool because of the ongoing insurgency in the neighbouring Federally Administered Tribal Areas (FATA) and its fallout on law and order in KP. This share is deducted from the divisible pool before any other allocation between the federal and provincial governments or among the provinces. Table 8 summarises the provincial shares in the horizontal distribution of tax revenues under the 7th NFC award and the budgeted amount received by the provinces in FY2011/12.

The increased fiscal space for the provinces created by the 7th NFC Award was, to some extent, curtailed by the greater expenditure responsibilities devolved to the provinces under the 18th Amendment. The last few years, particularly FY2007/08 onwards, have seen the international price of oil escalate, resulting in an increase in the cost of electricity generation, which depends heavily on imported fuel. The federal government did not, however, adjust electricity prices against the higher cost of production and absorbed most of this change in the form of subsidies. This has severely restricted its fiscal space.

Table 8

Horizontal Distribution of Divisible Pool of Tax Revenues

Province	Share (%)	Amount (PRs Billion) in 2011/12
Punjab	51.74	530.81
Sindh	24.55	251.86
KP	14.62	149.99*
Balochistan	9.09	93.26
Total	100.00	1025.91

Source: Government of Khyber Pakhtunkhwa (2010).
* Does not include 1 percent transferred to KP on account of the war on terror.

As we have noted, one of the objectives of the electricity subsidy is to equalise electricity tariffs by consumer group across all regions of the country, but as our calculations show, this has resulted in unequal tariff subsidies across the provinces.

The provinces' TDS shares can be compared with their share of tax revenue in the horizontal distribution of tax revenues under the 7th NFC award. The award is an agreement on how major tax revenues should be distributed between the federating units and the centre. The spirit of this agreement would be violated if the centre were to use its own share of tax revenues for province-specific expenditures in a manner that departs consistently (year after year) from the revenue-sharing arrangement under the award. Although the federal government would be justified in departing from the NFC allocation if a province were to suffer a temporary shock (such as floods or drought), escalating oil prices and the consequent rise in electricity generation costs cannot be treated as a temporary shock. The NFC award is, therefore, a useful yardstick to judge if the federal government has judiciously allocated its tariff subsidies across the provinces.

Table 9 compares the shares of the provinces in the horizontal distribution of the divisible pool of taxes with their shares of TDS in FY2011/12. The comparison suggests that, in FY2011/12, Sindh and KP received a greater share of TDS than their share in the horizontal distribution of the divisible pool of taxes, while Punjab and Balochistan received a smaller share.

Another way of looking at this is to consider the relative share between the centre and the provinces and among the provinces if TDS were to be distributed among the provinces as part of the revenue-sharing arrangement under the NFC award.

Table 9

Comparison of Provincial Shares in Horizontal Distribution of Divisible Pool of Taxes and TDS, FY2011/12

Province	Horizontal Distribution of Divisible Pool of Taxes (%)	Share of TDS (%)
Punjab	51.74	45.83
Sindh	24.55	29.84
KP	14.62	16.56
Balochistan	9.09	7.78
Total	**100.00**	**100.00**

Source: NEPRA (Various Issues) and authors' calculations.

Table 10 summarises the changes in the vertical and horizontal revenue-shares for FY2011/12 if the divisible pool of taxes were adjusted for the TDS. If PRs 251 billion of the subsidy (see Table 7) were to be transferred to the provinces, the centre's share would fall from 42.5 percent to 28.4 percent and the share of the provinces would rise from 57.5 percent to 71.6 percent. As a result of the adjustment, in the horizontal distribution, the shares of Punjab and Balochistan would go down to 50.58 percent and 8.83 percent, respectively, whereas Sindh and KP would gain from this arrangement with their shares going up to 25.59 percent and 15.00 percent, respectively. If we allow for such adjustments in the revenue-sharing arrangement, the federal/provincial shares will vary from year to year as the TDS is determined for each year unlike the federal/provincial shares under the NFC award, which are constant.

Table 10

Vertical and Horizontal Distribution with and without TDS, 2011/12

	Share of 7th NFC Award (%)	Share of NFC Award (PRs Billion)	TDS (PRs Billion)	Share with TDS included in Transfers (PRs Billion)	Adjusted Share (%)
Vertical Distribution					
Federal	42.5	758.28	–251.21	507.07	28.4
Provincial	57.5	1,025.91	251.21	1,277.12	71.6
Total	100	1,784.91		1,784.91	100
Horizontal Distribution					
Punjab	51.74	530.81	115.12	645.9	50.58
Sindh	24.55	251.86	74.95	326.8	25.59
KP	14.62	149.99	41.59	191.6	15.00
Balochistan	9.09	93.26	19.55	112.8	8.83
Total	100.00	1,025.91	251.21	1,277.1	100.00

Source: Government of Khyber Pakhtunkhwa (2010) and authors' calculations.

5. CONCLUDING REMARKS

Applying uniform tariffs across the country in the presence of highly divergent NEPRA-determined tariffs results in differential subsidies across DISCOs and provinces. The diverging subsidies across the provinces are principally because of differences in line losses (on account of technical and commercial losses, with the latter a euphemism for pilferage and corruption). DISCOs vary greatly in terms of area served, which can explain differences in technical losses. Differential subsidies to DISCOs because of differences in technical losses may be rationalised but those on account of commercial losses simply reward inefficiency and corrupt practices. Neither the DISCOs nor NEPRA distinguish between technical and commercial losses. This opaqueness should be removed to design tariff and subsidy policies that do not reward corrupt practices.

Differences in subsidies across DISCOs also imply very different allocations of federal expenditure across the provinces. The inclusion of TDS in the revenue-sharing arrangement between the centre and the provinces provides a better perspective on resource allocation between the centre and provinces and across the provinces. Technically, the federal government is under no obligation to follow the NFC award in allocating its expenditures, but in a federal structure, there should be some guiding principles that constrain the federal government's arbitrariness. In this paper, we have calculated TDS by consumer group, DISCO and province and used the NFC award as a yardstick to determine whether tariff subsidies by the federal government depart from the NFC principle. We find that they do.

Unless there is a clearly stated principle that carries a broad consensus and allows departures from the NFC award, federal expenditures that are province-specific should be judged against the benchmark of the award. Our analysis can be generalised to include not just the TDS but also other federal expenditures that might be similarly allocated to particular provinces. This would include, for example, subsidies provided to DISCOs for their losses.

There are other forms of resource transfers that are not fully reflected in the NFC award. Implicit subsidies on CNG and natural gas are also distributed differentially across the provinces. A comprehensive view of such subsidies should be reflected in the next NFC award in addition to incorporating a mechanism that governs federal/provincial sharing of expenditure shocks and subsidies that do not place an unsustainable fiscal burden on the centre or the provinces.

Appendix 1

TDS Calculation for LESCO

Description		NEPRA-recommen-ded fixed charge (PRs/kW/M)	MoWP-notified fixed charge (PRs/kW/M)	MoWP-notified variable charge (PRs/kWh)	NEPRA-recommen-ded variable charge for LESCO	Sales mix (GWh)	Installed capacity (kW)*	Subsidy (PRs million)
Residential								
(a) For sanctioned load less than 5 kW								
Up to 50 units		–	–	2	3	132		132
Consumption exceeding 50 units								
01-100 units		–	–	5.79	9.27	2,412		8,394
101-300 units		–	–	8.11	10.5	2,338		5,588
301-700 units		–	–	12.33	13.5	733		857.6
Above 700 units		–	–	15.07	15.5	565		243
(b) For sanctioned load 5 kW and above								
Time of day (TOD): Peak		–	–	13.99	15	0		0
Time of day (TOD): Off-peak		–	–	8.22	9.5	0		0
Subtotal of Consumption Units						**6,180**		
Subsidy Subtotal								**15,214.14**
Commercial–A2								
(a) For sanctioned load less than 5 kW		–	–	14.77	15	689		158.47
(b) For sanctioned load 5kW and above								
Regular		400	400	9.72	14.5	383		1,830.74
Time of use (TOU): Peak		400	400	13.2	15	39		70.2
Time of use (TOU): Off-peak		400	400	8.01	9.5	172		256.28
Subtotal of Consumption Units						**1,283**		
Subsidy Subtotal								**2,315.69**
Industrial								
B-1(a)	Up to 25 kW (at 400/230 volts)	–	–	10.51	11.5	362		358.38
B-1(b)	Up to 25 kW (TOU peak)	–	–	13.99	15	11		11.11
B-1(b)	Up to 25 kW (TOU off-peak)	–	–	8.22	9.5	55		70.4
B-2(a)	Exceeding 25-500 kW (at 400 volts)	400	400	9.14	10	1,232		1,059.52
B-2(b)	Exceeding 25-500 kW (TOU peak)	400	400	12.77	15	59		131.57
B-2(b)	Exceeding 25-500 kW (TOU off-peak)	400	400	8.01	9.3	302		389.58
B-3	For all loads up to 5,000 kW at 11/33 kV (TOU peak)	380	380	12.68	14.7	405		818.1
B-3	For all loads up to 5,000 kW at 11/33kV (TOU off-peak)	380	380	7.75	9.2	3,245		4,705.25
B-4	For all loads at 66.132 kV and above (TOU peak)	360	360	12.37	14.5	91		193.83
B-4	For all loads at 66.132 kV and above (TOU off-peak)	360	360	7.46	9.1	559		916.76
Subtotal of Consumption Units						**6,321**		
Subsidy Subtotal								**8,654.5**
Single-point Supply for Further Distribution								
C1(a)	Supply at 400 volts Sanctioned load less than 5 kW		–	11.55	12	1		0.45
C1(b)	Supply at 400 volts Sanctioned load 5 kW and up to 500 kW	400	400	10.35	11	41		26.65

Continued—

Appendix-1—(*Continued*)

C1(c)	Supply at 400 volts Sanctioned load 5 kW and up to 500 kW (TOU peak)	400	400	13.01	15	0		0
C1(c)	Supply at 400 volts Sanctioned load 5 kW and up to 500 kW (TOU off-peak)	400	400	8.01	9.3	2		2.58
C2(a)	Supply at 11,33 kV load up to and including 5,000 kW	380	380	10.25	11	324		243
C2(b)	Supply at 11,33 kV load up to and including 5000 kW (TOU peak)	380	380	12.6	14.7	6		12.6
C2(b)	Supply at 11,33 kV load up to and including 5,000 kW (TOU off-peak)	380	380	7.75	9.2	24		34.8
C3(a)	Supply at 66 kV and above Sanctioned load above 5,000 kW	360	360	10.1	11	38		34.2
C3(b)	Supply at 66 kV and above Sanctioned load above 5,000 kW (TOU peak)	360	360	12.18	14.5	0		0
C3(b)	Supply at 66 kV and above Sanctioned load above 5,000 kW (TOU off-peak)	360	360	7.35	9.1	0		0
Subtotal of Consumption Units						**436**		
Subsidy Subtotal								**354.28**
Agricultural Tube-wells (Tariff D)								
SCARP		–	–	10	10	263		0
Agricultural tube-wells (Punjab and Sindh)		200	120	6.77	8	54	14,583.3 *	66.42
SCARP and agriculture 5 kW and above (TOU peak)		200	200	13	14.5	54		81
SCARP and agriculture 5 kW and above (TOU off-peak)		200	200	8	9.1	740		814
Subtotal of Consumption Units						**1,111**		
Subsidy Subtotal (due to variable)								**961.42**
Subsidy Subtotal (due to fixed cost component)								**14***
Other Categories								
Public lighting (G)		–	–	13.73	14.5	100		77
Residential colonies (H)		–	–	12.92	13.5	5		2.9
Traction (I)		–	–	11	12.5	1		1.5
AJK tariff (K)		360	360	13.3	–	–		
TOU peak		360	360	13.3	–	–		
TOU off-peak		360	360	7.92	–	–		
Rawat Laboratory		–	–	11.5	–	–		
Subtotal of Consumption Units						**106**		
Subsidy Subtotal								**81.4**
Total Consumption Units						**15,437**		
Total Subsidy (in Millions)								**27,595.43**

Source: NEPRA.

* The only entry in this column is where the MoWP and NEPRA charges for capacity differ; all other entries are omitted for this column. In our calculations, where the two tariffs are identical there is no impact on TDS calculation. NEPRA determined a fixed charge of PRs 200/kW/month and a fixed revenue of PRs 35 million for LESCO for a year. Using this information, installed capacity is estimated to be 14,583.3 kW for LESCO. The subsidy due to fixed costs for agricultural consumers is PRs 80/kW/month. Multiplying the subsidy (PRs 960/kW/year) by installed capacity (14,583.3 kW), we arrive at the subsidy due to the fixed-cost component: PRs 14 million for the entire year.

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Energy-Cost Optimisation in Water-Supply System

FARRUKH MAHMOOD and HAIDER ALI

1. INTRODUCTION

Water, being the basic requirement of life, is important to all living organism, human health and food production. A positive correlation between economic growth and rate of water utilisation has also been observed in a growth model with water as a productive input for private producers [Barbier (2004)]. In addition, high per-capita consumption (PCC) of water is regarded as an indicator of the level of economic development where per-capita water consumption is defined as the average of water consumed by a person in a day. The declining availability of water supply, mainly due to global climate change, is one of the important issues faced by many developing countries at the present time. It is estimated that nearly two third of nations across the globe will experience water stress by 2025.[1] Thus, the safety and availability of clean water is an on-going concern within the global village.

In Pakistan, drinking water supplies are generally obtained from either surface water sources (i.e. rivers, streams, lakes) or the underground aquifers. Unfortunately, both sources are subject to pollution due to anthropogenic activities. Water supply systems (WSS) require energy in each of the stages of water production (pumping it from underground) and distribution chain. A number of studies [i.e., Abdalla (1990); Nguyen, *et al.* (2009); Khan, *et al.* (2012)] have analysed the economic and social cost of water degradation but a few studies at international level [Feldman (2009)] and no study in case of Pakistan, particularly after severe energy crisis, have analysed energy-cost optimisation in a WSS.

The most important factor in the design of a WSS is the estimation of water requirement for a community. The per-capita consumption of water varies from place to place and is affected by various factors i.e., climatic conditions, water pressure and quality, population size etc. There is no common understanding on the minimum per-capita water requirement for human health and economic and social development. According to World Health Organisation (WHO), minimum level of per-capita water consumption is twenty litre of water to take care of basic hygiene needs and basic food

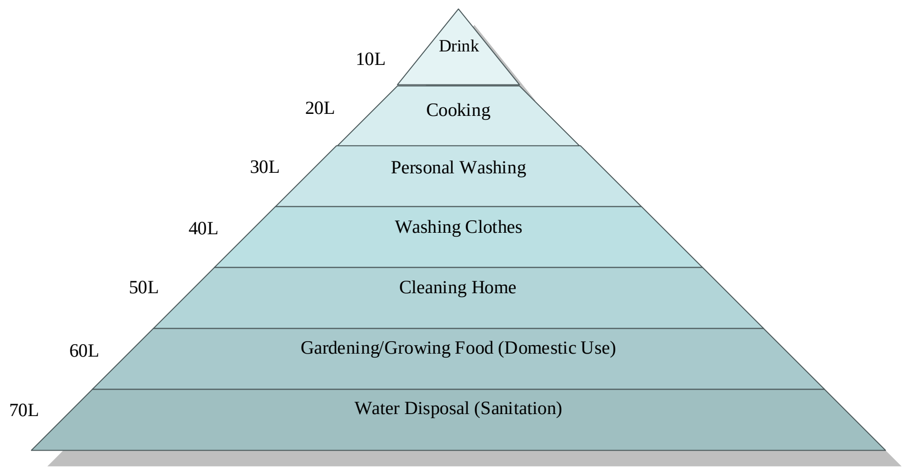
Farrukh Mahmood <farrukhmahmod_501@yahoo.com> is MPhil Student, Department of Economics and Finance, Pakistan Institute of Development Economics, Islamabad. Haider Ali <haider@pide.org.pk> is Lecturer, Department of Economics, Pakistan Institute of Development Economics, Islamabad.

[1]United Nations Environment Programme Report (2002).

hygiene. Laundering and cleaning would require more water. Taking into account that average household size of Pakistan is six;[2] a single unit of household requires a minimum of 120 litre of water per day for basic hygiene needs.

Figure 1 shows different categories of water need of an individual along with standard quantities of water requirement set by WHO to assess the accuracy of the per capita consumption of water for domestic use.

Fig. 1. Hierarchy of Minimum Water Requirements for Domestic Uses



Source: World Health Organisation Report (2006).

Primarily, there are two types of water-pumping systems for utilisation of underground aquifers. One is direct pumping system where the instantaneous demand is met by pumping water with no elevation storage provided. This direct pumping system is being phased out because of the operating costs. Severe load-shedding due to recent energy crisis is another reason why people are moving from this pumping system to other economical options. The second type is an indirect system in which the pumping station lifts water to an elevated storage tank which floats on the water system and provides system pressure by gravity. These days, majority of households (which utilise underground aquifers) use the indirect pumping system in Pakistan and have elevated storage tanks as this system does not require instantaneous energy supply for minute to minute water demand.

The underground WSS can be categorised into household and community water distribution system where the later implies a common elevated storage tank which flows water by gravity to each customer on the system. At household level, every household unit has to bear the fixed cost along with the variable cost of electricity consumption. Interestingly, the cost structure of the community WSS (capital investment in water infrastructure (reservoir and pipes) and operating and maintenance cost) is also not very

[2]Pakistan Statistical Bureau (2012).

different from that of household but due to large scale of production, it seems that average cost of producing water would be lower and all customers on community water system would incur a lower cost than otherwise. Under community WSS, number of customers and water pressure are negatively correlated. It implies that customers of community WSS have to face some additional cost to pump water from ground storage to elevated storage when lower pressure does not elevate the water. On the contrary, heights of the elevated-tank and water pressure are positively correlated.

The efficient operation of WSS is not just a technical issue. Prevailing energy crisis and focus of the government on demand-side energy policies (i.e., energy conservation) in Pakistan raises the need of using energy efficient techniques in every aspect of real life. Water supply systems are massive consumers of energy. Besides, the main life-cycle cost of a water pump is related to the energy spent in pumping, with the rest being purchase and maintenance cost of the equipments. Any optimisation in the energy efficiency of the water pump results in a considerable reduction of the total operational cost. Feldman (2009) asserts that energy efficiency can be achieved by; installing new technology, improving system design, installing variable speed of pump and reducing leakages.

Household WSS (individual unit) and community WSS (aggregate unit) are two major types of water systems in urban areas of Pakistan [Haydar, *et al.* (2009)]. This paper will examine whether community WSS relative to household WSS is more energy efficient or not. In other words, a single community WSS (assuming it consists of *'H'* number of household units) face less operational costs (energy consumption) than total operational cost faced by 'H' number of households when they work as individual entities. Besides, this study will determine the optimal threshold number of consumers under a single community elevated storage tank. This will allow determining the minimum number of customers required to make the option of building a given community WSS feasible.

The remainder of this paper is organised as follows. Section 2 contains the analytical framework and a brief description on data and variables. Section 4 includes discussion on the results of cost-benefit analysis of household and community water-supply systems. Finally, Section 4 concludes this study.

2. ANALYTICAL FRAMEWORK, DATA AND VARIABLES

Following Kim (1987), the theoretical framework to examine cost-structure of WSS is represented by:

$$C_i = C_i(p, y), \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where C_i is cost of producing water supply, $i = 1, 2$ index refers to household and community WSS, p is the vector of strictly positive input prices and y is the output. Thus, the cost function is given by:

$$C_i(p, y) = \min p.x,\ x \in v(y), \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where x is a vector of inputs and $v(y)$ is the input requirement set. From the cost function, it is possible to derive the cost minimising factor demand equations using Shephard's Lemma [Chambers (1989)].

$$\frac{\partial C(p,y)}{\partial p_i} = X_i(p,y). \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Scale economies (returns to scale) are important measurements for examining the potential for amalgamation and/or separation of (water) production units in view of the economic benefits. If there are economies of scale, larger firm (community WSS) can produce at lower average cost than smaller ones (household WSS). Scale economies are defined as the relative increase in output as a result of a proportionate increase in all inputs. In a nutshell, scale economies are measured by the relationship between average and marginal cost. Returns to scale (θ) are the inverse of the elasticity of output ε_{cy}.

$$\theta = \frac{c(p,y)}{MC*Y} = \frac{1}{\varepsilon_{cy}}. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Where $\varepsilon_{cy} = \partial lnC/\partial lny_i$ and MC is the marginal cost $MC_i = C/Y_i \times \varepsilon_{cy}$. Economies of scale exist if $\theta > 1$, constant returns to scale exist if $\theta = 1$ and decreasing returns to scale exist if $\theta < 1$. The important implication of this is that marginal cost pricing is not sufficient to recover costs for industries with economies of scale.

Total cost of installing a WSS consists of fixed cost and variable cost where the later varies with the level of output. Fixed cost of household WSS includes cost of tank, cost of motor, cost of water pipes, boring (drilling) cost, cost of wire, cost of joints for pipe and some miscellaneous expenses (i.e. cost of grease, cost of making holes in outer pipe etc.). Drilling cost depends positively on depth as well as radius of the earth bore while motor cost depends directly on the capacity (horse power) of the motor and indirectly on the depth of the bore (Data on prices of all variables used are given in Appendix 1). It is important to explain, here, that water-tank cost in case of individual household is taken for water-tank of three hundred gallon capacity (300*3.78=1134 litres) that is minimum size of tank available in the market. One rational is that this study pivots around WHO daily per-capita water requirements that vary from 120 litres (minimum) to 420 litres (maximum) per household.

The variable cost is basically the operational cost and is sum of cost of energy consumption and cost of wear and tear of capital.[3] Energy (mainly electricity in our study) cost is a product of units consumed times tariff rate whereas consumption of energy units depends on the (horse) power of motor and total time duration when motor works.

In community WSS, only fixed cost structure is a little different as it includes all those expenses incurred in household WSS plus compensation of water-supply staff. It is important to note that in the long run, the households can change the level of water consumption. Since acquiring a WSS is a decision of long-run planning horizon, households have to make decision either they should use independent or the community WSS.

Primary data on five community and fifty households WSS have been taken randomly for cost-benefit analysis from Islamabad/Rawalpindi district as it mainly consists of well-planned Government and private housing societies. Data on variables of cost of water tank, cost of motor, cost of water pipes and cost of joints for pipes have been taken from whole sellers and retail sellers while data on boring cost is taken from

[3]We are assuming a zero wear and tear cost to keep our analysis simple. This assumption does not invalidate our results.

private contractors. Data of electricity tariff are taken from Islamabad Electricity Supply Corporation (IESCO). Data are taken on market prices of water tank installed per gallon, capacity of motor (Horse Power), billing cost (price times units consumed) and cost of boring, water pipes and wire per feet. Same variables are also observed for elevated water supply system including construction rate of elevated water supply system.

3. RESULTS AND DISCUSSION

All variables are explained in three scenarios where the cost is estimated for depth of 150, 200 and 300 feet of earth bore. Household WSS usually has bore of 150 feet while community WSS can have either 200 or 300 feet earth bore. Descriptive statistics for the data on fixed variables are shown in Table 1.

Table 1

Descriptive Statistics (Fixed Cost Variables)

Variables (Feet)	Bore Depth	Minimum	Maximum	Average	S.D
Inner Pipe	150	165	170	167.5	3.53
	200	200	220	210	14.14
	300	300	320	310	14.14
Outer Pipe	150	150	155	152.5	3.53
	200	200	205	202.5	3.53
	300	300	305	302.5	3.53
No. of Joints	150	15	16	15.5	0.70
	200	20	21	20.5	0.70
	300	30	31	30.5	0.70
Rope	150	155	160	157.5	3.53
	200	205	210	207.5	3.53
	300	310	320	315	7.07
Electric Wire	150	160	170	165	7.07
	200	10	20	15	7.07
	300	10	20	15	7.07
Miscellaneous Expenses (Rs)	150	600	800	700	141.42
	200	11000	12000	11500	707.10
	300	17000	18000	17500	707.11

It can be seen from Table 1 that all variables depend positively on the depth of earth bore. One anomaly is seen in case of wire per feet where increased depth of earth bore reduces the length of wire. It is because increased depth of bore needs high-power motor for water suction (which simultaneously pumps water from underground aquifer and throw it into the system), that precludes need of a separate water pump. Therefore, wire is required just to connect the motor with electricity source. Sum of market values of all these above variables along with water-motor cost, drilling (boring) cost, water-tank cost and working staff (in case of only community WSS) yield total fixed cost for community and household water supply systems. Table 2 below presents a brief picture of total fixed cost for both WSS.

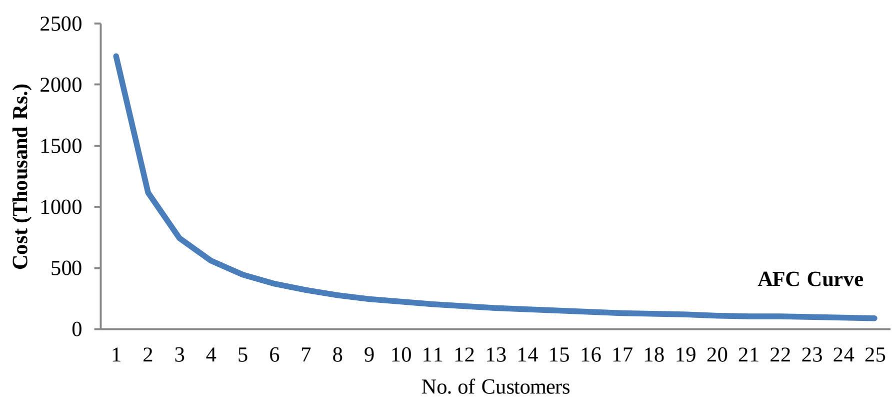
Table 2

Total Fixed Cost (Thousand Rs) of Water Supply Systems

Bore Depth (Feet)	Household WSS	Community WSS
150	88.812	1651.225
200	154.373	1732.000
300	472.848	2232.500

The major difference in fixed cost of both systems is primarily due to construction cost of elevated water tank in case of community WSS. Fixed cost of community WSS includes cost of elevated water tank of 8000 gallon (8000*3.78 = 30240 litres) capacity. This construction cost alone is higher than total cost of a single household WSS under 150 bore depth (See Appendix). Besides, the motor cost of community WSS is also much higher than the cost of motor used in household WSS. But, this huge fixed cost of community WSS can be divided among customers of this system to bring the per-head cost down to the fixed cost faced by an individual in case of 150 bore depth (as household usually utilises water up to 150 bore depth). The diagram below shows how average fixed cost responds to increase in number of customers.

Fig. 2. Average Fixed Cost (AFC) of Community WSS



The depth of boring for individual household cannot go beyond 150 feet due to the low capability of the machine used in household WSS while, for community WSS, it can be 300 feet as the machines used in this system is highly powerful. It can be deduced from Table 2 that it is not beneficial to develop community WSS unless number of houses exceed 25 (2232.500/88.812 = 25.137). Interestingly, a community WSS can serve much greater number of households than just twenty five and, in that case, average fixed cost would be even further lower. If we take 420 litres of daily water consumption by a housing unit (WHO standard); a community WSS, in this case, can serve seventy two household units with average fixed cost that is one-third of total fixed cost incurred under household water supply system.

The remaining part of total cost is variable cost which includes operational cost of a WSS whereas daily operational hours of motor depend on the daily water requirement of a household. Table 3 below presents electricity units consumed and energy cost for WHO's established hierarchy of minimum water requirement under both household and community WSS.

Table 3

Variable (Operational) Cost of Water Supply Systems

			Households Daily Water Requirement (Litres)				
		Bore Depth	120	180	240	360	420
Electricity Units Consumed	Household	150	51.874	77.811	103.748	155.621	181.558
		200	142.653	213.979	285.306	427.959	499.285
		300	1141.224	1711.836	2282.448	3423.671	3994.283
	Community	150	22.824	34.237	45.649	68.473	79.886
		200	51.874	77.811	103.748	155.621	181.558
		300	163.032	244.548	326.064	489.096	570.612
Billing Cost (Rs)	Household	150	300.349	450.524	841.393	1262.090	1472.438
		200	1156.916	2638.367	3517.822	5276.734	6156.189
		300	17198.243	25797.364	34396.485	51594.728	60193.850
	Community	150	132.154	198.231	370.213	555.320	647.873
		200	420.697	631.045	841.393	1918.812	2238.614
		300	2010.184	3015.276	4020.368	6030.553	7035.645

Table 3 explains that electricity cost is positively correlated with daily water requirement as well as depth of earth bore. An increase in daily water requirement increases operational time of the motor required filling the tank; hence, resulting in higher billing cost. An increase in depth of bore raises operational cost in two ways. First, it reduces the suction rate of the pump, hence, increasing the time of motor working (for details on suction rate and bore; see, Table A2 in Appendix). Second, increased bore depth requires more energy to pump water from underground aquifer and throw it into the system; that in turn requires water motor of higher capacity (which bears higher cost). That is why billing cost of community WSS is lower than billing cost of individual WSS. On the other hand, the billing cost of household WSS is much higher than that of community WSS.

To compare the operational (variable) cost between the two systems, it is realistic to compare billing cost of household WSS at 150 earth bore with billing cost of community WSS at 300 earth bore. Billing cost of community WSS is then divided among 25 households (for the reason discussed above that a community WSS can only be built if there are at least 25 households to share its total fixed cost) for a better appraisal of average household cost under community WSS. This will give correct apportionment of the difference of energy cost (and, hence, energy consumption) between the two WSS. Besides, this analysis will also be extended for 72 household units as it has been estimated that a community water tank of 8000 gallon capacity can serve 72 households for daily water requirement of 420 litres.

Figure 2 below depicts trends in billing cost with respect to daily water requirements for both water supply systems whereas trend in cost of community WSS is shown for an average unit under community WSS; first assuming it has 25 customers and, then, by assuming it has 72.

Fig. 3. Billing Cost of Household and Community WSS

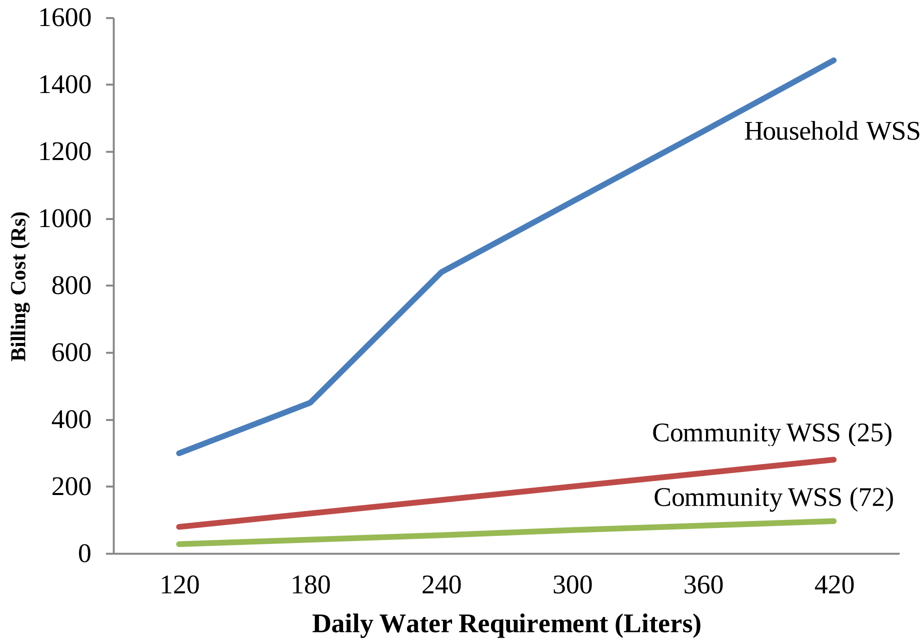


Figure 2 shows that household WSS is a massive consumer of electricity as compared to community WSS. Besides, the gap is increasing at increasing rate with increase in demand of water for daily requirements (that depends on household size and water-consuming habits). The operational cost under community WSS gets further lower in case of increased units of households (72 units). One of the possible reasons of this lower operational cost under community WSS is economies of scale where a centralised system with greater scale of production can utilise better inputs resulting in decreasing cost. These results suggest that building of community WSS (if and only if there are, at least, more than twenty five housing units) not only reduces fixed cost but also results in lower operational cost of water system. In addition, community system supplies cleaner drinkable water relative to individual water system as the former sucks water 300 feet under the earth surface.

4. CONCLUSION

Recent energy crisis in all most all developing countries and particularly in Pakistan forced government agencies to focus on demand-side energy policies, especially energy conservation, as a short-term solution. This study presents a view on how individual water supply systems are bulk consumers of electricity while community water supply systems can provide daily water requirements at much lower consumption rate of electricity; hence, resulting in twofold benefit of lower consumption of electricity and lower total cost (in monetary terms) of per-capita water.

This study also reveals that a minimum of twenty five households are required to bear the fixed cost of building a community water supply system. If the number of customers in community water supply system rises to seventy two, this fixed cost comes down to almost one-third of the cost an individual household incurred for developing his own water system. Besides, the results show that average billing cost goes down to less than hundred if community water supply system includes seventy housing units. In addition, community system supplies cleaner drinkable water relative to individual water system as the former sucks water 300 feet under the earth surface. Based on these results, it is suggested that community water system should be made compulsory for developing housing colonies. Municipal authorities of Islamabad/Rawalpindi region can develop community water systems in those sectors where tube wells are supplying water but elevated tanks are not constructed. This will incur less operational cost to each household due to less consumption of electricity as elevated tank precludes electricity requirement for throwing water from ground tank to elevated tank.

APPENDIX

Table A1

Market Price of Inputs for Household and Community WSS

		Price (Rs)/Unit	
Variable	Unit	Household WSS	Community WSS
Inner Pipe	Feet	12	950
Outer Pipe	″	235	950
Rope	″	10	–
Wire	″	25	200
Drilling Cost	″	100	120
Joints	No.	230	1250
Motor Cost	2 Horse Power	20000	–
	5 Horse Power	70000	–
	20 Horse Power	350000	350000
Plastic Tank Cost	300 Gallon	6000	–
	400 Gallon	8000	–
Cement Tank	Cubic Feet	–	120*
Working Staff	Rs	–	6000

*Cost of building an elevated water tank of 8000 Gallon capacity at this rate requires (on average) 1.2 Million Rupees.

Table A2

Water Suction (Litre per Hour) Capability of the Motor

	Motor Capacity (Horse Power)	
Depth of Bore (Feet)	2 HP	20 HP
150	8327.902	189270.5
200	3028.328	83279.02
300	378.541	26497.87

Source: Pakistan Engineering Council, Islamabad.

Table A3

Tariff Rate for Electricity

Bracket	Unit	Tariff (Rs)
I	1-50	2.00
II	51-100	5.79
III	101-300	8.11
IV	301-700	12.33
V	Above 700	15.07

Source: IESCO (2013).

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Energy Crisis and Productive Inefficiency: Micro-Evidence from Textile Sector of Faisalabad

HAIDER ALI and MUHAMMAD NAWAZ

1. INTRODUCTION

Energy, being an essential component of every production process, plays a pivotal role in the growth process of a country. The production process has undergone a massive transition from labour intensive to energy intensive techniques [Stern and Cleveland (2004)]. Now, it is widely recognised that industrialisation is an energy-intensive process; hence, uninterrupted supply of energy is necessary to keep the production process in run. In addition, high per-capita energy consumption is considered as an indicator of the level of economic development. This positive correlation between energy consumption and output growth (and development) led many countries, particularly developing ones, to design policies for subsidised energy provision with focus on supply-side in late eighties. At the same time, some European countries (i.e. Germany, Denmark, Belgium, Sweden) formulated energy policy focusing on demand-side (energy conservation), and achieved smaller growth rates in energy consumption without any reduction in economic growth [Pintz (1986)].

After recent episodes of oil price increase (started from 2006-07), tight financial position and huge trade deficits forced many developing countries (Pakistan, in particular) to pull out, at least moderately, from the policy of subsidised energy supply [Alahdad (2012) and Malik (2012)]. The energy demand in Pakistan has also been increasing steadily in every sector of the economy and future energy need of Pakistan is forecasted to be, at least, three times that of today within next two decades.[1] The focus of energy policy in Pakistan has been the demand side as it is believed that energy crisis in Pakistan is a management and not a capacity issue.[2] Besides, demand-side policies are being adapted to save not only capital but also foreign exchange of the country.

Haider Ali <haider@pide.org.pk> is Lecturer (Economics) at the Pakistan Institute of Development Economics, Islamabad. Muhammad Nawaz <mnawaz@pide.org.pk> is Junior Researcher at the Pakistan Institute of Development Economics, Islamabad.

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[1]NTDC Report (2011).

[2]Framework of Economic Growth 2012, Planning Commission.

These demand side energy policies e.g. energy conservation, energy-prices mechanism etc. have proved to be a serious constraint in the industrial growth of Pakistan [Siddiqui (2004); Aqeel and Butt (2011) and Malik (2012)]. Importantly annual production loss due to power shortages is about two percent of gross domestic product [Abbasi (2011)]. Various studies [i.e., Bose, *et al.* (2005) and Wijayatunja and Jayalath (2008)] have tried to estimate the output loss due to power outages. In case of Pakistan, a few attempts have been made to quantify the cost of unserved energy [Lahore Chamber of Commerce and Industry (1986); Pasha, *et al.* (1989) and Siddiqui, *et al.* (2011)]. Siddiqui, *et al.* (2011) also quantified the industrial production loss due to shift hours whereas the other studies focused on power outages only.

Textile being the largest industrial sector of Pakistan generates the country's highest export earnings of about 58 percent; providing the bulk of employment (39 percent) to largely unskilled as well as underutilised workforce, and contributes 8.5 percent to GDP.[3] Textile production is comprised of cotton ginning, yarn, fabric, home textiles, towels, hosiery and knitwear, readymade garments and canvas. These components are being produced both in the large and small scale organised sector as well as in unorganised cottage/small and medium units.

Textile industry is presently comprised of 521 textile units with installed capacity of 10.0 million spindles and 114000 rotors making Pakistan to have third largest spinning capacity in Asia with spinning capacity in Pakistan being 5 percent of the total world capacity and 7.6 percent of the capacity in Asia.[4] Despite this vigorous and export oriented textile industry, dismal performance of textile exports (decreased from 65 percent of total exports in 2007 to 53 percent in 2012)[5] can be mainly attributed to the stifling power shortages. This crisis has left investors fighting for their survival and, in some cases, they are shutting down production units in Pakistan and/or moving abroad (especially in Bangladesh). In other cases, some export-specific production units are, now, unable to meet international orders and have converted into local production units with capturing local market in order to fulfil its average fixed cost. Besides, the power crisis caused prolonged delays in delivery schedule both at intra and inter industry level resulting in less competitiveness of the industry along with tough competition from regional competitors i.e., China, India, Bangladesh etc. These problems in textile industry are structural in nature and cannot be resolved through financial support of the government [Alam (2011)].

Textile production is not only energy but also time consuming process where a conversion of cotton into single type of good e.g. shirt, vest, or socks takes about two months with the involvement of many supporting sub-sectors. It is important to note that every sector of textile industry is not equally energy-intensive and has different level of energy consumption and dependency but delay in accomplishing output orders in any sub-sector involuntarily causes further delays in making the finished product. These delays cause extraordinary production losses (as both domestic and foreign customers turn back) and badly affect capability of the textile industry. Furthermore, energy gap also varies among different sectors of the industry due to disparate scale of production

[3]Ministry of Textile Industry Report 2013.
[4]*Pakistan Textile Journal* (Various Issues).
[5]*Pakistan Economic Survey, 2012-13*.

and input mix. Large scale production sectors are using alternative sources of energy like generators; thus, reducing their energy gap and production loss at increased cost of final products. Therefore, high energy intensive industries may not have higher energy gap relative to less energy intensive industries that are unable to purchase costly energy inputs due to capital constraints or bad market conditions (as less orders reduce economies of scale).

These sector-level differences of energy gap and resulting production loss have not been analysed earlier in case of any industry in Pakistan. A recent study by Siddiqui, *et al*. (2011) calculated total industrial output loss by taking into account all major industries including textile and reported that output loss falls in the range of 12 percent to 37 percent due to power outages. This study does not take into account the production delays by sub-sectors of textile industry at all. This restrictive assumption of homogeneity of sub-sectors (at least, with regard to energy consumption) may result in a bias towards under-estimation of the impact of energy shortage on production cost for the reason discussed above. Further, the study is based on a survey conducted in the second quarter of 2008 while taking 2007 as the reference year. It cannot, therefore, account for impact of recent developments regarding energy crisis in the textile industry i.e., severity of power outages, capital flight, increased use of alternative energy resources etc. Against this backdrop, the present study would significantly contribute to our understanding about the impact of energy crisis on textile sector.

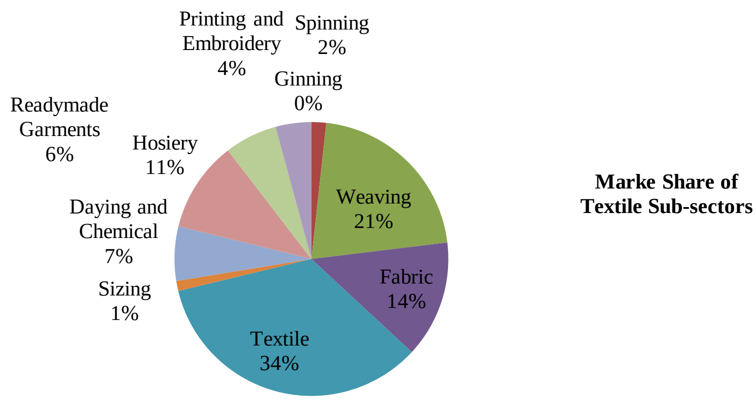
Based on primary data from various sectors and sub-sectors of textile industry, this study reveals which sub-sectors of textile industry are more energy deficient relative to other ones. This work also attempts to calculate the magnitude of production losses due to different size of lags in accomplishing production orders. Most importantly, it is the first attempt to estimate producers' willingness to pay for uninterrupted energy supply. Therefore, the contribution of this study is twofold in the sense that it not only estimates production loss of textile sector due to unavailability of energy but also it reports producers' willingness to pay for uninterrupted energy supply at various sub-sectors level.

The remainder of the study is organised as follows. Section 2 details the data, variables and methodology. Section 3 contains a brief discussion on the results while final section concludes the study.

2. DATA, VARAIBLES, AND METHODOLGY

The study primarily utilises the primary data from the textile industry of district Faisalabad, Pakistan. According to the Faisalabad Chamber of Commerce and Industry [FCCI (2013-14)], there are almost 1090 registered units of different sub-sectors of textile industry. According to *Economic Survey of Pakistan* (2012-13), this industry is categorised into ginning (*GIN*), spinning (*SPN*), weaving (*WEA*), fabric and knitting (*FAB*) and cotton cloth sectors whereas cotton-cloth sector is further subdivided into sizing (*SIZ*); dyeing, chemical and processing (*DCP*); textile (*TEX*); hosiery (*HOS*); readymade garments (*RMG*) and printing and embroidery (*PEM*). This study covers 125 firms (sub-sectors of textile industry) randomly selected according to their percentage share in the market as shown in Figure 1. Fiscal year 2008 is taken as the reference year because at that time energy crisis was in initial stages.

Fig. 1. Market Share of Different Sectors of Textile Industry in Faisalabad



Source: The Faisalabad Chamber of Commerce and Industry (FCCI, 2013-14).

In Pakistan, energy crisis has badly affected the production process of major local and export oriented textile sectors of Pakistan. In order to identify the production loss (*PL*) and its magnitude due to energy crisis in every sector of the industry, Siddiqui, *et al.* (2011) is followed. Firstly, the production and energy loss is computed as a whole and sub-sector-wise. The production loss is product of output per labour-hour (*OPLHz*) and total loss of labour hours (*TLLHz*) in each sub-sector.

$$PL_i = (OPLHz)_i \times (TLLHz)_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where *i* explains number of firms. Output per labour-hour (*OPLHz*) depends on annual output and annual working hours whereas the later is product of shift-hours of firm, number of shifts, number of workers and annual work-days. Total loss of labour-hour (*TLLHz*) requires the average labour hour loss, number of workers and work-days. For computation of energy loss and compensated energy-loss, energy loss per-day without alternative source (*ELWAS*) is calculated as follows.

$$ELWAS = ERH \times LSH \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where *ERH* and *LSH* are energy requirements per-hour and load-shedding hours per-day, respectively. The major contribution of this study is that it takes both electricity and gas as sources of energy inputs measured in their respective units. Energy required per-hour is obtained by dividing the energy unit consumed per-month (*EUCM*) and working hour per-month (*WHM*).

$$ERH = EUCM / WHM \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Working hour per-month is attained by multiplying working hour per-day and total work days of a firm. After computing the energy loss per-month, the compensated energy loss is calculated which is the difference between energy loss per-day without the use of alternative-source (*ELWAS*) and energy loss per-day after using the alternative source (*ELAAS*) such as stand-by generators.

$$CELM = ELWAS - ELAAS \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

The energy loss per-month in the presence of alternative source makes Equation (2) as:

$$ELAAS = ERH \times (LSH - UASH) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

Here *UASH* is the usages of alternative source per-hour and the computation of *ERH* requires a change in Equation (3) in the light of Equation (5). The whole process gives the production loss, energy loss and compensated energy loss for both the whole and sub-sector wise. Production order delays are the delays which firms are facing due to the interruption in energy provision. Total number of order delays in particular year and number of order delay days per-order are used for the analysis.

2.1. Producer's Willingness to Pay for Uninterrupted Energy Supply

On-going energy crisis has reduced the production level and the producers of textile sector are compelled to use alternative energy source such as heavy stand-by generators and self-production of energy. These producers are paying large amount for uninterrupted energy to fulfil their production orders. So, this sub-section relates with the producer willingness to pay for uninterrupted energy supply (alternative energy source).

In order to analyse the producer willingness to pay for alternative energy sources (input), the work(s) of McConnell and Bockstael (2005), modified by Zapata and Carpio (2012) are followed. The theoretical stance of producer willingness to pay requires both consumer and producer side. On consumer and producer side, utility maximisation framework subject to budget constraint and both profit maximisation as well as cost minimisation framework subject to production constraint are required. After having the indirect utility function, indirect profit function and cost function from the optimisation framework, the compensated and equivalent variation need to be mentioned. Non-labour income $\bar{h}$ is assumed to be function of profit that can be obtained from the linkages between the consumer and producer. $\bar{h} = \bar{h}\left(\pi\left(p_y, r, q\right)k\right)$, and written as:

$$Z\left[\bar{h}\left(\pi\left(p_y, r, q\right), k\right), L, P_Z\right] = Z_0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

where, L, P_z and r are non-labour income, prices of goods used by consumer and input prices, respectively. In compensated variation (CV) and equivalent variation (EV) concept, change in the vector of input quantity "q" from "q_0" to "q_1" make the amount of money to hold the condition described below:

$$Z\left[\bar{h}\left(\pi\left(p_y, r, q_0\right), k\right) L, P_z\right] = Z\left[\bar{h}\left(\pi\left(p_y, r, r_1\right), k\right) - CV, L, P_Z\right] \quad \ldots \quad (7)$$

$$Z\left[\bar{h}\left(\pi\left(p_y, r, q_0\right), k\right) + EV, L, P_z\right] = Z\left[\bar{h}\left(\pi\left(p_y, r, q_1\right), k\right), L, P_Z\right] \quad \ldots \quad (8)$$

Equations (7) and (8) represent the economic values that producer is willing to pay for better input quantity level. It is obvious that positive CV and EV measures lead to the better welfare and negative CV and EV generate the welfare loss. CV and EV can also be explained by the producer willingness to pay (WTP) function d, defined as:

$$d = \bar{h}\left(\pi\left(p_y, r, q_1\right), k\right) - \bar{h}\left(\pi\left(p_y, r, q_0\right), k\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

CV and EV functions are described above which depend on the initial and final levels of non-labour income [McConnell (1990)]. The best availability of any input quantity/level, "q_1" may increase the profit as d > 0. In addition, it also represents the maximum amount of profit that producer is willing to accept (forgo) to give up (obtain) the benefits of new input quantity level, "q_1".

It has been assumed that non-labour income is a linear function of firm profit and other factors defined by "*k*". It can also be assumed that change in input quantity "*q*", from "q_0" to "q_1" is also the linear function of the difference in profits, written as:

$$d = \pi\left(p_y, r, q_1\right) - \pi\left(p_y, r, q_0\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

The above equation yields that the maximum amount of money a producer is willing to pay for the improvements of input quantity level which may reduce the difference between ex-post (after new input) and ex-ante (before new input) firm's profit levels.

In our analysis, the old input level is described by the current energy provision to all industrial sectors of Pakistan. Water and Power Development Authority (WAPDA) and Sui Northern Gas Pipeline Limited (SNGPL) have been the supplier of electricity and gas provision to all textile industries of Faisalabad, respectively. The ongoing energy crisis has badly affected their production level and they have to rely on alternative energy source such as heavy standby generators, working on oil, solar energy plants and other such expensive opportunities to run their industries. So, "q_0" is energy provision in form of electricity and gas and "q_1" are alternative expensive energy sources.

It is also apparent that alternative energy sources are more expensive as compared to traditional energy sources. That is why, industrialists pay higher amount for that which reduces their profit as well (if price remains same). So, "*r*" is energy price that is categorised in two components "r_0" and "r_1", where former is the price of traditional energy provision and latter is the price of alternative energy sources.

The analysis requires the specific form of production function for both cost minimisation and profit maximisation. From these forms, we can drive all the equations written above and extend the analysis for comparative statics of WTP variation function. It is also helpful for the sign and implication of input price effect, output price effect and input quality effect. The expected sign are as:

$$\frac{\partial d}{\partial r_0} < 0, \qquad \frac{\partial d}{\partial r_1} < 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

For better input quantity level or alternative energy source, the willingness to pay for producer would be higher and the variation function for own and cross price is negative.[6]

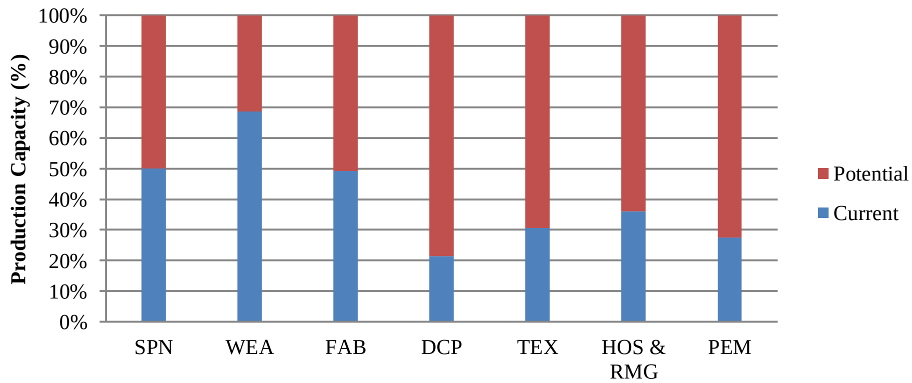
3. RESULTS AND DISCUSSION

This section presents the results of production loss and number and duration of production order delays due to energy crisis in different sub-sectors of textile industry. In addition, willingness to pay (WTP) responses for uninterrupted energy supply across the sub-sectors will be discussed.

3.1. Production Analysis

Energy crisis forced all sectors of the industry to produce less than their potential levels. However, due to different scale of production and level of dependency on energy inputs, the gap between actual and potential production level varies across the sectors. Figure 2 depicts theses production capacity gaps.

Fig. 2. Current Production Capacity of Different Textile Sectors



Spinning, weaving and fabric sectors have the highest use of alternative resources (mainly electric generators) and are producing 50 percent, 68 percent and 50 percent of their potential level, respectively. The maximum gap of potential and current output is apparent for textile, dyeing, chemical and processing and printing and embroidery firms. Lower production capacity in dyeing, chemical and processing (*DCP*) sector is exerting negative effects on production in textile (*TEX*), hosiery and readymade garments (*HOS* and *RMG*) and printing and embroidery (*PEM*) as the latter sectors depend upon *DCP*. These sectors are using gas-intensive alternative resources; hence, it can be deduced that production loss is worse in gas dependant industries than in electricity dependant. Load-shedding of gas has aggravated the cost of these firms where many units have purchased boilers to keep their production process in run. Rice-waste, corn-waste and coal are being used as an input in these boilers whereas using coal as an input is subject to both quantity and quality constraints. Pakistani coal is not of good quality and there are trade restrictions on import of coal from the neighbouring countries particularly India.

[6]Depend on substitutions and complements input alternatives. Here, only complement is more relevant.

Spinning and weaving and sizing have no production loss from gas shortage but the later one depends more on electricity as compared to former ones. The unserved energy-loss is higher in electricity-intensive industries than gas-intensive industries. Overall, textile, dyeing and hosiery and readymade garments firms are more energy dependant as compared to others and facing severe production crises in their industries. The current situation has also adversely affected the labour market where textile, hosiery and readymade garments and dyeing sectors are the major affectees. The situation is less severe in those sectors where a working shift consists of ten hours rather than eight hours.

It can be seen from Table 1 that labour-hour loss is the highest in the textile sector followed by hosiery and garments sectors that depend upon the former. In weaving sector, there is less labour-hour loss because large scale of production and high demand of good have allowed producers to use alternative resources at the time of electricity load-shedding. Printing and embroidery sector is also using alternative sources to continue working at time of load-shedding. Production loss is highest in textile sector followed by dyeing, chemical and processing sector under both shifting hours. Zero production loss under gas as an input in weaving and spinning sectors is because these sectors primarily depend upon electricity and use electricity generators in load shedding hours. It is important to note that production loss reduces as working hours of a shift increase from eight to ten. It basically indicates that increased labour-hours are not proportionate to energy loss and firms may increase their output level by increasing their working hours.

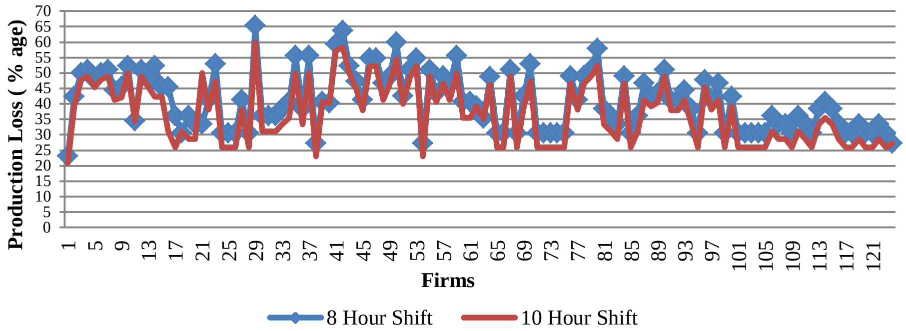
Table 1

Production and Labour-Hour Losses (Thousands Units Per-Day)

			Sectors of Textile Industry						
			SPN	*WEA*	*FAB*	*DCP*	*TEX*	*HOS & RMG*	*PEM*
Labour-Hour Loss	8-Hour Shift	Electricity	0.12	0.06	0.11	0.24	0.99	0.93	0.06
		Gas	0.06	0.00	0.01	0.15	0.58	0.56	0.03
	10-Hour Shift	Electricity	0.12	0.06	0.11	0.24	0.99	0.93	0.06
		Gas	0.06	0.00	0.01	0.15	0.58	0.56	0.03
Production Loss	8-Hour Shift	Electricity	0.01	1.19	2.81	13.89	28.58	2.33	2.74
		Gas	0.00	0.00	0.26	8.77	14.73	0.49	1.57
	10-Hour Shift	Electricity	0.01	0.96	2.25	11.11	22.95	1.87	2.19
		Gas	0.00	0.00	0.21	7.02	11.83	0.39	1.25

The production loss for both 8-hour and 10-hour shifts in textile industry is shown below in Figure 3. It ranges between of 23 to 65 percent for 8 hour shift while 21 to 60 percent for 10-hour shift. This production loss is greater than the loss (25.6 percent) calculated by Lahore Chamber of Commerce and Industry (LCCI) for Punjab during 1984-85 crises and, also, above the range of 12 to 37 percent estimated by Siddiqui, *et al*. (2011) in 2008 when the energy crisis was in initial stages.

Fig. 3. Production Loss of Textile Sector



The 65 percent production loss of textile industry clearly indicates that up to 10-hour per day electricity load-shedding and 4 days a week gas load-shedding has thrown textile sector into troubles resulting in huge output losses, loss of competitiveness in international market (next section will demonstrate this phenomenon) and capital outflow of major textile industries to neighbouring countries.

3.1.1. *Production Orders and Delays*

Energy crisis had adversely affected production orders, both local and foreign, by increasing cost of production and by causing delay in completion of production orders. As explained earlier, these delays in completion of orders depend on the size of the firm and production delays in other sectors of the industry on which a sector depends for intermediate product. Table 2 presents a brief picture of this scenario in the textile industry of Faisalabad.

In 2008, textile firms have the highest local and export orders as percentage of the total orders per-year while spinning sector has the least local orders in 2008 which is just 4.3 percent of total orders obtained by the whole textile sector. In 2013, international orders in all sectors have decreased as compared to reference period; expect fabric which showed growth in export orders from 6.8 to 17 percent. It is obvious that textile and hosiery and garments sectors have been unable to fulfil the international requirements and faced reduction in their export demands as compared to 2008. Further, embroidery and weaving and sizing firms have no export orders in both 2008 and 2013. The emerging results show that energy crisis has reduced the production orders in both international and national market which resulted in loss of production.

Table 2

Production Orders and Delays (Percentage of Concerned Orders Per-Year)

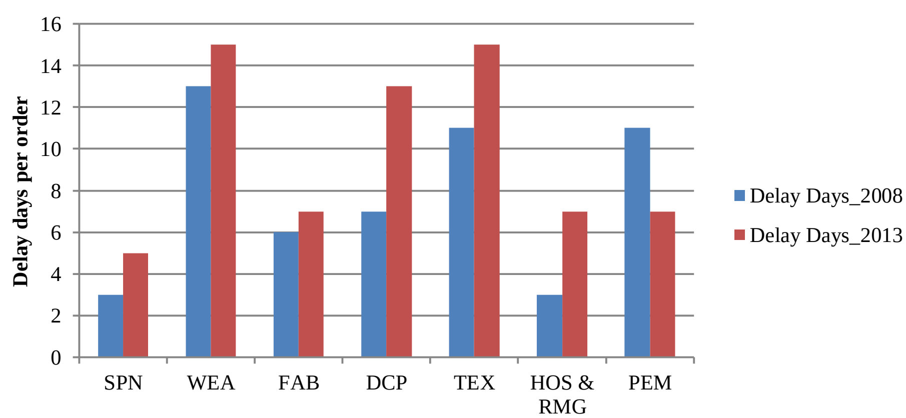
	Sectors of Textile Industry							
	Years	*SPN*	*WEA*	*FAB*	*DCP*	*TEX*	*HOS & RMG*	*PEM*
Local Orders	2008	4.3	15.2	5.0	18.6	34.5	14.7	7.8
	2013	3.1	0.2	3.5	16.5	39.2	13.3	7.1
Local Order Delays	2008	22.8	47.8	23.3	31.8	31.7	16.3	27.3
	2013	26.5	50.7	34.8	42.1	53.8	30.1	27.3
Export Orders	2008	6.4	0.0	6.8	3.2	60.3	23.2	0.0
	2013	3.7	0.0	17.3	1.9	45.5	32.6	0.0
Export Order Delays	2008	0.0	0.0	6.4	0.0	8.2	11.1	0.0
	2013	0.0	0.0	9.5	3.6	10.3	12.8	0.0

It can be seen from Table 2 that energy crisis has slowed down the production process in the textile industry where both local and foreign production orders have reduced in almost all sectors of the industry. Textile sector is an exception where local orders have increased in 2013 as compared to 2008. This result can be explained by looking at the export orders of this sector which has experienced a sharp decline in export orders. Unable to meet the international orders on time, the textile sector has changed its preferences from foreign market to local market so that it may fulfil its fixed cost and keep its existence in the market. It can be termed as a positive externality of recent energy crisis where local market is now enjoying more variety of textile products after energy crisis than it has before this crisis.

Increase in export orders of fabric (*FAB*) and hosiery and readymade garments (*RAM*) sectors are due to conversion of production plants on alternative resources and increased demand in international market of these Pakistani products. Increase in production order-delays shows that the problem of interrupted energy supply has not been addressed in correspondence with the magnitude of the crisis and the situation is getting worse.

For even a deeper analysis how energy crisis is worsening the production process, delay-days per production (local) order are presented in Figure 4. It can be seen that order delay has increased in all sectors of the textile industry except printing and embroidery (*PEM*). Dyeing, chemical and processing sector is experiencing the highest delay duration in completion of an order due to the energy crisis.

Fig. 4. Delay-Days per Local Production Order



Overall the average duration of a local production order delay in the textile sector has increased from seven days to ten days that clearly shows the worsening of the crisis and hence textile production. On the other hand, export order delay cannot exceed more than three working days as a norm of international business in majority of cases.

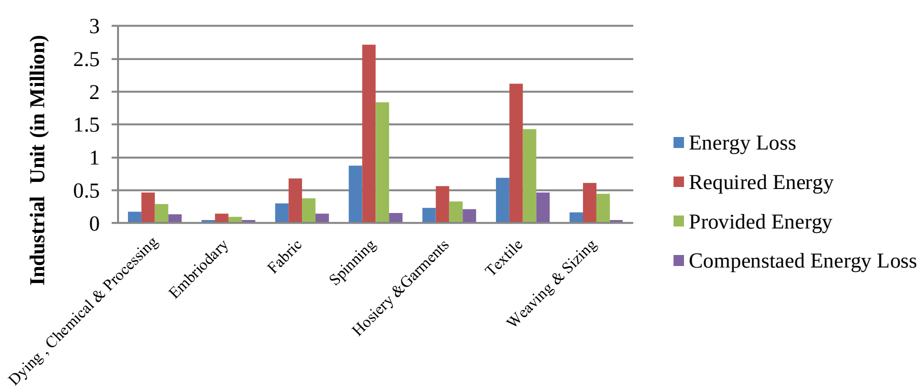
3.2. Energy Analysis

Industrial sector in general and textile sector in particular is experiencing the worst energy crisis of Pakistan's history where eight hours per day scheduled electricity load shedding with a minimum of two hours per day unscheduled load shedding is prevalent. In addition, textile sector is facing four days a week gas load shedding that is resulting in huge production losses across the industry. Adaptation of alternative resources by firm owners have lessened the magnitude of the problem over the time but the tight financial position and growing energy crisis are making it difficult to get rid of this problem completely. Increased hours of a working shift are normally practiced to minimise the unserved energy loss but the issue becomes even more critical when the load shedding hours are pegged with peak-time working hours of the firms. Many of the firms have dual input requirement of both electricity and gas as these sectors have implanted technology where they can use whatever input is available at the time. In is notable that in presence of gas, electricity is not used for running of production process as electricity unit is costly than a unit of gas. This study analyses energy loss (both electricity and gas) faced by each sector of the textile industry, first, with respect to shifting hours of a firm and then peak-time load shedding hours.

(a) ***Shifting Hour Criteria***

Figures 5 and 6 explain the total energy (electricity and gas, respectively) requirement of different sectors of the industry; supply of energy; how much these sectors have compensated for deficiency in energy requirement and the existing deficiency level. Electricity consumption is the highest in spinning and textile sectors that require 18.35 and 14.29 thousand units per-day, respectively. Gas consumption is highest in textile and dyeing and chemical sectors where the need is of 88.63 and 21.25 thousand units per-day, respectively. On the other hand, embroidery sector has the lowest electricity consumption per-day and fabric sector has the lowest gas consumption per-day.

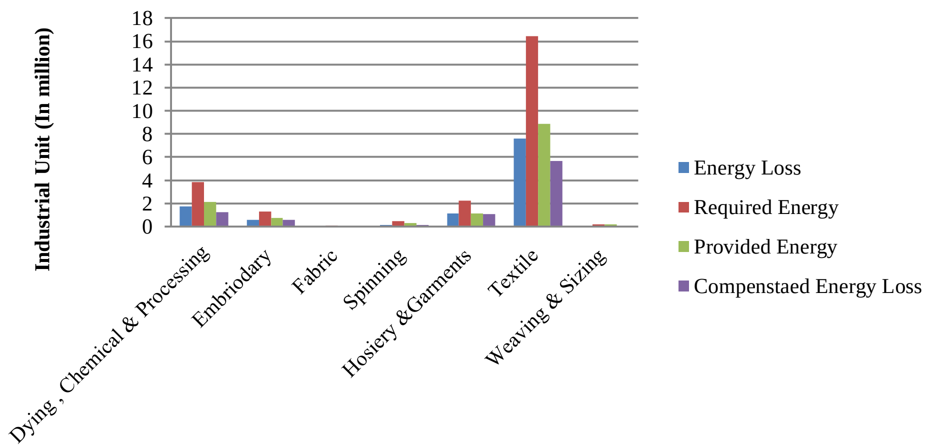
Fig. 5. Electricity Loss of Textile Sectors (Per-month)



Spinning, Textile and Fabric sectors are facing severe electricity loss but the textile sector is the one that is bearing highest cost by employing alternative sources to compensate for energy loss. Although energy loss is the highest in spinning sector yet this sector is not using alternative sources to minimise its loss. Being highly electricity dependant sector, spinning needs a huge fixed cost to finance a complete alternate for smooth functioning of production process. Hosiery and garments and embroidery sectors are almost fully compensating their energy loss by using alternative sources. Electricity gap is minimum in *DCP* and *WEA* sectors where only severity of crisis (increased load shedding hours) has raised their electricity loss against their employed alternatives. Besides, *DCP* sector is more gas dependant than electricity dependant; hence, requires less expenditure on electricity resources.

Figure 6 shows the gas requirements and shortfalls in different sectors of textile industry. Contrary to electricity, gas load-shedding is not on daily basis rather it happens according to a certain schedule of four days a week. Textile is facing the highest energy (gas) loss followed by *DCP* and hosiery and garments. Textile sector requires 91.55 thousand units gas per-day, the highest demand in the industry and fabric has the minimum gas requirement. As a result, the textile industry is more energy intensive sector in terms of both electricity and gas.

Fig. 6. Gas Loss of Textile Sectors (Per Month)



Many firms in textile sector are using boilers as an alternative resource for gas load shedding whereas wood, rice waste, corn waste and, in some cases, coal has been used as input. Environmental perspective of using these boilers is far worse but covering that cost is beyond the scope of this paper. Hosiery and garments sectors are sufficiently equipped with alternative resources to keep the production process in run in case of no energy provision.

(b) ***Peak Time Load-Shedding Hour Criteria***

Most of the firms confirm that they face severe shortage of electricity during their peak time of business and production activity. Each value of concerned group of firms has more electricity requirements during peak times as compared to shift-hour defined above. Figures 7 and 8 explain the total energy (electricity and gas, respectively) requirement and loss situation of different sectors of the industry.

Electricity requirement for spinning sector is almost 3.2 million units per-month while government is providing only 1.8 million units. In this way, this sector is facing electricity shortage of 1.4 million units per-month and compensating 0.25 million units to its energy loss through standby generators and other alternative sources, left over with huge energy deficiency. The weaving and sizing firms are least compensating their energy loss same is true for shifting hour criteria.

Fig. 7. Electricity Loss of Textile Sectors (Per Month)

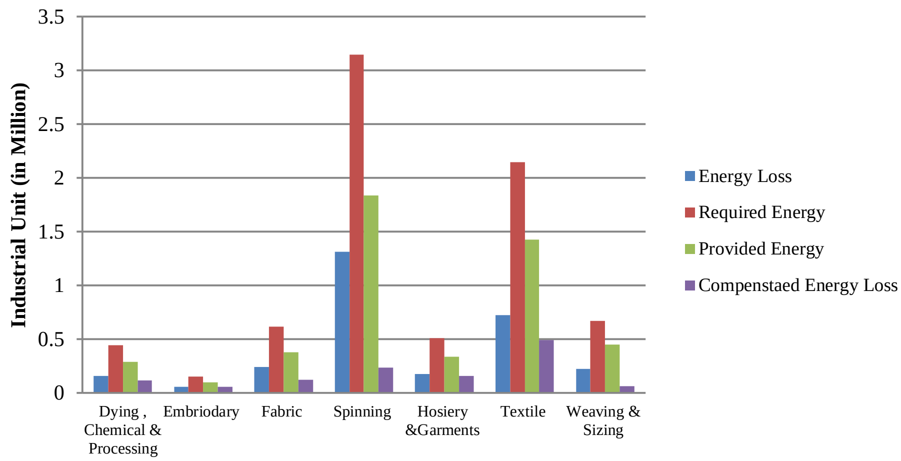
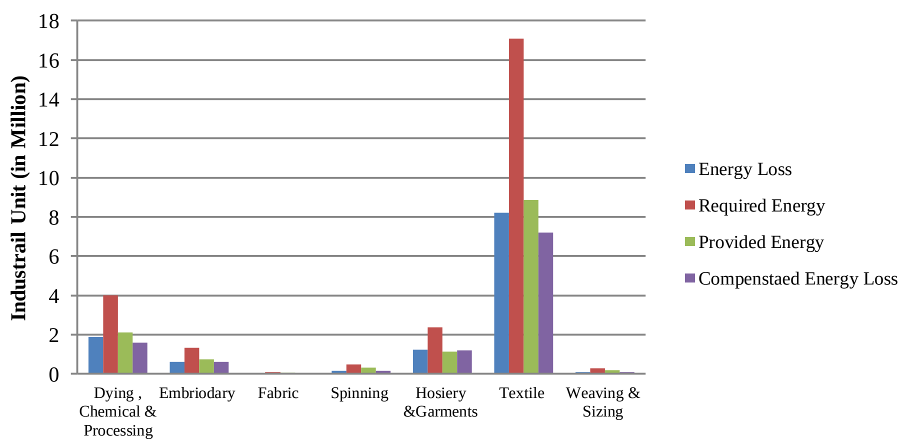


Figure 8 depicts the picture of gas using firms that have higher gas values as compared to shift-hour and weight according to shift-hour criteria. Fabric, spinning and weaving and sizing are free from the issue of gas shortage. They have less demand as well they compensate according to their requirements. But textile, dyeing, chemical and processing and hosiery and readymade garments are facing the severe shortage of gas in spite of the utilisation of alternative source in order to fulfil their requirements. In peak hour load shedding environment, we found that firms are facing the severe loss of energy and producing the less output. Overall, spinning sector is facing the high deficiency of electricity while textile and dyeing, chemical and processing are facing the huge deficiency of gas and their alternative sources cannot fulfil their requirements.

Fig. 8. Gas Loss of Textile Sub-sectors (Per Month)



3.3. Willingness to Pay (WTP) for Uninterrupted Energy Supply

The shortage of energy in textile sectors has compelled producers to show their willingness to pay for uninterrupted energy supply per unit of energy. Table 3.3 presents the estimates of WTP for uninterrupted energy supply.

Table 3.3

Willingness To Pay (WTP) for Uninterrupted Energy Supply

		Sectors of Textile Industry						
		SPN	*WEA*	*FAB*	*DCP*	*TEX*	*HOS & RMG*	*PEM*
(WTP)	% of Firms	66.67	60.87	73.33	66.67	61.54	57.14	77.78
	Maximum (Rs.)	8	11	9	20	13	10	10
	Minimum (Rs.)	3	4	5	4	2	6	4
	Average (Rs.)	5.50	6.79	6.82	9.22	6.25	8.71	7.29

Out of 125 sample of industrial firms, only 80 (64 percent of total) were willing to pay for uninterrupted energy supply. The remaining firms were skeptical about provision of uninterrupted supply even at a higher cost of input. Less interest of firm owners in uninterrupted energy supply is due to lack of trust on public policies and/or their less ability to face further shocks after recently faced shock of higher price of electricity.[7] On average more than fifty five percent firms in each sector are willing to pay higher if they are provided nonstop energy supply.

The maximum willingness to pay was 20 Rs in *DCP*. The minimum willingness to pay is 2 Rs in the textile firms. Textile sector has lost its foreign competitiveness due to recent energy crisis and further increase in input prices would result in complete loss of the foreign market. It has already been shown that hosiery and readymade garments have employed alternative resources for compensating their energy loss; hence, that sector is less willing to pay for uninterrupted energy supply. Interestingly, in *HOS and RAM* sector, those firms that are willing to pay higher for energy supply are offering high (above than average) prices per unit of energy.

In spite of all this energy and production crisis in textile industry, the average range of willingness to pay is high that shows animal spirit of the entrepreneurs of textile sectors who can make progress and bring this industry on top of the world if they were given necessary raw material, in this case energy, to keep production process in run. Sector wise willingness to pay is given below in Figure 9 where all of the curves have negative relation with the number of firms under each sector, clearly defining the shape like demand curve.

[7]We conducted our survey in the end of September and October at that time; the entire industry faced almost 50 percent increase in energy units. This huge increment also discourages their willingness to pay for uninterrupted energy supply.

Fig. 9. Willingness to Pay for Uninterrupted Energy Supply by Textile Sectors

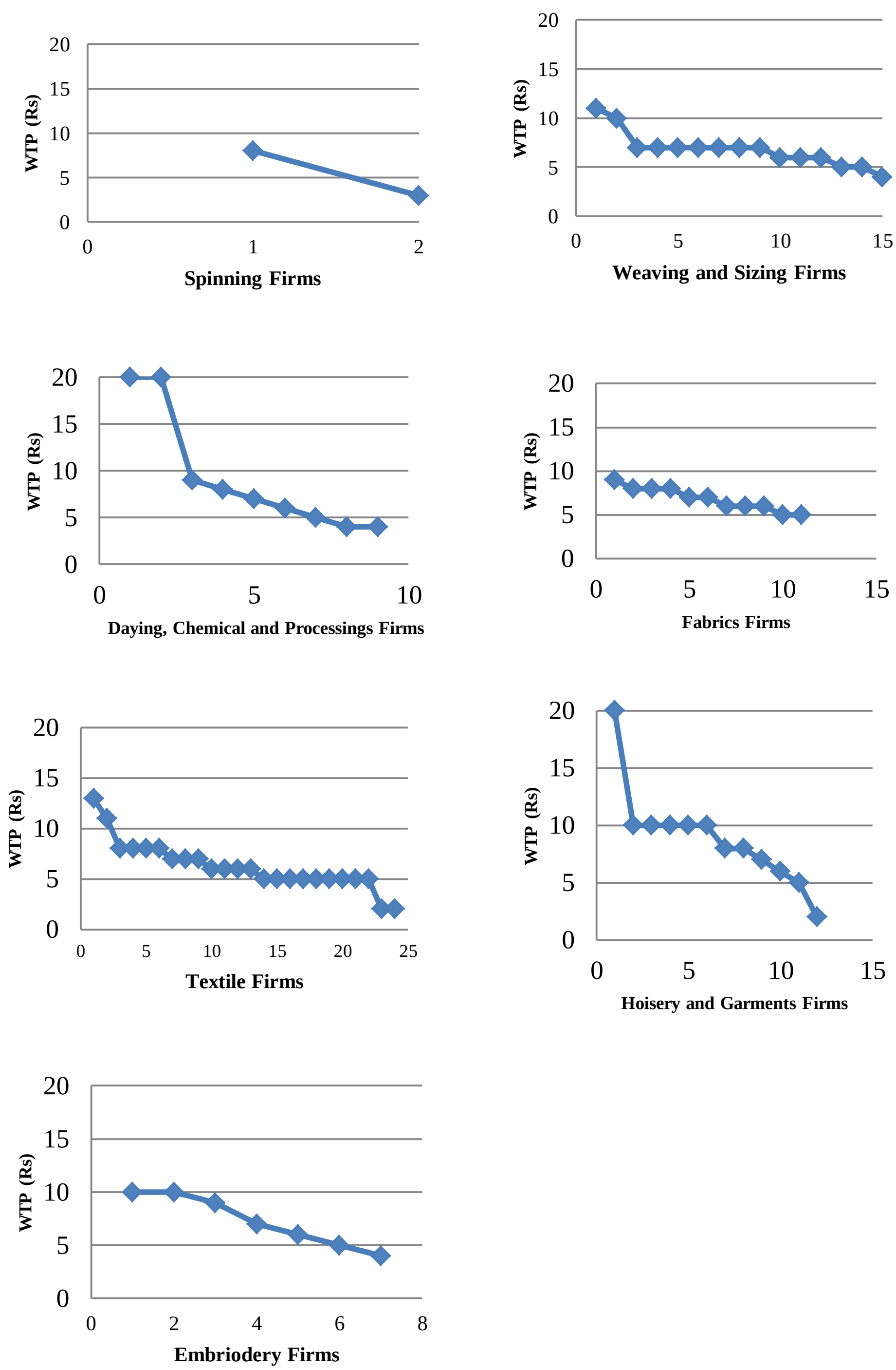
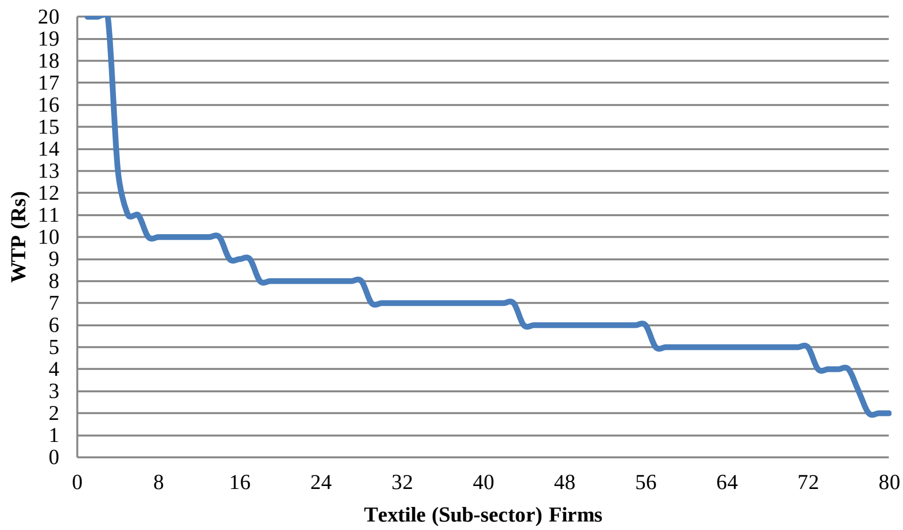


Figure 10 below is showing the willingness to pay curve of textile industry that varies from two to twenty rupees per unit for uninterrupted supply of energy.

Fig. 10. Willingness to Pay Curve of Textile Industry for Uninterrupted Energy Supply



If the first and last ten firms are ignored for time being, the curve shows that most of the firms fall between the ranges of five to nine rupees per unit of energy. This curve is representing the overall willingness to pay of various sectors with different capacity of production and; hence, an approximate picture of the textile industry. This positive price signals need for new supplies of energy resources into the system.

4. CONCLUSIONS

Since 2007, major export oriented textile sector has been unable to meet the demand of both national and international orders due to heavy planned and unplanned energy outages in Pakistan. This outage has appeared in number of findings; intense production loss, big industrial units have been converted into smaller one, most of the industries have shut-down and large amount of capital flight (industries), in particular to competing neighbouring countries, heavy loss of competitiveness in international market and loss of business confidence by investors.

This study covers 125 firms of textile industry of Faisalabad. The results reveal that textile industry is facing 23 to 65 percent production loss for 8-hour shift and 21 to 60 percent for 10-hour shift due to interruption in energy supply. Hosiery and readymade garments sector has highest shares in production loss while weaving and sizing firms have minimum shares in production loss. Textile firms have the highest labour hour loss per-day in both shift-hours, including in hosiery and readymade garments and dyeing, chemical and processing industries. The energy outage has not only had adverse impact on production but also created major delays in production orders. The highest percentage increase in local order delays (as compared to its reference period, 2008) are seen in textile firms, hosiery and readymade garments and dyeing, chemical and processing industries. In international market, the percentage increase in order delays is observed for fabric firms, higher than that of textile and hosiery and readymade garments. Furthermore, dyeing, chemical and processing firms have highest order delays problem in both local and international markets. It is evident that delays in production orders clearly indicate fewer orders in near future. Most of the firms in the industry have lost their both local and international orders. Weaving and sizing firms have severe reduction in their local orders while textile firms have strengthened as compared to reference period, 2008.

The findings reveal that spinning firms are more electricity consuming and electricity deficient in Pakistan while textile firms are facing big loss in their production due to the gas outage. The entire firms in textile industry have taken the stand-by generator as alternative source in order to kill the heavy schedule and unscheduled load-shedding and to reduce the major output loss. They are trying to compensate (maximum) their energy loss according to their requirements but still they are facing the huge energy as well as production loss. This heavy energy loss has compelled them to express their willingness to pay for uninterrupted energy supply. From the sample, only 64 percent of the firms are willing to pay for uninterrupted energy supply. On average, the whole sub-sectors are willingness to pay around 5 rupees per-energy unit. The embroidery firms have highest willingness to pay while hosiery and readymade garments have least willingness to pay. These findings are helpful for the policy makers to make the best energy policy in favour of textile sector that may reduce the production loss and generate the huge employment in this sector.

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Comments

This study is also part of the research projects being funded by the Pakistan Institute of Development Economics to promote innovative research ideas and novelty in techniques needed to explore burning issue of energy crises in Pakistan. First of all, I would like to congratulate authors for presenting well researched study on the effect of energy crises at the firm level of the worst affected industrial area of Punjab. Authors have made good contribution in the existing literature by exploring well into problems of the textile sector at the micro level in Pakistan while earlier study by Siddiqui, *et al*. (2011)[8] have computed total losses for industrial sector from prevailing energy crises. Authors have dealt with methodology very well by decomposing losses into output, labor hours and order delays from energy crises-defined in terms of electricity and gas load shedding at the firm level. Furthermore, the study measures the producer's maximum willingness to pay (WTP) to avoid losses from energy crises by using Hicksian approach – Compensation variation and relate it with willing to pay (WTP). The study found that about 79 percent firms of Faisalabad are willing to pay from Rs1 to Rs 20 per unit for uninterrupted supply of energy. However, I would like to make few suggestions to authors for further improvement in the study.

First, this article uses Hicksian concept of WTP in explicitly dynamic structure while Hicksian is static in nature. Theory suggests that in dynamic setting compensation variation or equivalent variation can have expected value but their relationship to the concept of willing to pay (WTP) becomes more complicated. It is because in addition to compensation variation or equivalent variation, the willing to pay (WTP) depends on the timing of the function of these values as even if compensation variation or equivalent variation are unchanging with the acquisition of new information, willing to pay (WTP) will generally not be and at any point in time willing to pay (WTP) will not be equivalent to expected CV or EV – this could have been incorporated as limitation of this study.

Second, authors have computed industrial losses for gas and electricity separately at the firm level which is good to look into the separate impact of the energy sources used. However, total losses from electricity and gas may also be computed and included in the tables representing losses to output, employment and order delays from electricity and gas load shedding.

Third, authors may incorporate the route map in policy guidelines for handling with energy crises in the short and medium terms especially for micro level firms. It will not only bring to light the usefulness of this kind of study hardly undertaken at micro level in Pakistan due to endless efforts and patience involved but will also help in policy targeting.

Lubna Naz

PhD Scholar,
PIDE, Islamabad.

[8]Siddiqui, R., H. H. Jalil, M. Nasir, W. S. Malik, M. Khalid (2011) The Cost of Unserved Energy: Evidence from Selected Industrial Cities of Pakistan. (PIDE Working Papers 75).

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Impact of Climate Change on Electricity Demand: A Case Study of Karachi District

RAFAT MAHMOOD, SUNDUS SALEEMI, and SAJID AMIN

1. INTRODUCTION

Out of the climatic variables such as temperature, humidity, precipitation, cloud cover, etc., electricity demand has been found most responsive to changes in temperature [Parkpoom and Harrison (2008); Al-Hamadi and Soliman (2005); Hor, *et al*. (2005)]. According to National Aeronautics and Space Administration, the decade from 2001 to 2010 was the warmest worldwide while the rise in surface temperatures of South Asia region by the end of the century is projected around 3.3^{o}C average annually (IPCC);[1] not only are the average temperatures rising but the range of extreme temperatures is also widening. Increase in temperatures can affect human lives significantly; the present study focusses on examining the impact of climate change on demand for electricity in Pakistan.

With both the average and extreme temperatures rising across the globe, it is expected that cooling requirements of people will increase and heating requirements will decrease [Howden and Crimp (2001)]. These effects contribute to changing demand for electricity as the need for air-conditioning, refrigeration, water temperature regulation etc. change [Amato, *et al.* (2005); Rosenthal, *et al.* (1995)]. Though, recognising the importance of this issue, a number of studies have been conducted internationally on analysing future demand conditions of different countries [e.g. Rosenthal, *et al.* (1995); Parkpoom and Harrison (2008); Howden and Crimp (2001)] literature in Pakistan largely lacks in this dimension.[2] The estimation of such changes in demand is important as they can have important consequences for electricity generation capacity building. Given the electricity crisis that has hit Pakistan economy, the study becomes even more relevant as it goes beyond the current demand conditions of the country and looks into the long run need of capacity generation. As there is a protracted time lag between recognition of

Rafat Mahmood <rafat@pide.org.pk> is Staff Economist at the Pakistan Institute of Development Economics, Islamabad. Sundus Saleemi <sundus.saleemi.pide.org.pk> is Staff Economist at the Pakistan Institute of Development Economics, Islamabad. Sajid Amin <sajidamin78@gmail.com> is Assistant Professor at the Pakistan Institute of Development Economics, Islamabad.

Authors' Note: The authors would like to thank Dr Munir Ahmed, Dr Abdul Qayyum and Dr Abdul Jalil for their useful comments and suggestions. Errors and omissions, however, are our own.

[1]Intergovernmental Panel on Climate Change.

[2]Most of the papers that have estimated energy demand equation [Chaudhary (2010); Nasir, *et al*. (2008); Khan and Qayyum (2009)] do not take temperature as an explanatory variable [Jamil and Ahmed (2011)] further exploration of the subject has not been undertaken. A recent study [Ali, *et al*. (2013)] looks at impact of climate change on electricity demand considering the whole of Pakistan altogether. The nature of the problem, however, requires a more disaggregated analysis.

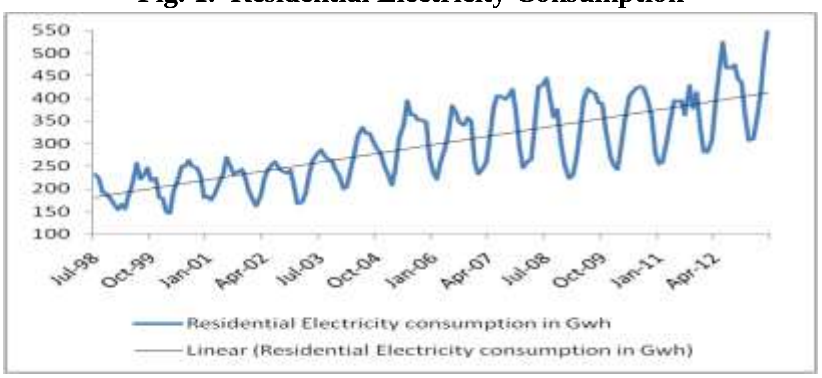
demand needs for electricity and its capacity building, the study will prove helpful for government regarding design of energy policy.

The objectives of the present study are (1) estimation of impact of temperature variation on electricity demand in Pakistan in residential and commercial sectors, and (2) projection of the changes in demand for electricity for the two sectors of the economy under different temperature rise scenarios. As the analysis is still in progress, we will share only the results for a single region i.e. Karachi and its suburbs. Section 2 discusses data and variables used in the analysis while Section 3 deals with methodology and estimation. Results and accompanied discussion is presented in Section 4 followed by sensitivity analysis in Section 5 while Section 6 concludes the paper.

1. DATA AND VARIABLES

Monthly data on electricity consumption of residential and commercial sectors,[3] from July 1998 to June 2013, have been obtained from Karachi Electric Supply Corporation (KESC).[4] The data on average monthly temperatures for this time period have been taken from Pakistan Meteorological Department (PMD).[5] A look at the data (Figures 1 and 2) shows that electricity consumption has considerable seasonal fluctuations and a time trend both in the residential and commercial sectors.[6] During the period the maximum monthly average temperature was 36°C and minimum 11.9°C. A simple graph of temperature reveals a slightly increasing time trend pointing to global warming impacts.[7] Consequently, a modest increase in cooling degree days and decrease in heating degree days can also be observed as shown in Figures 3 and 4.

Fig. 1. Residential Electricity Consumption



[3]These sectors have been found in literature to be the most sensitive to changes in temperature as opposed to agriculture and industrial sectors [Rosenthal, *et al*. (1995)].

[4]We are especially thankful to Saad Hasan Latif, KESC for his co-operation.

[5]We owe gratitude to Numerical Modeling group of Research and Development Division, Pakistan Meteorological Department (PMD), Islamabad, International Development Research Center (IDRC), Dr Munir Ahmed, PIDE, and Muhammad Nawaz and Hasan Siftain, PIDE for co-operating with us in this regard.

[6]To substantiate the point that fluctuations in electricity demand are in a large part dependent on temperature variations, Hodrick-Prescott filter is used to separate growth in electricity consumption from fluctuations in electricity consumption and the latter is regressed on temperature variables. It is found that temperature variables significantly influence fluctuations in electricity consumption. For estimation output see Appendix I.

[7]Global Warming is a very gradual process and our dataset spanning only 15 years may be inadequate to capture it fully.

Fig. 2. Commercial Electricity Consumption

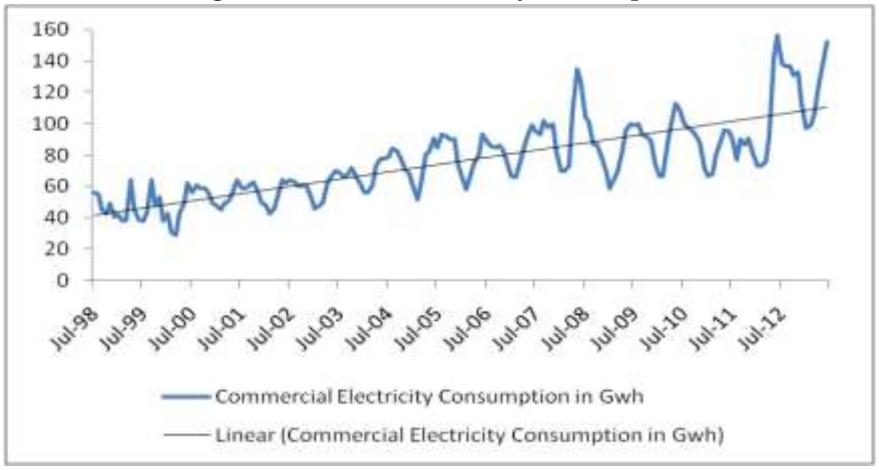


Fig. 3. Monthly CDDs

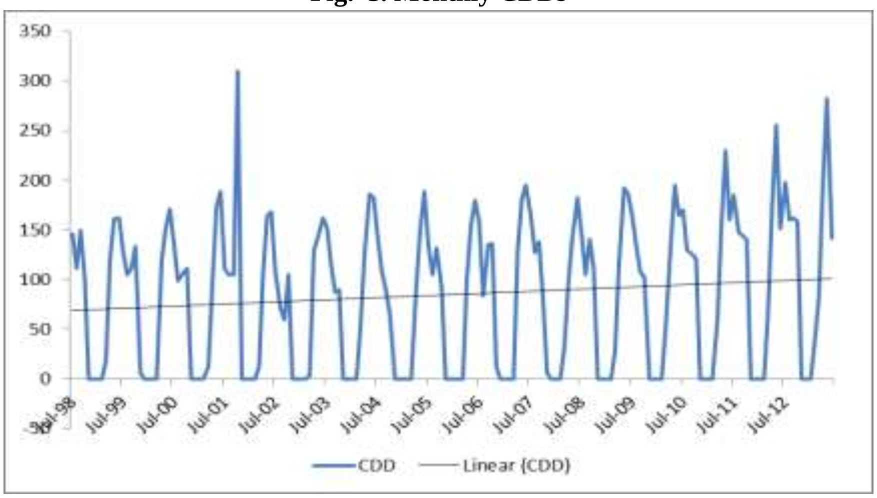
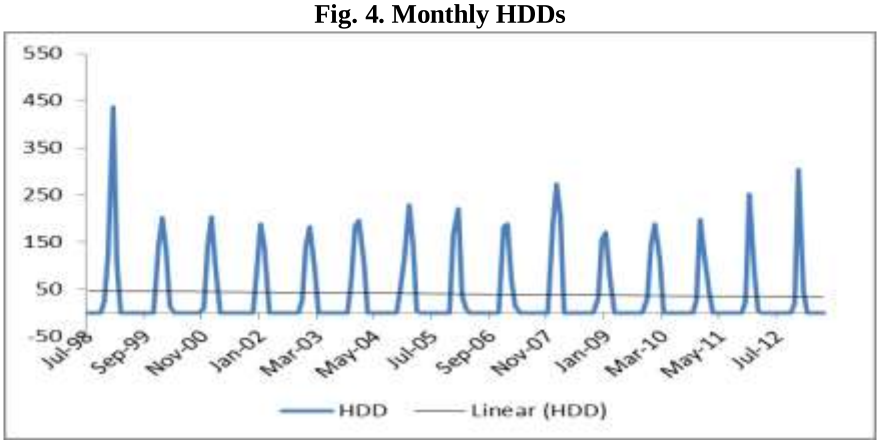


Fig. 4. Monthly HDDs



Following Munoz and Sailor (1998), the present study employs degree day method for incorporating temperature variations.[8] A degree day is defined relative to a base temperature wherein the heating degree day (HDD) refers to a day when temperature is lower than the base and heating is required to reach the base temperature and vice versa. Thus, at the temperature equivalent to base temperature, electricity demand is considered to reach the lowest level as the atmosphere itself facilitates the achievement of desired comfort level for individuals. In this way, without introducing squared term in the analysis, HDD and CDD are utilised to incorporate u-shaped relationship between temperature and electricity demand. Further, following Yuan and Qian (2004), the study uses the definition of degree days as given below.

$$HDD_i = \gamma(T_b - T_i)m \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

$$CDD_i = (1-\gamma)(T_i - T_b)m \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

Where HDD_i and CDD_i are monthly heating degree days and cooling degree days respectively for region *i* where regions are defined as the area served by a particular power distribution company, in this case, KESC, T_i is the monthly average temperature of region *i*, T_b is the base temperature, *m* is the number of days in the month under consideration, γ is a binary variable that equals 1 if $T_i < T_b$ and 0 otherwise.[9] The base temperature is taken at 26°C.[10]

3. METHODOLOGY AND ESTIMATION

The dependent variable in our model is the monthly demand for electricity[11] in residential and commercial sectors of Karachi and its suburbs which is regressed on both the heating and cooling degree days to estimate the relationship between the two. As electricity demand does not depend on temperature variables alone, control variables should also be included in the analysis such as GDP growth, population and price per unit of electricity [Jamil and Ahmed (2011)]. Due to lack of data at regional level, the effect of time-varying variables is captured by using trend in the regression [Pilli-Sihvola, *et al.* (2010); Amato, *et al.* (2005)].

Initially the relationship between electricity consumption and average monthly temperature has been studied using the following equation.

$$E_{it} = \gamma_{1i} + \gamma_{2i}Temp_t + \gamma_{3i}trend + \varsigma_{it} \qquad \ldots \quad \ldots. \quad \ldots \quad \ldots \qquad (3)$$

where

E_{it} : Monthly electricity demand in GWh in sector *i*,
$Temp_t$: Monthly average temperature in the region,

[8]The degree day method has been employed in literature to capture the non-linear relationship between temperature and electricity demand [Amato, *et al.* (2005); Ruth and Lin (2006)].

[9]Ideally degree days should be calculated using daily data on temperature. However due to lack of access to such data we have used monthly temperatures in our analysis.

[10]In summers optimal room temperature is set at 26°C by Water and Power Development Authority (WAPDA), Pakistan.

[11]Proxied by electricity consumption.

trend : The trend variable used to capture the impact of all the time-varying factors, and

ς_{it} : Residual term

Next, to take non-linearity of the relationship between temperature and electricity demand into account, the following equation has been employed.

$$E_{it} = \beta_{1i} + \beta_{2i}HDD_t + \beta_{3i}CDD_t + \beta_{4i}trend + \varepsilon_{it} \quad \dots \quad \dots \quad \dots \quad (4)$$

where

HDD_t : Monthly heating degree days in region i,

CDD_t : Monthly cooling degree days in region i,

ε_{it} : Residual term

The study uses Ordinary Least Squares (OLS) estimation procedure for the analysis because if the assumptions required for proper functioning of OLS method hold, the estimators thus obtained have been proved to possess some ideal properties.[12] The estimators are linear and unbiased, and are efficient estimators in that they have minimum variance amongst a class of linear unbiased estimators. Given the desirability of properties of OLS estimators, the decisive factor in opting for OLS turns out to be whether or not the required assumptions for the procedure hold. In the present analysis, the underlying relationship between electricity demand and degree days calls for a linear model.[13] All the individual variables are tested for stationarity and are found to be stationary at I(0)[14] while testing with Granger Causality test, one way causality is found between temperature variables and electricity demand. The problem of autocorrelation was observed which is dealt with by adding AR and MA terms in the regression [Prais and Winsten (1954)] after observing the correlogram while White Heteroscedasticity-consistent standard errors and covariances [White (1980)] were obtained after correcting the issue of heteroscedasticity in the data. In addition, as the number of explanatory variables in our model is not large and the degrees of freedom are satisfactory, the application of OLS technique to the model is justified. Finally the obtained residuals from the regressions have been tested for stationarity and are found to be stationary reinforcing the appropriateness of the estimation technique used in our analysis [Box and Jenkins (1970)].

4. RESULTS AND DISCUSSION

As a first step towards establishing a relationship between electricity consumption and changes in temperatures induced by climate change, residential electricity consumption has been regressed on monthly mean temperature and trend. Results are provided in Table 1. The coefficient of temperature turns out significant at 1 percent and is corroborating the theoretical claims that demand for electricity increases with increase in temperatures.[15,16] Similarly for the commercial sector of Karachi and its adjoining

[12] Gauss-Markov Theorem attributed to Gauss (1821) and Markov (1900).

[13] Bartholomew, *et al*. (2002).

[14] Results of Unit Root tests are given in Appendix II.

[15] Demand for electricity is derived demand which changes with the change in use of electrical appliances.

[16] It is possible that the electricity consumption data may not be reflecting the true demand for electricity since the city experiences load-shedding due to electricity shortages.

areas regressing electricity consumption on temperatures gives a significant positive coefficient to the temperature variable showing that in this sector too, electricity demand rises with rising temperatures (Table 1). The positive and significant coefficient of trend means that electricity consumption surges with surges in its time varying determinants other than temperature.

Table 1

Regression of Electricity Consumption on Temperature

	Coefficients			
Dependent Variable	Average Monthly Temperature (S.E.)	Trend (S.E.)	Adjusted R^2	F-Statistic (Prob.)
Residential Electricity Consumption (GWh)	2.673*** (1.01)	1.315*** (0.14)	0.907	431.27 (0.00)
Commercial Electricity Consumption(GWh)	0.78*** (0.26)	0.40*** (0.05)	0.890	361.04 (0.00)

***Significant at 1 percent.

In the next step the electricity consumption of the residential sector was regressed on the monthly HDDs and CDDs. Table 2 shows the regression results. A meaningful positive coefficient of the CDD variable implies that electricity consumption inflates as temperatures intensify; when temperatures rise above the threshold temperature of 26ºC more electricity is used through the use of fans, air conditioners etc. to bring temperatures at comfortable level. The significant but negative coefficient of the HDD entails that declining temperatures necessitate a need for heating to bring it to comfortable levels, leading to electricity use declines.[17] One plausible explanation for this behaviour could be that space heating requirements are being fulfilled by the use of other energy sources like gas, firewood, coal etc. The trend coefficient enters again significantly positive meaning that electricity usage increases with time.

Table 2

Regression of Electricity Consumption on Monthly CDDs and HDDs

	Coefficients				
Dependent Variable	CDD (Prob.)	HDD (Prob.)	Trend (Prob.)	Adjusted R^2	F-Statistic (Prob.)
Residential Electricity Consumption (GWh)	0.172*** (0.05)	–0.146*** (0.05)	1.321*** (0.18)	0.896	307.01 (0.00)
Commercial Electricity Consumption (GWh)	0.044*** (0.013)	–0.025** (0.012)	0.398*** (0.057)	0.888	282.56 (0.00)

***Significant at 1 percent. **Significant at 5 percent.

Likewise, regressing the electricity consumption in the commercial sector on the monthly HDDs and CDDs along with trend provides a significant positive coefficient of the CDD reiterating that, the use of electricity expands with increase in the number of days requiring cooling and the negative but significant coefficient of the HDD variable

[17] Results are in corroboration with earlier literature, see Amato, *et al*. (2005).

denotes that rising need for heating contracts the electricity use. The trend coefficient is consistent with our previous results and has the similar explanation. [18,19]

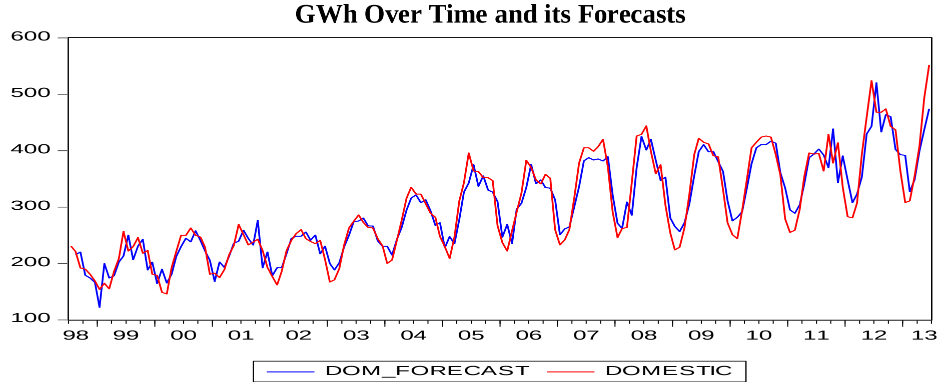
5. SENSITIVITY ANALYSIS

Figures 5 and 6 show the demand for electricity by residential and commercial sectors against their respective forecasts obtained by using Equation 4. Given the apparent success of forecasts in explaining the actual values, we use Equation 4 to test for sensitivity of electricity demand to temperatures under different global temperature scenarios. Following Parkpoom, *et al.* (2008), year 2012 is taken as a baseline scenario while projections are done for a rise in temperature by 1°C, 2°C, and 3°C respectively.[20] Thus sensitivity curves are obtained and compared for each scenario as presented in Figures 7 and 8.

It is found that generally the rise in electricity demand is more pronounced in the relatively hot months of the years as compared to relatively cold ones suggesting surging peak loads in summer season.

Under 1°C rise in temperature scenario, residential electricity consumption is expected to rise in the range of 1.14 percent to 1.27 percent, for a 2°C rise in temperature, the range is found to be 2.3 percent to 2.5 percent while if the temperature increases by 3°C electricity demand may rise by 3.5 percent to 3.8 percent. On similar trends, commercial electricity consumption is likely to rise by 2.3 percent to 3.6 percent under 3°C temperature rise scenario. The greater sensitivity of peak demand to temperatures suggest the need for capacity installation over and above that needed to cater to rise in electricity demand attributable to economic growth. [21]

Fig. 5. Residential Electricity Consumption in GWh Over Time and its Forecasts



[18]The coefficient of CDD is greater in magnitude than the coefficient of HDD which may also indicate that electricity demand is more sensitive to high temperatures. This result is in concurrence with available literature e.g. Sailor and Pavlova (2003).

[19]The coefficients of temperature variables have higher magnitudes in case of residential electricity demand as compared to commercial hinting at relatively larger sensitivity of the former to changes in temperature.

[20]A more sophisticated analysis could be conducted by using Climate Change Scenarios Data for Karachi. However due to lack of access to this data for years prior to 2071, we have adopted a rather generalised approach.

[21] The results are found in line with literature available in this regard e.g. Howden and Crimp (2001).

Fig. 6. Commercial Electricity Consumption in GWh and its Forecast

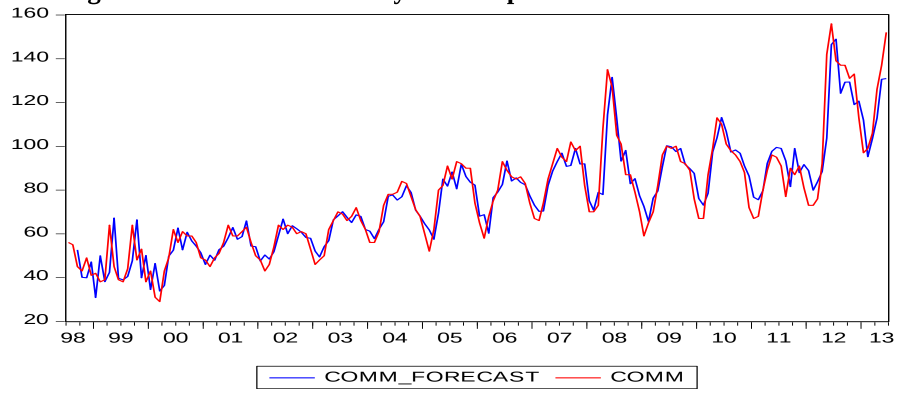


Fig. 7. Residential Base Consumption and Projected Consumption

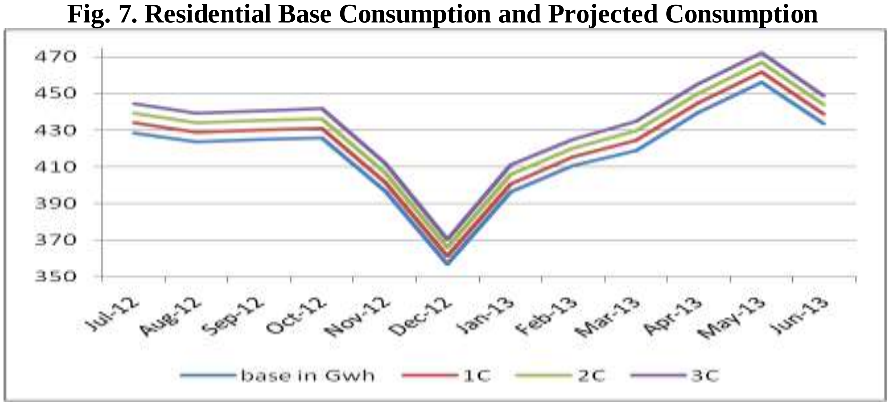
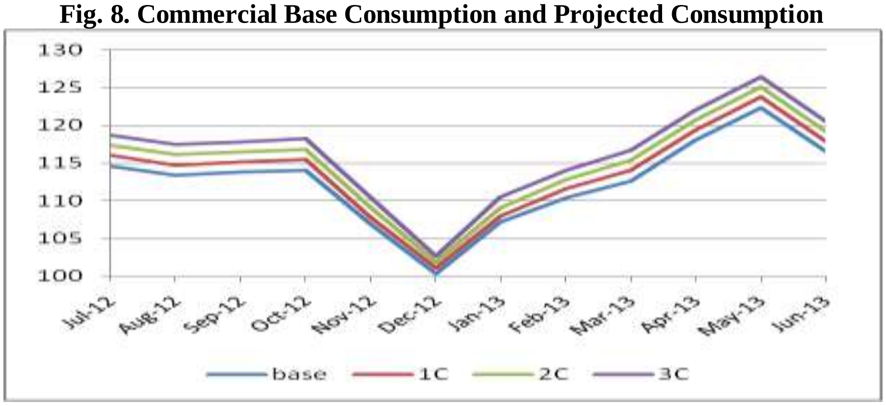


Fig. 8. Commercial Base Consumption and Projected Consumption



6. CONCLUSION

The study finds impact of climate change, proxied by rising temperatures, on electricity demand in Karachi and its suburbs. The analysis suggests a significant positive response of electricity demand to rise in temperature and thus points towards increase in electricity demand in the region in future owing to climatic variations. The percentage increase in electricity demand as projected in this analysis seems too small to be worried about (3.8 percent at most), possibly because of primitive nature of temperature regulation mechanisms used by the residents. Two points, however, should be kept in mind while drawing any inferences even for the case of Karachi region alone. Firstly, the percentage increase in electricity demand found in the present study is the rise in demand attributable only to escalating temperatures disregarding changes in trends of all the other factors that affect increase in demand. It is expected that with growth in GDP and population as well as mechanisation and other socio-economic factors, electricity demand will increase in future over and above that which is induced by temperature. Secondly, electricity consumption understates true demand for electricity owing to excessive load shedding in Pakistan in the period considered for analysis which holds true for Karachi as well. If both of these factors are taken into account, the rise in electricity demand in response to climate change is expected to become more pronounced in magnitude and thus calls for more careful planning by the relevant authorities regarding capacity building and load management.

Appendix I

Impact of Temperature on Fluctuations in Electricity Consumption

Fluctuations	Coefficient: Average Monthly Temperature (Celsius)*	R^2	F-Statistic (Prob.)
Residential Electricity Consumption	5.157118 (0.000)	0.748996	174.0664 (0.000000)
Commercial Electricity Consumption	1.135120 (0.000)	0.660234	113.3533 (0.0000)

*Estimation done through OLS.

Fluctuations	Coefficients** CDD (Prob.)	HDD (Prob.)	R^2	F-Statistic (Prob.)
Residential Electricity Consumption	0.186857 (0.0003)	–0.152476 (0.0021)	0.746678	128.2180 (0.000000)
Commercial Electricity Consumption	0.049638 (0.0000)	–0.027119 (0.0052)	0.660815	84.74841 (0.000000)

**Estimation done through OLS.

Appendix II

Results of Unit Root Test

(i) Residential Electricity Consumption

		Adj. t-Stat	Prob.*
Phillips-Perron Test Statistic		–3.823886	0.0174
Test Critical Values:	1% Level	–4.010143	
	5% Level	–3.435125	
	10% Level	–3.141565	

(ii) Commercial Electricity Consumption

		Adj. t-Stat	Prob.*
Phillips-Perron Test Statistic		–4.526310	0.0018
Test Critical Values:	1% Level	–4.010143	
	5% Level	–3.435125	
	10% Level	–3.141565	

(iii) Average Monthly Temperature

		Adj. t-Stat	Prob.*
Phillips-Perron Test Statistic		–5.320169	0.0001
Test Critical Values:	1% Level	–4.010143	
	5% Level	–3.435125	
	10% Level	–3.141565	

(iv) Cooling Degree Days

		Adj. t-Stat	Prob.*
Phillips-Perron Test Statistic		–6.467832	0.0000
Test Critical Values:	1% level	–4.010143	
	5% level	–3.435125	
	10% level	–3.141565	

(v) Heating Degree Days

		Adj. t-Stat	Prob.*
Phillips-Perron Test Statistic		–6.467832	0.0000
Test Critical Values:	1% level	–4.010143	
	5% level	–3.435125	
	10% level	–3.141565	

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Comments

This study is also part of the research projects being funded by the Pakistan Institute of Development Economics to promote innovative research ideas and novelty in techniques needed to explore burning issue of energy crises in Pakistan. First of all, I would like to appreciate authors of the study for identifying the variables of interest in this context. The study provides results and makes projections for electricity demand of residential and commercial sectors of Karachi under various temperature scenarios—the largest city of Pakistan—as detailed work on other affected areas still continues. The study used latest data on electricity consumption of industrial and residential sector of Karachi from 1998–2013 and also used average monthly temperature. The study employed degree day method of Munoz and Sailor (1998)[22] to incorporate temperature variations. The results suggest that rising temperature has effect on electricity demand of residential and commercial sectors of Karachi and its suburbs.

However this study has few weaknesses which are as follows:

- Authors have not mentioned objectives, source of data, sample covered and findings of the study in the abstract.
- Section on the Survey of related studies has not been included separately. Authors need to explore well in the issue of the impact of temperature variation on electricity demand and for that a comprehensive knowledge of earlier studies on the issue is needed.
- Ordinary least square technique has been used to test the hypothesis of impact of temperature variation on electricity demand of residential and commercial sectors of Karachi which may give spurious relationships in the presence of non-stationary variables. Since this study uses monthly time series data for which more appropriate techniques from time series could have been used.

Lubna Naz

PhD Scholar,
PIDE, Islamabad.

[22]Munoz, J. R. and Sailor, D. J. (1998) A Modelling Methodology for Assessing the Impact of Climate Variability and Climatic Change on Hydroelectric Generation. *Energy Conversion and Management* 39:14, 1459–1469.

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Electricity Demand in Pakistan: A Nonlinear Estimation

SAIMA NAWAZ, NASIR IQBAL, and SABA ANWAR

1. INTRODUCTION

Pakistan has plunged into darkness because of severe electricity shortage over the last few years. The electricity shortfall has reached 4,250 MW with demand standing at 16,400 MW and generation at 12,150 MW in June 2013 (PEPCO). The load shedding and power blackouts act as a binding constraint to the economic growth through their impact on employment, trade and poverty [Kessides (2013)]. The existing statistics reveal that Pakistan has witnessed low GDP growth rate during the periods of low or negative electricity growth and during the periods where electricity growth picked up there is an increase in GDP growth rate [Pakistan (2013)]. The power crisis has destroyed the industrial sector of Pakistan. Around 40 percent factories and industry units have now been closed and around 7.5 percent of labour force is out of jobs only because of this dilemma.[1]

The studies on the power crisis amongst other issues such as governance, transmission and distribution losses, circular debt etc. have also highlighted tremendous increase in the demand for electricity as the leading factor contributing to the persistent demand supply gaps. Over the last three decades, there has been an upsurge in the demand for electricity owing to urbanisation, industrialisation, rural electrification, growth in agriculture and service sectors, rapid growth in domestic demand and rising per capita income. The actual demand was not fully anticipated because of the failure to forecast and plan for future, upgrade existing plants and set up new generating stations in the face of rapidly rising demand [Kessides (2013)].

The precise assessment of electricity demand thus remains imperative concern for policy makers in Pakistan. The objective of this paper is to estimate the electricity demand function for Pakistan in nonlinear fashion using time series data over the period 1971–2012. According to best of my knowledge, there is no study that estimates electricity demand function for Pakistan with the possibility of nonlinearity. In this study, the smooth transition regression model has been used to reexamine the relationship

Saima Nawaz <saima.nawaz@comsats.edu.pk> is Assistant Professor, COMSATS Institute of Information Technology, Islamabad. Nasir Iqbal <nasir@pide.org.pk> is Assistant Professor, Pakistan Institute of Development Economics (PIDE), Islamabad. Saba Anwar <saba@pide.org.pk> is Research Economist, Pakistan Institute of Development Economics (PIDE), Islamabad.

[1]http://talibmag.com/effects-of-electricity-crisis-in-pakistan/

among electricity consumption, real income, and own energy prices. Using this nonlinear approach, we can identify the economic variables that explain the transition of the electricity consumption-income-price nexus from one regime to another.

The rest of this paper is structured as follow: Section 2 summarises the existing literature concerned with the electricity demand function; Section 3 briefly discusses the electricity sector in Pakistan; Section 4 explains the data sources and estimation methodology to be used here; Section 5 presents our results and Section 6 concludes the study.

2. LITERATURE REVIEW

There are number of studies that estimate the electricity demand function in Pakistan including Masih and Masih (1996), Siddique (2004), Lee (2005), Khan and Qayyum (2009), Jamil and Ahmed (2010), Shahbaz, *et al*. (2012) and Javid and Qayyum (2013) among others. These studies mainly employed causality test and co-integration method to identify the causal association between electricity consumption and economic growth. Few studies have concluded that causality runs from energy consumption to GDP [Masih and Masih (1996); Lee (2005); Aqeel and Butt (2001); Siddique (2004)]. On the other hand, few predicted unidirectional causality from real activity to electricity consumption [Jamil and Ahmed (2010)]. Shahbaz, *et al.* (2012) investigate the linkages between energy consumption and GDP using Cobb-Douglas production function over the period 1972-2011 by employing ARDL method. This study indicates that energy consumption enhances economic growth. The causality analysis confirms the existence of feedback hypothesis between energy consumption and economic growth. Javid and Qayyum (2013) estimated the electricity demand function by employing the structural time series technique over the period 1972-2010 for Pakistan. This study finds that the nature of relationship is not linear and deterministic but stochastic.

The empirical literature provides mixed and conflicting results with respect to the electricity consumption-economic growth nexus. There is no consensus on the direction of causality between electricity consumption and economic growth. This inconsistency in outcome is largely due to the use of different econometric techniques and time periods, among other things. As we discussed, these studies mainly use cointegration method to analyse the energy-economic growth nexus.[2] However, Lee and Chiu (2013) argue that these studies assume that "the cointegration relationship of energy demand model takes a linear function form i.e. considered only linear cointegration framework ignoring the non-linear cointegration, which may lead to the misleading conclusion that no cointegration exists between energy demand and its determinants".

The use of non linear methodologies was later witnessed in several studies. For example Hu and Lin (2008) confirm the non-linear cointegration between GDP and disaggregated energy consumption for Taiwan. This study shows that adjustment process of energy consumption toward equilibrium is highly persistent when an appropriate threshold is reached. Esso (2010) used non-linear cointegration method to estimate the energy demand function for African countries. Gabreyohannes (2010) argues that explanatory power of energy consumption-economic growth model can be improved

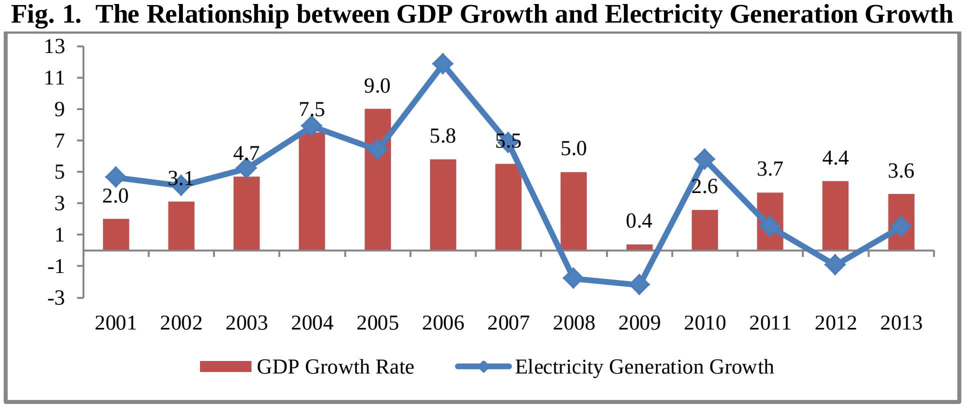
[2]For international see for example Belloumi (2009); Athukorala and Wilson (2010) and so on.

when non-linear effect is included. This helps to design appropriate policies. Thus in this study, we use smooth transition regression model to reexamine the relationship among electricity consumption, real income, and own energy prices for Pakistan using time series data over the period 1971-2012.

3. ELECTRICITY SECTOR IN PAKISTAN

Pakistan has been facing electricity crisis right from its inception to present day. In 1947, Pakistan had capacity to produce only 60 MW for its 31.5 million people and rest was to be imported from India. Pakistan, recently, is producing around 12000 MW with the shortfall of 4000 MW. This crisis has led to formidable economic challenges adversely affecting economic growth. The Figure 1 depicts a strong positive relation between the GDP growth rate and the growth rate of electricity generation.[3] Trend analysis shows that average GDP growth rate remains low during the period of low growth rate of electricity generation. The GDP growth has declined from 5.8 percent in 2006 to 3.6 percent in 2013 when growth rate of electricity generation has declined from 11.8 percent to 1.5 percent during the same period. It is estimated that load shedding and power blackouts have caused a loss of around 2 percent of GDP. The industrial production and exports have been severely affected by power crisis in Pakistan. The growth rate of industrial sector has declined from 7.7 percent in 2007 to 2.7 percent in 2012. A study has shown that industrial output has declined in the range of 12 to 37 percent due to power shortages [Siddiqui, *et al*. (2011)]. The export growth declined from 4.6 percent to –2.8 percent during same period.

Fig. 1. The Relationship between GDP Growth and Electricity Generation Growth



Source: Pakistan (2013).

4. DATA AND METHODOLOGY

4.1. Data

Our empirical analysis is based on time series data covering the period 1971-2012. The data on electricity consumption and output is obtained from World Development Indicators (WDI). For electricity consumption, we have used electric power consumption

[3]The simple correlation between these two variable is 0.513.

(kWh) per capita. The electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution and transformation losses and own use by the heat and power plants. For output, we have used GDP per capita at constant local currency units. GDP per capita is gross domestic product divided by midyear population. The data on prices is collected from various issues of the *Pakistan Energy Year Book*. The average real prices are derived by adjusting for CPI. The log transformation is applied on all the variables.

4.2. Methodology

The stationarity properties of the variables are examined using standard unit root test such as Augmented Dickey Fuller (ADF) test and Philips-Perron (PP) test. However, in the presence of a structural break, the standard ADF tests are biased towards the non-rejection of null hypothesis. Shahbaz and Lean (2012) pointed that the standard unit test such as AD and PP may provide inefficient and biased estimates in the presence of structural break in the data.

To overcome this problem, we have used unit root test proposed by Saikkonen and Lutkepohl (2002) and Lanne, *et al*. (2002). The model with structural break is considered $y_t = \mu_0 + \mu_1 t + f_t(\theta)'\gamma + \epsilon_t$. Where $f_t(\theta)'\gamma$ represents the shift function while θ and γ are unknown parameters and ϵ_t is error term generated by $AR(p)$ process with unit root. A simple shift dummy variable with the shift date T_B is used on the basis of exponential distribution function. The function $f_t = d_t \begin{Bmatrix} 0 & t < T_B \\ 1 & t \geq T_B \end{Bmatrix}$ does not involve any parameters θ in the shift term $f_t(\theta)'\gamma$ where γ is a scalar parameter. Differencing this shift function leads to an impulse dummy. We follow Lanne, *et al*. (2002) to choose the structural breaks exogenously which allows us to apply ADF-type test to examine the stationarity properties of the series. Once a possible break is fixed, a more detailed analysis may be useful to improve the power of the test. The critical values are tabulated as in Lanne, *et al*. (2002).

After establishing the time series properties of the variables, we estimated electricity demand function for Pakistan. To estimate linear demand function for comparison purpose with the existing literature, we apply Autoregressive distributed lag (ARDL) bound testing approach to cointegration proposed by Pesaran, *et al*. (2001) to examine the long run relationship between the variables.[4] To examine the stability of the ARDL bounds testing approach to cointegration, we apply stability test namely CUSUM and CUSUMSQ. Akaike Information Criteria (AIC) is used to select the optimal lag length.

To estimate nonlinear electricity demand function, we employ smooth transition autoregressive model (STAR) introduced by Teräsvirta (1998)—the most significant regime switching model.[5] The STAR models are widely used to estimate nonlinear relations for time series data because of their smooth transition mechanism in different regimes. In contrast to threshold autoregressive models that use indicator function to control the regime switching process, STAR models make use of logistic and exponential function for this purpose. Various studies have shown that these models can fit the

[4]For more detail on ARDL see Pesaran, *et al*. (2001).
[5]For more detail on STAR see Teräsvirta (1998).

regime switching mechanisms properly for evaluation of nonlinear dynamism of variables [Van Dijk and Teräsvirta (2002)]. After fitting the nonlinear model, various diagnostic tests are used to check the adequacy of the proposed model including serial correlation, uneven variance and normality tests.

5. EMPIRICAL RESULTS

The descriptive statistics analysis and correlation matrix among the variables are presented in Table 1. This analysis gives information on the mean, range and the scale of the relationship between the variables. The descriptive statistics show that the average electricity consumption per capita is 5.5 kWh. The average GDP per capita is Rs 10.04 and average real price of electricity is Rs 1.29. The correlation coefficient matrix shows that output and prices have positive and significant correlation with the electricity consumption.

Table 1

Descriptive Statistics

Statistics	L_nE_t	L_nO_t	L_nP_t
Mean	5.50	10.04	1.29
Maximum	6.16	10.48	1.68
Minimum	4.49	9.58	0.78
Std. Dev.	0.55	0.27	0.25
Observations	42	42	42
Correlation			
L_nE_t	1.0000		
L_nO_t	0.9826*	1.0000	
L_nP_t	0.7768*	0.7125*	1.0000

Note: The * represents the significant correlation.

The time series properties of the data are tested using augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) statistics. The results of ADF and PP tests on the integration of the variables are reported in Table 2. The results indicate that all variables are non-stationary at level. Further, all variables turn out to be stationary after applying difference transformation indicating that all variables are integrated of order one.

Table 2

Results of the Unit Root Test

	ADF		PP		
Variables	Intercept	Intercept and Trend	Intercept	Intercept and Trend	Results
L_nE_t	–2.02	–0.18	–2.02	–0.24	Non-stationary
ΔL_nE_t	–5.42	–6.24	–5.44	–6.25	Stationary
L_nO_t	–0.90	–1.74	–0.29	–1.85	Non-stationary
ΔL_nO_t	–5.87	–5.83	–4.56	–4.97	Stationary
L_nP_t	–2.17	–2.63	–2.02	–1.68	Non-stationary
ΔL_nP_t	–4.56	–4.97	–4.56	–5.00	Stationary

Note: The critical values are –3.60, –2.94 and –2.61 at 1 percent, 5 percent and 10 percent respectively with intercept and –4.20, –3.52 and –3.19 at 1 percent, 5 percent and 10 percent respectively with intercept and trend.

To confront the possibility of structural break, we have used test proposed by Saikkonen and Lutkepohl (2002) and Lanne, *et al*. (2002). The results of Saikkonen and Lutkepohl unit root test are presented in Table 3. We use an impulse and shift dummy to detect the structural break in all variables. The electricity consumption per capita is stationary at first difference with presence of structural break in 1992. The implementation of structural adjustment program and shift of electricity generation mix from hydro to thermal are the foremost sources of this structural break. The real GDP per capita is stationary at first difference and has a structural break in 1980 that primarily occurs due to policy reversal from nationalisation to privatisation. The electricity prices are stationary at first difference with structural break in 1996.

Table 3

Saikkonen and Lütkepohl Unit Root Test

Variables	Impulse Dummy	Shift Dummy	Break
L_nE_t	–2.44	–2.45	1992
ΔL_nE_t	–5.00***	–3.60***	1992
L_nO_t	–0.96	–1.35	1980
ΔL_nO_t	–5.25***	–3.44**	1980
L_nP_t	–2.81	–2.48	1996
ΔL_nP_t	–4.20***	–2.92**	1996

Note: Critical values [Lanne, *et al*. (2002)] are –3.48, –2.88 and –2.58 at 1 percent (***), 5 percent (**) and 10 percent (*) respectively.

The long run and short rum impact of output and prices on electricity consumption are estimated using ARDL bound testing approach to cointegration. The appropriate lag length is one based on the AIC. The F-statistics that we obtained for the demand function is 5.8 which support the hypothesis of cointegration for the proposed model (Table 4). These results confirm the long rum relationship between the electricity consumption, output and prices.

Table 4

Result of Bounds Testing to Conintegration

F-Statistic	95% Lower Bound	95% Upper Bound
5.8068	4.1556	5.2670

We also apply Johansen and Juselius (1990) cointegration approach to confirm the robustness of a long run relationship among the variables. The results confirm the existence of a long run relationship among electricity consumption, output and prices (Table 5). These findings also reveal that long run relationship is valid and robust.

Table 5

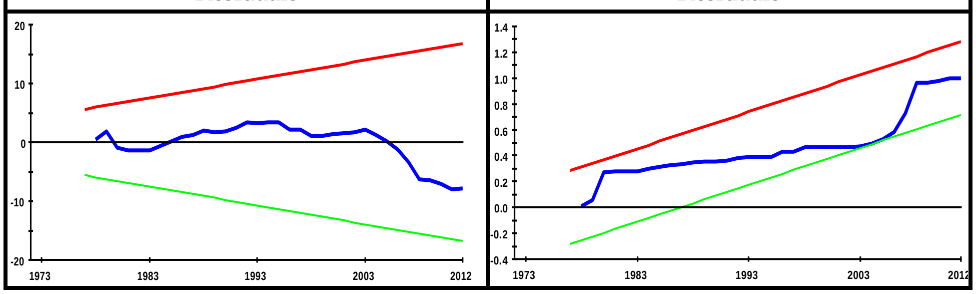
Results of Johansen Cointegration Test

Hypothesis	Trace Statistics	Max-Eigen Statistics
None *	41.20099***	28.29968***
At most 1	12.90131	7.715994
At most 2	5.185311	5.185311

The autoregressive distributed lag model has been employed to estimate electricity demand function in linear fashion. This is done for the sake of comparison with the earlier literature. The results are presented in Table 6. We have used various diagnostic tests to ensure that the model is adequately specified. F-statistics confirms the adequacy of the estimated model. The results of serial correlation test, normality test and heteroscedasticity test are consistent with requirements. The CUSUM and CUSUMSQ tests are applied to examine the stability of long run parameters and results are plotted in Figure 2. The figure portraits that plotted data points are within the critical bounds implying that the long run estimates are stable. The straight lines represent critical bounds at 5 percent significance level.

Fig. 2. Plot of Cumulative Sum and Cumulative Sum of Squares of Recursive Residuals

Cumulative Sum of Recursive Residuals	Cumulative Sum of Squares of Recursive Residuals



The long run estimates show that output has a positive impact on electricity consumption implying that increasing level of development amplifies the demand for electricity consumption. The estimated coefficient is 1.3 which is statistically significant at 1 percent level showing that 1 percent increase in GDP per capita raises demand for electricity by 1.3 percent. This indicates that electricity demand is highly sensitive to the development of overall economy. Our findings are comparable with the existing literature [see e.g. Javid and Qayyum (2013)]. The long run estimates further exhibit that electricity prices have a positive impact on electricity consumption. The estimated coefficient is 0.56 which is statistically significant at 1 percent level implying that 1 percent increase in prices leads to 0.5 percent increase in electricity consumption. The small value of coefficient indicates that consumption is not reactive to price change. Further, the positive association signifies that prices are below the optimal level.

The short run estimates show that GDP per capita has a positive influence on electricity consumption. The estimated coefficient is 0.24 which is significant at 10 percent level implying that increase in the growth rate of GDP per capita by 10 percentage points increases the growth of electricity consumption by 2.4 percentage points. Similarly, electricity prices have a positive and significant impact on electricity consumption. The estimated coefficient is showing that 10 percentage points increase in the growth of prices causes escalation in electricity consumption by 1 percentage point. It is also noted that the coefficient of lagged error correction term is negative and statistically significant at 1 percent level of significance. The significance of error correction term supports the established relationship among the variables. The negative coefficient implies that the deviation in the short run towards long run is corrected by 18 percent from the previous period to the current period.

Table 6

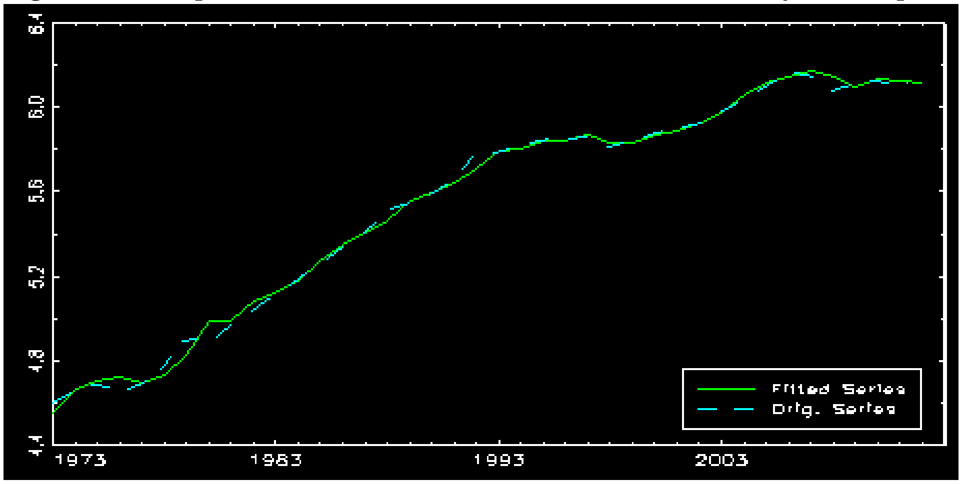
ARDL Estimates (1,0,0)

Variables	Coefficient	Std. Error	T-Statistics
		Long Run Results	
LnO_t	1.3064	0.27648	4.7252***
LnP_t	0.56351	0.22063	2.5541***
Constant	–8.1680	2.6323	–3.1030***
		Short Run Results	
ΔLnO_t	0.24089	0.13495	1.7850*
ΔLnP_t	0.10390	0.03926	2.6465***
ECM_{t-1}	–0.18438	0.07053	–2.6140***
R^2		0.31	
F-Statistics		5.45***	
Serial Correlation		0.60246[.438]	
Normality Test		0.86242[.650]	
Heteroscedasticity Test		0.79563[.372]	

The first step in the estimation of STAR model is to select appropriate transition variable from all variables existing in model and the one with the highest probability of rejecting the null hypothesis of linearity will be chosen as the transition variable. The results show that the transition variable is electricity prices and appropriate mode is logistic smooth transition autoregressive model with one of type 1 (LSTAR1). Selecting electricity prices as the threshold variables, the LSTAR1 nonlinear model is considered for modelling the electricity demand in Pakistan.

The estimation results of LSTAR1 model are presented in Table 7. We have used various diagnostic tests to ensure that the model is adequately specified. The results of normality test are consistent with requirements. The results show that there is no autocorrelation error in the LSTAR1 model. The residuals of nonlinear LSTAR1 model are even with variance; therefore there is no variance unevenness in the model. The absence of variance unevenness and serial autocorrelation in the residuals of this model add to the reliability of the obtained results. The comparison between the real trend and the fitted trend of electricity consumption is presented in Figure 3.

Fig. 3. The Comparison between Real and Fitted Trend of Electricity Consumption



The two regime model indicates that the slope coefficient equals 12.8, which signifies a rather fast transition from one regime to another. The threshold extreme of the mode is 1.46—the anti-logarithmic value is 4.32 as the real price of electricity. The average real electricity price is Rs 3.88 which is below the threshold level i.e. Rs 4.32. These results are consistent with the findings of linear model where we argue that the positive association between electricity price and electricity consumption is mainly due to the reason that the prices are below the optimal price level. The estimation results further show that the impact of price becomes insignificant after reaching the threshold level. The estimated coefficient of electricity consumption is insignificant in the non-linear part of the model.

For further explanation on the estimation results of the model, two extreme regimes of the model, that is the mode in which transition function is considered as 0 and 1 (G=0, G=1), are specified as below:

First extreme regime (G=0)

$$LnE_t = -0.93 + 0.83LnE_{t-1} + 0.17LnO_t + 0.17LnP_t$$

Second extreme regime (G=1)

$$LnE_t = -9.63 + 0.45LnE_{t-1} + 01.22LnO_t + 0.26LnP_t$$

The estimated coefficient of output is positive and statistically significant in both regimes implying that output per capita is the major determinant of electricity demand in Pakistan. However, the influence of GDP per capita is greater during the second regime.

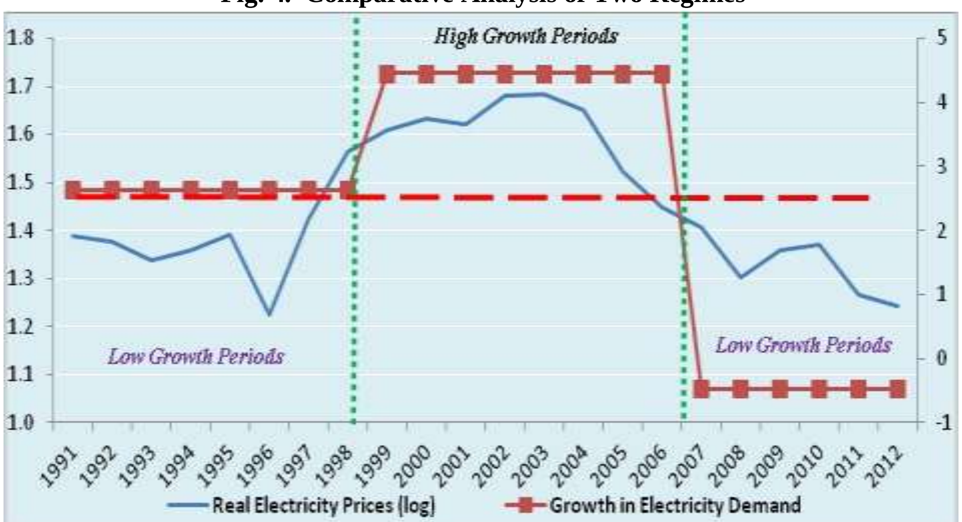
Based on these findings, it can be concluded that electricity demand in Pakistan follows an asymmetric pattern. The demand has strongly been influenced by GDP during high growth period 1999-2006. The price effect during this period has remained insignificant. Whenever, prices are below the threshold level, prices have significant positive impact on the electricity demand. The Figure 4 demonstrates the relationship among electricity prices, GDP per capita growth and average electricity demand.

Table 7

STAR Model with Logistic Transition Function Estimates

Variables	Coefficient	Std. Error	T-Statistics
The Linear Part of the Model			
L_nE_{t-1}	0.8288	0.0806	10.285***
L_nO_t	0.1694	0.0530	3.1962***
L_nP_t	0.1686	0.0566	2.9790***
Constant	–0.9372	1.1275	–0.8312
The Non-Linear Part of the Model			
L_nE_{t-1}	–0.3825	0.2219	–1.7238*
L_nO_t	1.0547	0.5003	2.1082**
L_nP_t	0.0904	0.2666	0.3394
Constant	–8.6937	4.0496	–2.1468**
Slope Parameter γ	12.869	15.643	0.8227
Threshold Extreme C	1.4639	0.0487	30.054***
$\bar{R}^2$			0.99
ARCH-LM Test [p-Value(F)]			0.50
Normality Test (JB Test) [p-Value(Chi^2)]			0.12
Test for Autocorrelation (no-autocorrelation) [p-Value]			0.73

Fig. 4. Comparative Analysis of Two Regimes



The time span from 1991 to 2012 is divided into two regimes. Regime 1 with prices below the threshold level during 1991-1998 and 2007-2012 and regime 2 with price above the threshold level over the period 1999-2006. The figure shows that during regime 2, the average growth in the electricity demand was around 5 percent coupled with high economic growth and electricity prices. On the other hand, the growth in the electricity demand was low during regime 1 in which the growth was also low and prices were below the optimal level.

6. CONCLUDING REMARKS

The present study has estimated the linear and nonlinear electricity demand function for Pakistan using time series data over the period 1971-2012. The study has employed logistic smooth transition regression model for estimation. Time series properties have shown that all variables are stationary at first difference with the possibility of structural break. The estimation results have shown that there is a long run relationship among electricity consumption, GDP per capita and electricity prices.

In the long run, electricity consumption is primarily determined by the level of development. The elasticity of electricity consumption with respect to GDP per capita is greater than unity. The contribution of GDP per capita in determining the demand for electricity is more than unity in high growth period. These observations suggest that continuous investment in electricity generation is required to meet the future requirement of electricity.

The further analysis has shown that the price of electricity has minor impact on electricity consumption. The small value of coefficient indicates that consumption is not reactive to price change. The nonlinear estimation has shown that the average prices of electricity are below the threshold or optimal level. The positive association holds till the prices have reached the optimal level. The prices beyond the optimal level have insignificant contribution to the electricity consumption. These findings suggest that electricity demand is insensitive to the changes in the electricity prices especially beyond the threshold level. The obvious reason for the fragile relationship between electricity demand and electricity prices is lack of alternatives for electricity. Electricity is the main source of energy in Pakistan. The cost of easily available alternative such as oil is higher than the electricity prices. This forces the utilisation of electricity even under increasing prices. The availability of cheap alternatives such as coal, gas or other renewable sources will change the dynamics of the relationship between electricity consumption and electricity prices.

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Comments

I would like to congratulate authors for presenting latest estimates on electricity demand in Pakistan. This study is part of the research projects funded by the Pakistan institute of Development Economics to promote innovative research ideas and novelty in techniques needed to explore burning energy issues of Pakistan. This study makes useful contribution in the existing literature by estimating electricity demand with the new time series model L-STAR – logistic smooth transition model or two regime switching model. This technique distinguishes this study from the earlier contributions in that the former studies have assumed linear relationships in between economic growth or per capita income and electricity demand and used cointegration technique for testing the assumption. The study is well structured as all sections have been properly organized and have coherence. The study provides latest estimates on electricity demand and its relationship with electricity prices and per capita income in Pakistan using data for 1971–2013.

However this study needs to improve on two weaknesses. First, the study has used non-linear technique by using reference of the work done earlier by researchers not in Pakistan. Only a few studies have been mentioned in the section on literature review and more could have been explored. Furthermore, this study has used cointegration technique and found long run relationship between electricity demand, per capita income and electricity prices which is conflicting with the justification for using non-linear technique. This requires on authors to either review the introduction of the study or use other grounds for nonlinear technique use in Pakistan.

Lubna Naz

PhD Scholar,
PIDE, Islamabad.

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Disaggregate Energy Consumption, Agricultural Output and Economic Growth in Pakistan

MUHAMMAD ZAHIR FARIDI and GHULAM MURTAZA

1. INTRODUCTION

The performance of an economy is generally measured by sustained rise in GDP growth over the period of time. The economic growth is the major goal of macroeconomics. According to neo-classical growth theory, the core factors of growth are labour and capital. In addition to these factors; technological progress, human capital development etc. are the most efficient factors of production. Development of technology and use of mechanisation in production process require energy at massive scale. So, energy has become a crucial factor of economic growth indirectly.

Energy is widely regarded as a propelling force behind any economic activity and indeed plays a vital role in enhancing production. Therefore, highly important resources of energy will enhance the technology impact manifold. Quality energy resources can act as facilitator of technology while less worthy resources can dampen the power of new technology. Ojinnaka (1998) argued that the consumption of energy tracks with the national product. Hence, the scale of energy consumption per capita is an important indicator of economic modernisation. In general countries that have higher per capita energy consumption are more developed than those with low level of consumption.

The importance of energy lies in other aspect of development—increase in foreign earnings when energy products are exported, transfer of technology in the process of exploration, production and marketing; increase in employment in energy industries; improvement of workers welfare through increase in worker's salary and wages, improvement in infrastructure and socio-economic activities in the process of energy resource exploitation. Thus in the quest for optimal development and efficient management of available energy resources, equitable allocation and efficient utilisation can put the economy on the part of sustainable growth and development. Arising from this argument, adequate supply of energy thus becomes central to the radical transformation of the nation's economy.

Muhammad Zahir Faridi, PhD <zahirfaridi@bzu.edu.pk> is Assistant Professor at Bahauddin Zakariya University, Multan, Pakistan. Ghulam Murtaza <GM.QAUI@gmail.com, ghulammurtaza_14@pide.org.pk> is Visiting Lecturer at Bahauddin Zakariya University, Multan, Pakistan.

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The main objective of the study is to investigate the effect of disaggregate energy consumption on agricultural output and generally overall growth in Pakistan. Because agriculture is the mainstay of Pakistan economy and is basic production sector. The manufacturing sector, services sector and even communication sector have secondary position albeit their growth rates are higher in absolute terms. The growth rate of agricultural sector is very low. When structural changes have occurred, the process of mechanisation has taken place in the agricultural sector. The use of energy has increased for running the machinery like tubewells, tractors, threshers etc. Due to shortfall of energy, the output of agricultural sector has dropped.

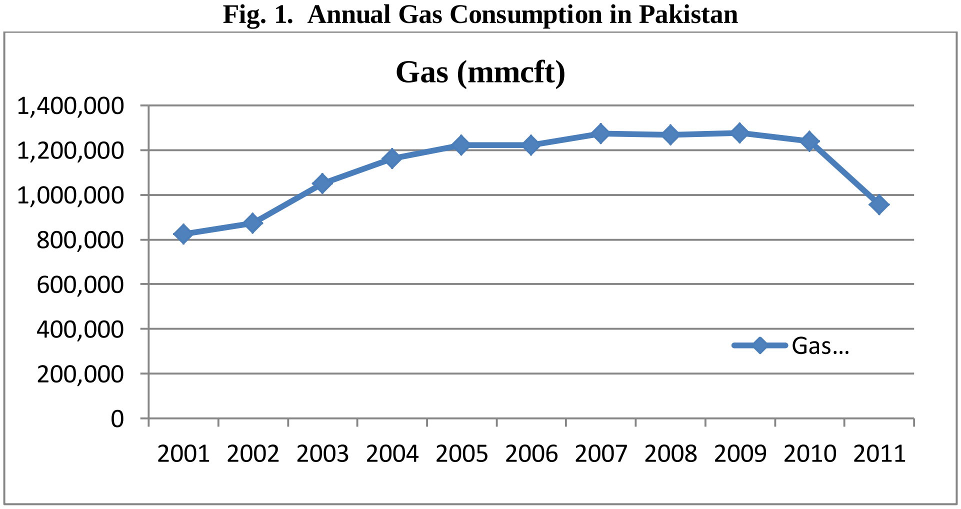
One of the interesting features of the study is that it differentiates short run and the long run effect because it has been observed that impact of energy consumption varies from short to long run for the same country. For this purpose, we have employed ARDL modelling to co-integration to find out long run and short run effect. Unit root problem of the data is handled by ADF test. The rest of the article is structured as follows. Trends and structure of energy variables are given in Section 2. Section 3 provides literature review in detail while data and methodology are given in Section 4. Empirical results and their discussion are presented in Section 5. At the end, some policy implications for energy consumption are suggested on the basis of empirical results.

2. TRENDS AND SIZE OF PAKISTAN ANNUAL ENERGY CONSUMPTION

Total energy consumption measured in oil consumption is 38.8 million tonnes in the year of 2010-11. Currently gas consumption is the leading one in total energy consumptions that is 43.2 percent of total energy consumption. Since 2005-06, Gas, electricity and coal consumption are equally utilised. Oil consumption stood at second position regarding usage as its usage is 29 percent of total energy consumption.

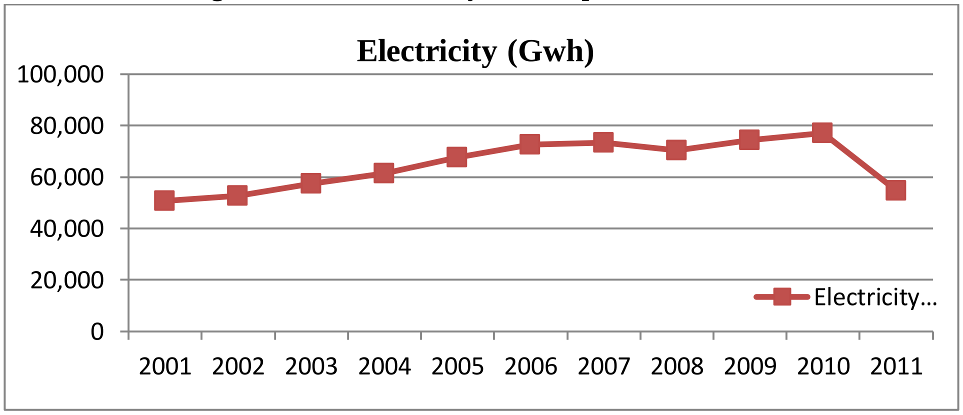
We present the trends of energy consumption at disaggregate level in Pakistan over the last decade. The Figure 1 explains the trends of annual gas consumption. While, Figure 2 and Figure 3 provide the trends of annual electricity consumption and annual oil consumption respectively.

Fig. 1. Annual Gas Consumption in Pakistan



Gas consumption share is equal to four percent of total energy consumption during 2005-06 to 20010-11. This is because of the substitution of gas for expensive energy sources. The consumption of oil in Pakistan decreased by three percent during the period 2001-2011 because of high prices of oil in the international market. Since the year 2001-02, a decreasing trend is observed in the consumption of petroleum products.

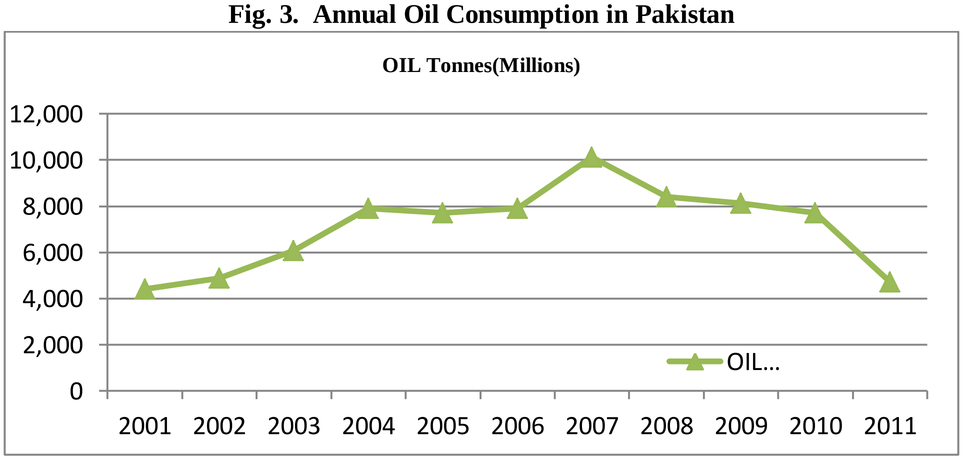
Fig. 2. Annual Electricity Consumption in Pakistan



Source: Pakistan Economic Survey (Various Issues).

Yet it is observed that there has been an increase in oil consumption from 2004-10, the overall average increase for last ten years stood at 11 percent per annum. Trends indicate that due to high volatility in the oil prices consumption intensity is shifting from oil consumption to some others sources of energy consumption. Figure 2 indicates that the trend of annual electricity consumption (in Giga Watt Hour) over the last ten years i.e., 2001-2011. Trends show that electricity consumption increased continuously till 2007 and then fell. But after the year 2010, there is sharp decline in electricity consumption. Thus, Gas, electricity and oil consumption trends indicate an annual increase at an average rate of 5.1 percent, 4.8 percent and 7.7 percent respectively.

Fig. 3. Annual Oil Consumption in Pakistan



Source: Pakistan Economic Survey (Various Issues).

3. LITERATURE REVIEW

Theoretically, neo-classical and endogenous theories both suggest that energy use and efficiency are drivers of economic growth. Though there are many studies that find a direct relationship between productivity and energy consumption in the industrialised world [see Worrell, *et al.* (2001)], evidence from the developing world remains inconclusive. Few disaggregated studies have been conducted on this issue and the studies using data aggregated at the national or economic level indicate mixed findings. Further complicating the relationship is the extent to which economic growth and energy consumption can theoretically be decoupled, a question raised by ecological economists who argue thermodynamic laws limit such division. Below is a brief review of the various theories on the relationship between energy consumption, energy efficiency and economic growth, followed by a summary of a select list of empirical studies.

By incorporating energy end-use efficiency gains into a Cobb-Douglas production function, Wei (2007) theorizes about short-term and long-term effects of increased energy efficiency beginning with the production function specification as output is a function of labour, capital and some measures of energy consumption. In the short term, energy use efficiency is found to lower the cost of non-energy goods and increase the output of non-energy goods. A 100 percent rebound effect is evident such that in the short term, energy efficiency gains have no effect on absolute energy use. In the long term, the impact on non-energy output of energy end use efficiency is positive. The long term impact of energy use efficiency on total energy use is lower than the short-term impact. Wei also finds that energy use efficiency will increase real energy price in the long term. Van Zon and Yetkiner (2003) modify the Romer model to include energy consumption of intermediates and to make them heterogeneous due to endogenous energy-saving technical change. They found out that energy-saving technical transformation can enhance economic growth. On the other hand, it may dampen economic growth with the increase in energy prices that imply that rising real energy prices consistently will cause to harm economic growth.

Embodied technical change includes improvements in energy efficiency, thus positively linking improvements in energy efficiency to economic growth. They conclude that in an environment of rising energy prices, recycling energy tax proceeds in the form of R&D is necessary for both energy efficiency growth and output growth. Sorrell (2009) pointed out that conventional and ecological economists have conflict on the issue of energy effects on economic growth. The growth models presented by Neo-classical and new Endogenous growth theories give little importance to energy consumption as a major factor of production by giving argument that it has a small share in total cost of production. Ecological economist contests their point of view by replying that over the last two centuries, energy inputs are accelerating economic growth at valuable rate.

For a steady economic growth the role of technological change is of great importance as earlier growth models have integrated technological change as an important factor for growth [Solow (1956)]. Energy and raw material besides labour and capital cause to decrease the statistical residual. Onakoya, *et al.* (2013) studied the relationship between energy consumption and Nigerian economic growth during the period of 1975 to 2010 to find out energy consumption as an important variable for production. Co-integration results provided evidence of a long run relationship between energy consumption and economic growth which was positive. Same results were also found by Paul and Bhattacharya (2004) who employed Engle–Granger technique to investigate the direction of relationship between economic growth and energy consumption for India for the period of 1950-1996. Results revealed that energy consumption has causality for energy consumption. Hondroyiannis, *et al.* (2002) followed the same results in case of Greece by using vector error-correction estimation on the data from 1960-1996. The findings of the study indicate the existence of long run relationship.

Oh and Lee (2004) did not find the significant and positive effect of energy consumption on growth in case of Korea. For Bangladesh, Mozumder and Marathe (2007) examined a positive relationship between per capita income and per capita energy consumption. The relationship between gas consumption and growth was analysed by Apergis and Payne (2010) to reveal the co-integration among labour, capital, gas consumption and economic growth. ECM model was employed to find the bidirectional causality between gas consumption and economic growth but Yang (2000) opposed this relationship as his study show the absence of long run relationship between natural gas consumption and real GDP. Same results of no relationship are also found out by Aqeel and Butt (2001).

Shahbaz and Feridun (2011) investigated the impact of electricity consumption on economic growth in Pakistan between 1971 and 2008 by using ARDL technique to identify the long run relationship between electricity consumption and economic growth. Study gives the evidence of long run relationship between electricity consumption and economic growth but inverse is not true. Alam and Butt (2001) investigation provided the evidence that structural changes also cause to change the share of various energy consumption variables. And increase in energy is because of increase in economic activity as well as structural changes.

Javid, *et al.* (2013) argued that shocks to electricity supply will have a negative impact on economic growth. Nwosa and Akinbobola (2012) and Dantama, *et al.* (2011) come to a conclusion that govt. should adopt sector specific energy policies rather the one fit-for-all policy by observing positive aggregate energy consumption and sectoral output.

For Pakistan, Kakar and Khilji (2011) explored the nature of relationship between economic growth and total energy consumption for the period 1980-2009 by using Johansen Co- integration and confirmed that energy consumption is essential for economic growth and any energy shock may affect the long-run economic development of Pakistan. Ahmad, *et al*. (2013) analysed the impact of energy consumption and economic growth in case of Pakistan employing data from 1975 to 2009. The results of ordinary least squares test show positive relation between GDP and energy consumption in Pakistan.

A number of reviews of prior work compel us to make a healthy endeavour on the concerned issues because a little attention has been given to agricultural sector regarding energy consumption relationship. We have observed in the literature review most of the studies are emphasising on the relationship between overall growth and energy, manufacturing sector growth and energy. A few studies discuss the agricultural sector growth and energy. But the present study removes a number of imperfections of previous studies such as use of energy consumption and its relationship with overall economic growth instead of growth in agricultural sector at the disaggregate level. We have used fresh data on certain variables. An appropriate technique for co-integration, model specification and proper estimation technique is employed.

4. DATA AND METHODOLOGY

The present segment consists of data and methodology used to estimate effects of disaggregates energy consumption on economic growth and Agricultural output in Pakistan. To order to analyse relationships, secondary data from year 1972-2011 are employed and Auto Regressive Distributed Lags (ARDL) technique has been used.

(a) Data Source

The data generated from *Pakistan Economic Survey* (various issues), *Handbook of Statistics of Pakistan Economy*. While, data on variables of energy consumption, have been obtained from HDIP, Ministry of Petroleum and Natural Resources. The variables about which data are collected, are RGDP (Gross Domestic Product) that is used as dependent variable while RGFCF (Real Gross Fixed Capital Formation), TELF (Total Employed Labour Force), IR (Inflation Rate), TOC (Total Oil Consumption), TGC (Total Gas Consumption), TEC (Total Electricity Consumption), AGRI (Agricultural Output), TELF (Total Employed Labour Force), RAGFCF (Real Agricultural Gross Fixed Capital Formation), TOC (Total Oil Consumption), TGC (Total Gas Consumption), TEC (Total Electricity Consumption), ACRDT (Agricultural Credit).

(b) Methodological Issues

The study is based on time series data. In order to examine the properties of the time series data, we first examine the stationarity of data and then decide about the appropriate technique.

(i) *Stationarity of Data*

In practice, ADF test is used to check the stationary of variables to see if all the variables are integrated of degree one. In this case, the variables can be estimated by employing error correction model because of co-integrated series. However, if all the variables are not integrated of same degree i.e. some variables are integrated at I (1) or some are at I (0) or both I(1) and I(0) then ARDL modeling approach will be employed to identify the existence of long run and short run relationships among the variables.

(ii) *Auto Regressive Distributed Lag Approach to Co-integration*

ARDL approach will be applied only on single equation. It will estimate the long run and short run parameters of model simultaneously. The estimated model obtained from the ARDL technique will be unbiased and efficient. ARDL approach to co-integration is useful for small sample Narayan (2004). Engel-Granger and Johensan technique are not reliable for small samples. ARDL gives better results in sample rather than Johesan co-integration approach. ARDL approach has a drawback because it is not necessary that all variables are of same order. The variables can be at I(0) or I(1) or combination of both, the ARDL approach can be applied. If the variables are stationary at higher order of I(1) then ARDL is not applicable. ARDL approach consists of two stages. First, the long run relationship between variables is tested using F-statistics to determine the significance of the lagged levels variables. Second, the coefficient of the long run and short run relationship will be examined.

(iii) *Bound Testing Procedure*

The bound test is based on three basic assumptions that are; first, use ARDL model after identifying the order of integration of series Pesaran, *et al*. (2001). Second, series are not bound to possess the same order of integration i.e., the regressors can be at I(0) or I(1). Third, this technique estimates better results in case of small sample size. The vector auto regression (VAR) of order *p*, for the economic growth function can be narrated as Pesaran, *et al*. (2001);

$$Z_t = \mu + \sum_{i=1}^{p} \beta_i z_{t-i} + \varepsilon_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where x_t and y_t are included in vector z_t. Economic growth (RGDP) and agricultural output (AGRI) are indicated by y_t and x_t is the vector matrix which represents a set of explanatory variables such as [*Xt* = *RGFCF*, *TELF*, *TOC*, *TEC*, *TGC*, *IR*] and [*Xt* = *TELF*, *RGFCF*, *TOC*, *TGC*, *TEC*, *ACRDT*] for Model-1 and Model-2 and *t* denotes time indicator. Vector error correction model (VECM) is given as below:

$$\Delta z_t = \mu + \alpha t + \lambda z_{t-1} + \sum_{i=1}^{p-i} \gamma_t \Delta y_{t-i} + \sum_{i=1}^{p-1} \gamma_t \Delta x_{t-i} + \varepsilon_t \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where Δ is the first-difference operator. The long-run multiplier matrix λ as:

$$\lambda = \begin{bmatrix} \lambda_{YY} \lambda_{YX} \\ \lambda_{XY} \lambda_{XX} \end{bmatrix}$$

The diagonal elements of the matrix are unrestricted, so the selected series can be either I(0) or I(1). If $\lambda_{YY} = 0,$ then *Y* is I(1). In contrast, if $\lambda_{YY} < 0,$ then *Y* is I(0).

The VECM procedures described above are imperative in the testing of at most one co-integrating vector between dependent variable y_t and a set of regressors x_t. To build up the model, study uses Pesaran, *et al*. (2001) postulation of Case V, that is, unrestricted intercepts and trends.

(c) Description of the Variables

In the present analysis, we have used the variables like employed labour force and real gross fixed capital formation as theoretical variables for growth and there are three core variables relating to energy. Two variables are used as control factors. The explanation and hypothetical relation of these variables are given below.

Real Gross Domestic Product (RGDP)

Real gross domestic product at factor cost is used as proxy for economic growth. It is assumed as GDP expands over the period of time, the economy will grow. RGDP is measured in millions rupees.

Agricultural Output (AGRI)

In order to measure the performance of agricultural sector, we have used agricultural output measured at current market prices in million rupees.

Real Gross Fixed Capital Formation (RGFCF)

We have considered real gross fixed capital formation as a proxy for capital in the present study. It is measured at market prices in million rupees.

Total Employed Labour Force (TELF)

Labour is used as a core variable in economic growth model. It is expected that labour contributes positively to economic growth. The present study uses total employed labour force as a proxy for labour. Total employed labour force is measured in millions peoples.

Total Oil Consumption (TOC)

Total oil consumption is measured in thousands of tonnes per year. It is expected that oil consumption has positive relationship with growth.

Total Gas Consumption (TGC)

It is expected that the utilisation of gas consumption cause to increase the GDP growth positively. We have used total gas consumption in million cubic feet (mmcft).

Total Electricity Consumption (TEC)

Use of electricity in production process is an important factor. Due to shortage of electricity it is expected that total electricity consumption is contributing negatively to GDP growth as well as to agriculture output. The total electricity consumption per Annam is measured in Giga Watt hour (GWh) or (10^6 Kilo Watt hour).

Agricultural Credit (ACRDT)

Agricultural credit is used as a central variable in the present analysis. The expected impact of agricultural credit on output is positive. Agricultural credit is measured in million rupees.

Inflation Rate (IR)

In order to examine the effect of general price level on economic growth, we have used consumer price index as a proxy for inflation rate. The inflation rate has negative impact on economic growth because cost of the production increases, output falls and growth is retarded.

(d) Model Specification

The current study is based on general Neo-classical Production Function;

$$Y = A\,f\,(L, K) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

Where, Y = Total output, L = Total employed labour force, K= Total stock of capital, A= Total productivity factor.

We have employed extended neo-classical growth model by incorporating energy as a productivity factor as an endogenous variable.

$$A = f\,(TOC, TGC, TEC) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (4)$$

Substituting A in Equation (i), we obtained extended growth model.

$$Y = f\,(L\,,K\,,TOC\,,TGC\,,TEC\,) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (5)$$

Based on the suggested economic techniques, we have two specified model. These specified models are given below.

Model-1. Impact of Disaggregate Energy Consumption on Economic Growth

$$\begin{aligned}\Delta(RGDP)_t = {} & \beta_0 + \sum_{i=0}^{a}\beta_{1i}\Delta(RGFCF)_{t-i} + \sum_{i=0}^{b}\beta_{2i}\Delta(TELF)_{t-i} + \sum_{i=0}^{c}\beta_{3i}\Delta(TOC)_{t-i} + \sum_{i=0}^{d}\beta_{4i}\Delta(TGC)_{t-i} \\ & + \sum_{i=0}^{e}\beta_{5i}\Delta(TEC)_{t-i} \ \sum_{i=0}^{g}\beta_{7i}\Delta(IR)_{t-i} + \beta_8(RGDP)_{t-1} + \beta_9(RGFCF)_{t-1} + \sum_{i=1}^{f}\beta_{6i}\Delta(RGDP)_{t-i} + \\ & + \beta_{10}(TELF)_{t-1} + \beta_{11}(TOC)_{t-1} + \beta_{12}(TGC)_{t-1} + \beta_{13}(TGC)_{t-1} + \beta_{14}(IR)_{t-1} + u_t \quad \cdots \quad (6)\end{aligned}$$

Where, Δ is the first-difference operator while *Ut* is a white-noise disturbance term. This model would estimate the impact of disaggregate energy consumption on economic growth in which real GDP is used as dependant variable while real gross fixed capital formation (proxy for capital), total employed labour force, total oil consumption, total gas consumption an total electricity consumption are used as independent variables.

Equation (6) also can be viewed as an ARDL of order (*a, b, c, d, e, f, g*). Equation (6) indicates that economic growth tends to be influenced and explained by its past values. The structural lags are established by using minimum Schwarz Information Criteria (SIC). In our model, we will use the lagged value of first difference dependent variable and independent variables for short run and first lagged values of dependent and independent variables for long run. So, this model is consisted of both long run and short run coefficients of variables as well. Where β_1, β_2, β_3, β_4, β_5 and β_6, β_7 are the short run coefficients of variables and β_8, β_9, β_{10}, β_{11}, β_{12} and β_{13}, β_{14} are the long run coefficients of variables and β_0 is the intercept term.

Model-2. Impact of Disaggregate Energy Consumption on Agricultural Output

The second model would capture the effect of energy consumption on agricultural output in Pakistan with the help of some explanatory variables like TELF (Total Employed Labour Force), RGFCF (Real Gross Fixed Capital Formation), TOC (Total Oil Consumption), TGC (Total Gas Consumption), TEC (Total Electricity Consumption), ACRDT (Agricultural Credit); the unrestricted ECM model for Agricultural output is as under;

$$\Delta AGRI_t = \phi_0 + \sum_{i=1}^{p} \phi_{1i}\Delta(TELF)_{t\text{-}i} + \sum_{i=0}^{q} \phi_{2i}\Delta(RGFCF)_{t\text{-}i} + \sum_{i=0}^{r} \phi_{3i}\Delta(TEC)_{t\text{-}i} + \sum_{i=0}^{s} \phi_{4i}\Delta(TGC)_{t\text{-}i}$$
$$+ \sum_{i=0}^{t} \phi_{5i}\Delta(TOC)_{t\text{-}i} + \sum_{i=0}^{u} \phi_{6i}\Delta(ACRDT)_{t\text{-}i} + \sum_{i=1}^{v} \phi_{7i}\Delta(AGRI)_{t\text{-}i} + \gamma_1(AGRI)_{t\text{-}1} + \gamma_2(TELF)_{t\text{-}1}$$
$$+ \gamma_3(RGFCF)_{t\text{-}1} + \gamma_4(TEC)_{t\text{-}1} + \gamma_5(TGC)_{t\text{-}1} + \gamma_6(TOC)_{t\text{-}1} + \gamma_7(ACRDT)_{t\text{-}1} + \mu_t \quad \cdots (7)$$

Where Δ shows the first difference operator and U_t is the residual of the model.

Equation (7) also can be viewed as an ARDL of order (*p, q, r, s, t, u, v*). Where ϕ_{li}, ϕ_{2i}, ϕ_{3i} and ϕ_{4i}, ϕ_{5i}, ϕ_{6i}, ϕ_{7i} are the short run coefficients of variables and γ_1, γ_2, γ_3, γ_4, γ_5, γ_6 and γ_7 are the long run coefficients of variables and ϕ_0 is the intercept term.

The Wald Test (F-statistics)

After regression of Equation (6) and Equation (7), the Wald test (*F*-statistic) is computed to differentiate the long-run relationship between the concerned variables. The Wald test can be carried out by imposing restrictions on the estimated long-run coefficients of real GDP, total employed labour force, real gross fixed capital formation, total oil consumption, total gas consumption, total electricity consumption and inflation rate for the Model-1 as under:

The null hypothesis is as follows;

$H_0: \beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = 0$ (No long-run relationship exists)

Against the alternative hypothesis,

$H_1: \beta_8 \neq \beta_9 \neq \beta_{10} \neq \beta_{11} \neq \beta_{12} \neq \beta_{13} \neq \beta_{14} \neq 0$ (A long-run relationship exists)

If the calculated F-statistics does not exceed lower bound value, we do not reject Null Hypothesis and it is concluded that there is no existence of long run relationship between RGDP and independent variables. On the other hand, if the calculated F-statistics exceeds the value of upper bound, the co-integration exists between RGDP and independent variables. We will apply the Wald coefficient test on all lagged explanatory and dependant variables in the model Equations (7). Our null hypothesis will be that lagged coefficient of explanatory variables are equal to zero or absent from the model. If we do not reject the null hypothesis it means long run relationships among variables do not exist.

Null and alternative hypothesis for Model-2 to apply Wald test is as follows.

H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 0$ (No Cointegration Exists)
H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq \gamma_7 \neq 0$ (Cointegration Exists)

(d) The Time Horizons

To see the effects of explanatory variables on economic growth in case of Pakistan both in the short run and long run, we have to estimate the model which are given Equations (6) and (7) with OLS (Bound test approach to co-integration) technique and then normalise the resulting values. The ARDL model for the long run coefficient of

Model-1Equation (6) is to determine the long run effect of energy consumption on economic growth in Pakistan.

$$RGDP_t = \eta_0 + \sum_{i=1}^{k_1} \eta_{1i}(RGDP)_{t-i} + \sum_{i=0}^{k_2} \eta_{2i}(RGFCF)_{t-i} + \sum_{i=0}^{k_3} \eta_{3i}(TELF)_{t-i}$$
$$+ \sum_{i=0}^{k_4} \eta_{4i}(TEC)_{t-i} + \sum_{i=0}^{k_5} \eta_{5i}(TOC)_{t-i} + \sum_{i=0}^{k_6} \eta_{6i}(TGC)_{t-i}$$
$$+ \sum_{i=0}^{k_7} \eta_{7i}(IR)_{t-i} + \varepsilon_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

The ARDL model for the long run coefficients of Model-2 Equation (7) is to capture the long run energy consumption effects on agricultural output in Pakistan.

$$AGRI = \theta + \sum \theta (TELF) + \sum \theta (RGFCF) + \sum \theta (TOC)$$
$$+ \sum \theta (TEC) + \sum \theta (TGC) + \sum \theta (ACRDT) + \mu \quad \ldots \quad (9)$$

Now we will find the short coefficient of the model with error correction term. We will use the short run error correction estimates of ARDL model. The difference between actual and estimated values is considered as error correction term. Error correction term is defined as adjustment term showing the time required in the short run to move toward equilibrium value in the long run. The coefficient of error term has to be negative and significant. The short run error correction (ECM) model of Model-1 Equation (6) to find out impact of energy consumption on economic growth in time adjusting frame work to attain long run equilibrium is as follows;

$$\Delta RGDP_t = \rho_0 + \sum_{i=1}^{k_1} \rho_{1i}\, \Delta(\mathrm{RGDP})_{t-i} + \sum_{i=0}^{k_2} \rho_{2i}\, \Delta(\mathrm{RGFCF})_{t-i} + \sum_{i=0}^{k_3} \rho_{3i}\Delta(\mathrm{TELF})_{t-i} + \sum_{i=0}^{k_4} \rho_{4i}\, \Delta(\mathrm{TOC})_{t-i}$$
$$+ \sum_{i=0}^{k_5} \rho_{5i}\, \Delta(TGC)_{t-i} + \sum_{i=0}^{k_6} \rho_{6i}\, \Delta(TEC)_{t-i} + \sum_{i=0}^{k_7} \rho_{7i}\, \Delta(IR)_{t-i} + \lambda(ECM)_{t-1} + \varepsilon_t \quad \ldots \quad (10)$$

ECM_{t-1} is lagged error correction term of the model and λ is the coefficient value of ECM which is the speed of adjustment.

The short run (ECM) model of Model-2 Equation (7) to find out impact of energy consumption on Agricultural output in Pakistan in time adjusting frame work to attain long run equilibrium is as follows.

$$\Delta\, AGRI_t = \sigma_0 + \sum_{i=1}^{k_1} \sigma_{1i}\, \Delta(\, RGFCF)_{t-i} + \sum_{i=0}^{k_2} \sigma_{2i}\, \Delta(\, TELF)_{t-i} + \sum_{i=0}^{k_3} \sigma_{3i}\Delta(\, TOC)_{t-i}$$
$$+ \sum_{i=0}^{k_4} \sigma_{4i}\Delta(\, TGC)_{t-i} + \sum_{i=0}^{k_4} \sigma_{4i}\Delta(\, TEC)_{t-i} + \omega(ECM)_{t-1} + \mu_t \quad \ldots \quad (11)$$

ECM_{t-1} is lagged error correction term of the model and ω is the coefficient value of ECM which is the speed of adjustment.

The Error Correction Term (EC_{t-1})

The error correction term (EC_{t-1}), which instrument the adjustment speed in the dynamic model for restoring equilibrium. Banerjee, *et al.* (1998) grasped that a highly significant error correction term is further proof of the existence of stable long run relationship. The negative sign of error correction term also give uni-directional effect of variables.

4. RESULTS AND DISCUSSIONS

After discussing the data sources, we analyse the impact of disaggregate energy consumption on economic growth and Agricultural output on empirical grounds. To analyse these issues, we will provide an insight to draw some conclusions on the basis of empirical results of this research. The results are discussed as follows.

(a) Descriptive Analysis

The descriptive statistics of the study are presented in the Table 1. Descriptive statistics consists of procedures used to summarise and describe the characteristics of a set of data. The table shows the averages values, standard deviation, skewness, kurtosis and J. Bera values of the selected variables.

Table 1

Descriptive Statistics of Variables

Variables	Mean	Std. Dev.	Skewness	Kurtosis	J.Bera	Prob.
AGRI	587531.9	737717.6	1.70	5.41	28.33	0.00
IR	9.633333	5.732839	1.87	7.08	50.07	0.00
RGDP	1507061	1991864	1.07	2.38	8.16	0.01
RGFCF	8910.988	5118.798	0.76	2.87	3.81	0.14
TEC	32961.79	22153.06	0.40	1.96	2.77	0.24
TELF	31.31373	8.480152	0.26	1.98	2.13	0.34
TGC	550732.2	371132	0.78	2.41	4.53	0.10
TOC	10465494	5656927	-0.00	1.44	3.93	0.13
ACRDT	43420	66478	2.00	5.85	39.39	0.00

Source: Authors' calculations.

Our study is based on the 41 years of annual observation for the period 1972-2011. Descriptive statistics on some important variables are reported in Table 1. We have found that the average agriculture productivity is 587531.9 million rupees with 737717.6 units' standard deviation. The mean value of the total oil consumption, total gas consumption is 10465494 units, 32961.79 units and 550732.2 units respectively with low variability as compared with mean values. The value of Jarque- Bera JB test states that residual of the core variables like RGFCF, TEC, TELF, TGC and TOC are normally distributed. The values of the co-efficient of skewness show that almost all the variables are positively skewed expect total oil consumption.

(b) ADF Test for Stationarity

Table 2 explains the summary statistics of ADF test. The results of the test indicate that some variables are stationary at level and others are stationary at first difference. The findings of the study provide the justification of ARDL Approach.

Table 2

Results of ADF Test

Variables	ADF Statistic (At Level) Intercept	ADF Statistic (At Level) Trend and Intercept	ADF (With First Difference) Intercept	ADF (With First Difference) Trend and Intercept	Order of Integration
IR	–3.252	–3.394	–	–	I(0)
ACRDT	3.503	2.740	–1.848	–2.754	I(1)
RGDP	0.648	–1.289	–5.966	–6.346	I(1)
TELF	1.728	–0.477	–7.827	–8.092	I(1)
RGFCF	–0.602	–3.344	–	–	I(0)
TOC	–0.993	–3.568	–	–	I(0)
TGC	1.414	–2.831	-3.783	-2.948	I(1)
TEC	–2.076	–3.229	–	–	I(0)
AGRI	3.503	2.740	–1.848	–3.754	I(1)

Note: Results are based on authors' calculations.

Bounds Test for Co-integration

In the first step the existence of the long run relationship among the variables is needed. We have used Bound Testing Approach in order to examine the long run relationship. Table 3 interprets the findings of Wald-Test (F-Statistics) for long-run relationship.

Table 3

Results of Bound Test for Co-integration

Equations	F-statistic Calculated	Upper Bound Critical Value	Conclusion
Model-1 Equation (6) RGDP / RGFCF, TELF, TOC, TGC, TEC, IR	7.42 [0.0002]	4.90 (99%)	Co-integration exists
Model-2 Equation (7) ARGI / RGFCF, TELF, TOC, TGC, TEC, ACRDT	13.51 [0.000]	4.90 (99%)	Co-integration exists

Note: Computed F-statistic: 7.42 and 13.51 (Significant at 1 percent marginal values). Critical Values at $k = 7-1=6$ and $k = 7-1=6$ are cited from Pesaran, *et al.* (1999), Table CI (V), Case V: Unrestricted intercept and Unrestricted trend. The numbers in parenthesis shows the probabilities of F-statistic.

The value of F-statistics based on Wald test is given in second column. The upper bound values are reported in third column of Table 2. The results of the test indicate that there exits long-run relationship among the variables in both models.

Estimates of Energy Consumption and Economic Growth

The long-run estimates of the model-1 are reported in Table 4. The dependant variable is economic growth which is proxied as real GDP whereas RGFCF, TELF, TOC, TEC and TGC, IR are independent variables.

Table 4

Long- run Results of Disaggregate Energy Consumption and Economic Growth

Estimated Long Run Coefficients using the ARDL Approach			
ARDL(1,0,2,0,1,2,1) selected based on Schwarz Bayesian Criterion			
Dependent Variable is RGDP			
Regressor	Coefficient	Standard Error	T-Ratio [Prob]
RGFCF	604.54	332.51	1.81 [.083]
TELF	588561	523156	1.12 [.273]
TOC	.90	.29	3.00 [.007]
TGC	15.63	6.30	2.47 [.021]
TEC	–346.85	157.78	–2.19[.039]
IR	–69002	60625.9	–1.13 [.267]
C	–1.17	9592168	–1.22 [.235]
T	–779741	351826.6	–2.21 [.037]

Note: Results are based on Authors' calculations using Microfit 4.1.

We have observed that the value of regression coefficient of Real Gross Fixed Capital Formation (RGFCF) that is 604.54 which means that the one unit increase in Real Gross Fixed Capital Formation increases the economic growth (RGDP) by 604.54 units and this effect is strong and statistically significant. The expansion of infrastructure directly stimulates productive activities. The other channel may be that investment spending in various projects raises overall productivity and economic growth. Our results stay in line with Khan and Reinhart (1990); Blomstrom, *et al.* (1994) who find positive relationship between investment and growth.

Table 5

Short Run Estimates of Disaggregate Energy Consumption on Economic Growth

ARDL (1,0,2,0,1,2,1) selected based on Schwarz Bayesian Criterion			
Dependent variable is dRGDP			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
dRGFCF	229.9852	87.6733	2.6232[.014]
dTELF	153071.4	101752.5	1.5044[.145]
dTELF1	–205340.1	101328.0	–2.0265[.053]
dTOC	.34272	.077428	4.4263[.000]
dTGC	10.8104	2.3522	4.5958[.000]
dTEC	–92.0338	52.6229	–1.7489[.092]
dTEC1	–152.8186	54.7032	–2.7936[.010]
dIR	2370.6	16643.9	–14243[.888]
dC	–4460483	3357701	–1.3284[.196]
dT	–296635.0	113131.6	–2.6220[.014]
ecm(–1)	–.38043	.11781	–3.2290[.003]
ecm = RGDP –604.54*RGFCF –588561.3*TELF –.90*TOC –15.63*TGC + 346.8594*TEC + 69002.1*IR + 1.17E*C + 779741.9*T			
R-Squared .76189		R-Bar-Squared .61036	
DW-statistic 2.3488		F-stat. F(10, 26) 7.0393[.000]	

Note: Results are based on Authors' calculations using Microfit 4.1.

The coefficient of the employed labour force is although positive but insignificant. Our findings are matched with conventional neo-classical theories of growth [see Barrow and Sala-i-Martin (1995)].

The core variables of the study are energy variables i.e., total energy consumption, total gas consumption and total electricity consumption. We have noted in the present study that total oil consumption directly influence the economic growth. The value of the coefficient of oil consumption is 0.90 which means that an increase of one unit in total oil consumption raises real GDP about 0.90 units. The same results are found in the short run. The findings support the theoretical results. The reason may be that the wheel of the economic life cannot be run without oil now-a-days because of mechanisation and technological progress.

We have observed that the coefficient of total gas consumption is positive and highly significant. The real GDP increases almost 15.6 units due to one unit increase in total gas consumption. It is noted that the third variable of the energy turns out to be negative. The coefficient of the total electricity consumption is (–346.85) and statistically significant. The short run findings also indicate negative impact on growth. The analysis concludes that electricity is considered as limiting factor to economic growth in Pakistan. The reason may be that the continuous short fall of the electricity and electricity supply shock are the main causes of growth deterioration. Our results support the [Javaid, *et al.* (2013); Kakar and Khilji (2011); Shahbaz, *et al.* (2013); Onakoya, *et al.* (2013) and Yuan, *et al.* (2007)] findings.

The inflation rate is used as control variable in the growth model. The analysis concludes that the effect of inflation rate on economic growth is negative and statistically insignificant. Theoretically, it is sound because rising prices cause an increase in the cost of production. As a result production decreases and ultimately economic growth declines.

Interpretation of Error Correction Term (EC_{t-1})

The coefficient of ecmt-1 for Model-1 is equal to (–0.38) for the short-run model and implies that deviation from the long-term economic growth is corrected by 38 percent over each year at 1 percent level of significance.

Estimates of Disaggregate Energy Consumption and Agricultural Output

The value of regression coefficient of real Gross Fixed Capital Formation (RGFCF) is 8.92 which means that the one unit increase in real Gross Fixed Capital formation raises the Agricultural output by 8.92 units. The reason may be that investments in agriculture input industry like tractors, thrashers, tube wells and pesticides increase along with an increase in the income of the farmer. Therefore, per capita saving rate increases and ultimately growth per capita increases [Barro (1991)].

Table 6

Long- Run Estimates of Disaggregate Energy Consumption and Agricultural Output

ARDL(1,2,0,2,1,2,2) selected based on Schwarz Bayesian Criterion
Dependent Variable is AGRI

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
RGFCF	8.92	23.65	.377[.710]
TELF	3033	12712	.238[.814]
TOC	.054	.017	3.114[.006]
TGC	1.81	.47	3.817[.001]
TEC	–9.41	8.23	–1.142[.267]
ACRDT	8.83	.95	9.260[.000]
C	–208966	231783	–.901[.379]
T	–33472	11111	–3.012[.007]

Note: Results are based on Authors' calculations using Microfit 4.1.

We have observed that the value of regression coefficient of Employed Labour Force (TELF) is 3033. This means that the one unit increase in Employed Labour Force increases agricultural output by 3033 units and the result is statistically insignificant.

We have found that the coefficient of total gas consumption is 1.81 and statistically highly significant. The agricultural product increases by about 1.8 units due to one unit increase in total gas consumption. The results may be justified on the sound reasoning that fertiliser and pesticides producing industries have shifted their production process from electricity usage to gas usage considering it cheaper source of energy.

Table 7

Short Run Effects of Disaggregate Energy Consumption on Agricultural Output

Error Correction Representation for the Selected ARDL Model
ARDL(1,2,0,2,1,2,2) selected based on Schwarz Bayesian Criterion
Dependent Variable is dAGRI

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
dRGFCF	–1.03	7.19	–.14[.887]
dRGFCF1	–17.82	7.89	–2.25[.033]
dTELF	1409.2	5927	.23[.814]
dTOC	.007	.006	1.15[.259]
dTOC1	–.016	.007	–2.07[.049]
dTGC	.104	.18	.55[.582]
dTEC	-6.78	5.71	–1.18[.247]
dTEC1	–23.28	5.10	–4.55[.000]
dACRDT	.769	1.19	.64[.527]
dACRDT1	–1.92	1.17	–1.63[.114]
dC	–97067	109958	–.88[.386]
dT	–15548	5548.90	–2.80[.010]
ecm(-1)	–.464	.102	–4.52[.000]

ecm = AGRI –8.9289*RGFCF –3033.7*TELF –.054952*TOC –1.8115*TGC + 9.4111*TEC –8.8307*ACRDT + 208966.6*C + 33472.2*T

R-Squared	.98	R-Bar-Squared	.97
DW-statistic	1.83	F-stat. F(12, 24)	121.65[.000]

Note: Results are based on Authors' calculations using Microfit 4.

The estimated coefficient of Total Oil Consumption is .054. This means that the one unit increase in Total Oil Consumption increases agricultural output by .054 units. The estimated coefficient of Total Electricity Consumption (TEC) is –9.41 which implies that agricultural output is affected negatively by electricity consumption and is statistically significant. The agricultural credit is contributing positively in boosting up economic growth as coefficient of agricultural credit is 8.83 and is significant. Results are consistent with [Ayaz, *et al.* (2011)]. Formal credit directly influences agricultural productivity through investment and financing of fertilisers and seeds [Qureshi and Shah (1992); Jehanzeb, *et al.* (2008)].

Interpretation of Error Correction Term (EC_{t-1})

The value of Ecmt-1 for Model-2 is (–.46) which implies that the short run variables approach to long run variables by 46 percent each year. Negative and significant value of error correction term also provides further proof of existence of long run and unidirectional relationship [Bannerjee, *et al.* (1998)].

Diagnostic Tests

J-B normality test for residual is conducted to see residuals are normally distributed or not because one of the assumptions of CLRM is residuals are normally distributed with zero mean and constant variance. Breusch-Godfrey LM test is conducted to check the serial autocorrelation in our model. Autoregressive conditional heteroskedasticity (ARCH) is conducted to check the autocorrelation in the variance of error term. The outcomes of all these tests are reported in the Tables 8 and 10.

Table 8

Diagnostic Test

Diagnostic Tests of Model-1 [RGDP | RGFCF, TELF, TEC, TGC, TOC, IR]		
Test Statistics *	LM Version *	F Version *
* A:Serial Correlation*	CHSQ (1) = 1.6304[.202]	F(1, 21)= .96801[.336]*
* *	* *	
* B:Functional Form *	CHSQ (1) = 3.6478[.066]	F(1, 21)= 2.2968[.145]*
* *	* *	
* C:Normality	CHSQ (2) = 2.1778[.337]	* Not applicable *
* *	* *	
* D:Heteroscedasticity*	CHSQ (1) = .36585[.545]	F(1, 35)= .34953[.558]

Source: Authors' calculation using Microfit 4.1.

Table 9

Diagnostic Test

Diagnostic Tests of Model-2 [AGRI | RGFCF, TELF, TEC, TGC, TOC, ACRDT]		
Test Statistics *	LM Version *	F Version *
* A:Serial Correlation*CHSQ (1)	= .53399[.465]*	F(1, 18)= .26358[.614]*
* * *	*	
* B:Functional Form *CHSQ (1)	= 2.5889[.118]*	F(1, 18)= 1.3542[.260]*
* * *	*	
* C:Normality *CHSQ (2)	= 2.4167[.299]	* Not applicable *
* * *	*	
* D:Heteroscedasticity*CHSQ (1)	= .46974[.493]*	F(1, 35)= .45007[.507]*

Source: Authors' calculation using Microfit 4.1.

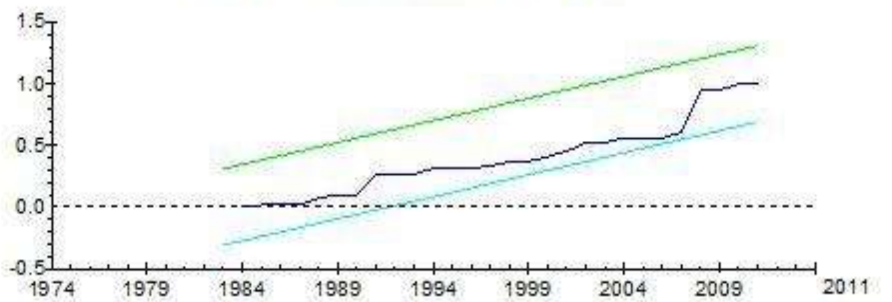
Stability Test

In order to check the stability of the Models, we plot the cumulative sum of recursive residuals CUSCUM and cumulative sum of recursive residuals of square CUSUMS. The results show that coefficients in our estimated models are stable as the graph of CUSUM and CUSUMS statistics lies in the critical bounds. The absence of divergence in CUSUM and CUSUMS graphs confirm that in our ARDL Models, short run and long run estimates are stable.

Stability Test for Model-1 [RGDP | RGFCF, TELF, TEC, TGC, TOC, IR]

The straight lines represent critical bounds at 5% significance level

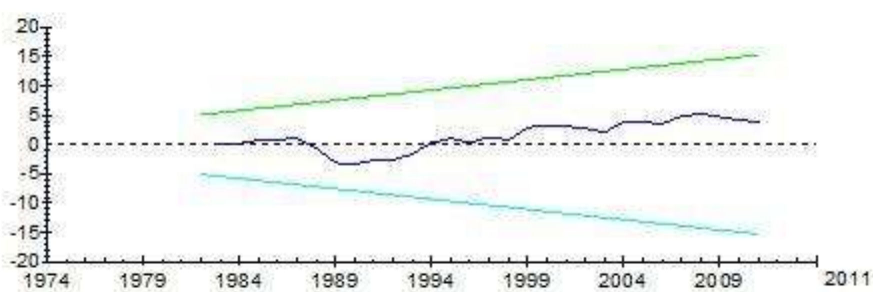
Plot of Cumulative Sum of
Recursive Residuals



The straight lines represent critical bounds at 5% significance level

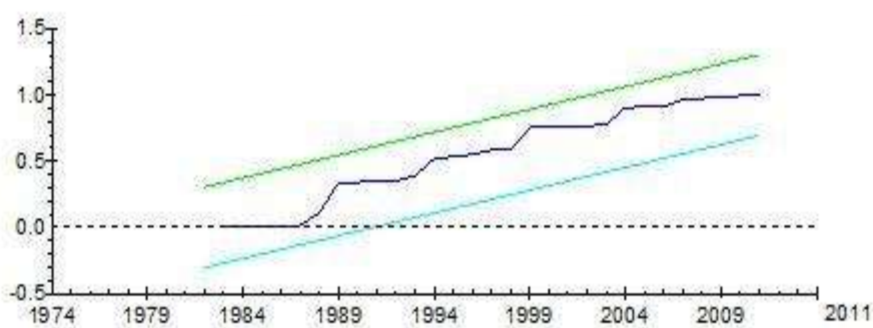
Stability Test for Model-2 [AGRI | RGFCF, TELF, TOC, TEC, TGC, ACRDT]

Plot of Cumulative Sum of
Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Plot of Cumulative Sum of
Recursive Residuals



The straight lines represent critical bounds at 5% significance level

5. CONCLUSIONS

In this study, we have analysed the impact of disaggregate energy consumption on economic growth and Agricultural output on empirical grounds with respect to Pakistan. Study has used ADF test which indicates mixed results with different order of integration. Existence of long run relationship among variables is examined for both models. Long run estimation and error correction representation of both models have been discussed and their interpretations are made. Findings of the study conclude that disaggregate energy consumption, economic growth and agricultural output are interlinked with each other in short as well as in long run.

The empirical analysis of disaggregate consumption on economic growth and on agricultural output leads to a number of conclusions for policy formulation. Electricity consumption and economic growth puts some essential policy implications on the economy of Pakistan. The unidirectional relationship of electricity consumption to economic growth and agricultural output leads us to draw a conclusion that shortage of electricity supply at the prevailing level can harm Pakistan's economic growth and agricultural output. As, consumption of electricity can influence national and agricultural output as it is the main source of energy, that is why it is significant to maintain the supply of electricity according to its demand. And since in cyclical sense economic fluctuations are also caused due to changes in electricity consumption which implies that electricity may be a leading indicator for business cycle. Another important implication is that as oil consumption and gas consumption are contributing positively to economic growth and agricultural growth. therefore, Pakistan energy sources (i.e., oil, coal and gas) other than electricity should be enhanced for sustainable economic growth because Pakistan production sectors like agricultural sector also rely on electricity consumption mainly and increasing demand of electricity as compared to its supply and insufficient installed capacity reduce agricultural as well as national output.

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Comments

The paper titled "Disaggregate Energy Consumption, Agriculture Output and Economic Growth: An ARDL Modelling Approach to Co-integration" touches upon an important subject of policy making in the context of economic growth.

Having said that let me point out some of the weakness which to my understanding if improved can make this paper very useful both for academia and policy-makers.

(i) The use of the econometrics technique such as ARDL is a norm now a day, hence putting the same in the title does not signifies it any more. So I would recommend that the authors should stick to the economic title only.

(ii) Putting such words on the title page, e.g. in the abstract *data ranges from 1972-2011 from a reliable source…* leaves the reader thinking that is it an insider job. Such mentioning is taken care of in the data and methodology section. Subsequently these sources are also not mentioned in data section.

(iii) There is a need to carefully review and state the objectives of the study.

(iv) There is no discussion of why the authors have just picker the agricultural out put to be a representative of the sub components of GDP and leave out other potential sectors which are also contributing to the economic growth such as manufacturing, communications etc.

(v) The descriptive analysis is out of context and does not help the reader in establishing the linkage between the variables of interest. The use of data is also not appropriate such as Figure 2 is totally out of context and not discussed at all.

(vi) There is a confusion across the paper as to authors are focusing on the consumption, the efficient consumption of the energy sources at disaggregated level or the energy-mix in use.

(vii) The qualification such as…. The study also fulfils a number of imperfections of previous studies such as not using appropriate technique for co-integration, model specification and methodological issues requires the literature review to be set accordingly and the next coming sections such as the methodology etc. to further qualify that.

(viii) Variables abbreviations such as *RGFCF, TELF…*does not convey its description.

(ix) There is no model as such, mentioning the variables in a simple production function with variables of interest a arguments of a function is not a model.

(x) Tables when placed needs an explanation, e.g., Table 1: on the descriptive statistics.

(xi) For estimation of the regression ARDL approach is used:

   (a) The results for unit root test are not provided for inclusion of intercept and trend or there is no plot of the data. Further for robust results often PP test is also applied but not in this case.

   (b) Now once it was observed that all the variables at I(1) except IR and RGFCF (which I don't know what these are) which are I(0). Then a simple cointegration method like Johanson and Jusilus or Engle and Granger was more appropriate leaving these two, as the ARDL is adopted if the variables under consideration have different order of integrations (i.e. a mix of I(0) and I(1)).

(c) While comparing the wald-F test for existence of cointegration Pesaran, *et al*. (2001) tables are used, which were for large samples (500-1000), for our case where the total observations are around 40 we have to use the tables provided by Naryan (2005) otherwise it may get non-parsimonious results as the F-test used here has a non-standard distribution and depends on the (1) Variables being I(0) or I(1), (2) No of repressors, (3) Intercept and/or trends and the (4) sample size. So we can not use the old tables for exploring the critical bound.

(d) The Cusum and Cusum Square tests are showing a unique picture, where the bounded line appears only the latter years and not for the whole sample period, please explain.

(xii) In the results description what bothers me is the results and there explanation, e.g. 1 unit Oil consumption leading to an increase of about just 0.90 units in the GDP. First I am unaware as to the use of Oil consumption units used here are in energy units or expenditures on oil consumption. Second these results are somewhat unexpected also not validated with the help of other studies.

(xiii) There is a strong possibility of multicollinearity in the estimation as both the Oil consumption and electricity usage is taken as explanatory variables.

(xiv) Further the results are totally in abeyance of any possible explanation. e.g. electricity consumption presents a negative relationship with economic growth.

(xv) Further taking inflation to be linked with economic growth means we may need to explore the sacrifice ratio, but that has to be through the demand side, whereas in Pakistan inflation may be arising from the supply side.

(xvi) Investment in human capital is not synonymous to R&D.

(xvii) The paper needs a through reading and then editing.

(xviii) Conclusions are based on empirical work which is largely not reflecting the true logics. Further basing policy recommendations which are not arrived at from the authors estimation should not be put forth.

Over all the study needs a thorough revision both in the context of theoretical understanding and the econometric methodology on how to estimate it.

Mahmood Khalid

Pakistan Institute of Development Economics,
Islamabad.

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The Role of Power Generation and Industrial Consumption Uncertainty in De-industrialising Pakistan

BUSHRA YASMIN and WAJEEHA QAMAR

1. INTRODUCTION

The term deindustrialisation refers to the process of socio-economic changes taking place due to reduction in the industrial capacity and/or the loss of industrial potential of an economy. This also connotes the secular decline in the share of industrial sector employment as observed in developed countries since 1970s. The secular shift from manufacturing to services sector reflects the impact of discrepancy in productivity growth between the said sectors. A faster rise in productivity in manufacturing sector than in services switches the employment from manufacturing to the services sector, as suggested by Rowthorn and Ramaswamy (1997).

Generally, deindustrialisation is considered as the natural outcome of economic development because it involves the transformation from primitive agriculture-based economy to the modern industrial-based. After the establishment of manufacturing sector, the long-run economic growth stimulates an innovation-based economy implying the services sector's growth [Galor (2005)]. However, the process requires a gradual shift accompanied by allied institutional and infrastructural reforms and the process of deindustrialisation occurs at the later stage of development.

The economic history of today's developed world discloses that the process of deindustrialisation started in these economies in late 1970s and the share of industrial output and employment tended to fall since then. Comparatively, in the developing world several attempts have been made for industrialisation, for sustainable economic growth. But, most of these were unable to develop their industrial sector and hence they are lagging behind the others in the pursuit of economic development. This inability can be attributed to the policy bottlenecks and the challenges faced by the industrial sector that lead toward the path of deindustrialisation, in contrast to the developed world. Such economic scenario is termed as 'premature deindustrialisation' in the literature.[1] Such deindustrialisation can have negative implications for the economy because the labour shed from industries may not be absorbed into the services sector and hence leads to

Bushra Yasmin <bushrayasmin@yahoo.com> is Associate Professor/Chairperson Economics Department, Fatima Jinnah Women University, Rawalpindi. Wajeeha Qamar is MPhil Student at the Department of Economics, Fatima Jinnah Women University, Rawalpindi.

[1]See Dasgupta and Singh (2006), p. 2 for reference.

rising unemployment in the economy. Moreover, the vulnerable growth of industrial sector may negatively affect the growth of other sectors due to its forward and backward linkages to the other sectors in economy.

The economy of Pakistan has been facing inconsistent industrial policies, liberalisation reforms and the macro-economic challenges in the form of energy crisis and political instability that ultimately reduced the potential of industrial sector. The country has been facing deindustrialisation since 1990s and the efforts to put the sector back on its trail are all in vain. The acute energy shortage, continuous power breaks down and government issues with Independent Power Producers (IPPs) on payment have badly affected the sector's capacity in power generation and distribution. In this regard, deindustrialisation in Pakistan with sup-optimal industrial growth can be attributed to the energy crises that prevented the industries to operate at their capacity level and hereby lowered the output growth. A consistent attrition in the economy's growing capability and the domestic energy shortages and excessive rise of electricity prices can be considered as factors thwarting the sector's competitiveness, as well.

In view of the role of energy crises in hampering industrial sector growth, an attempt is made to empirically investigate the extent to which the most significant component of energy i.e., electricity crises has played its role in deindustrialising Pakistan. The power generation and volatile power consumption by industrial sector along with domestic consumption, inflation and energy imports are selected as the major factors determining the time path of industrial sector's share in GDP. The Johansen Cointegration and the Error Correction Model are applied for this purpose. The Impulse Response Function (IRF) and Variance Decomposition are obtained to observe the effect of shocks to selective variables on the industrial share in GDP and to forecast the future role of the factors in determining industrial variation, respectively. The data from *World Development Indicators* and *Economic Survey* is used over the time period of 1970–2010.

The rest of the paper is organised as follows. Second section deals with the literature review. Third part discusses the trends of industrial sector growth and evolution of power sector in Pakistan. Fourth section discusses the methodology and the fifth section reports and interprets the empirical findings. Final section concludes the paper with some policy suggestions.

II. LITERATURE REVIEW

The understanding of possible impact of power sector crisis on the process of deindustrialisation is important as it provides the theoretical and empirical support to the analyses undertaken. The literature provides empirical evidence for the determinants of deindustrialisation in developed and developing economies, generally and is discussed below.

1. Evidence from the Developed World

The developed world has been on the path of services sector growth since 1970s and the economists have considered it as a process of "restructuring" or "creative destruction". This transition has been attributed to the higher productivity growth of industrial sector, North-South trade and outsourcing of manufacturing activities to the labour abundant developing countries [Alderson (1999); Lee and

Wolpin (2006)]. Alderson (1999) analysed the impact of globalisation on the process of deindustrialisation in the selected OECD countries. By using the panel data fixed effect regression technique, he concluded that the fall in manufacturing employment in the developed world is the result of outflow of direct investment and North-South trade. Additionally, the inverted U hypothesis has also been proven indicating the fact that the economic development in these countries has reached at a point after which there is a decline in manufacturing employment. However, Rowthorn and Ramaswamy (1999) established that deindustrialisation in the advanced economies is the result of the economic development and higher productivity of manufacturing sector as compared to other sectors. The role of North-South trade and problems faced by manufacturing sector in these economies has little contribution towards the process of deindustrialisation.

Nickell, *et al.* (2008) explained that across the OECD countries, difference in the pace of deindustrialisation can be attributed mainly to the differences in the productivity across manufacturing, agricultural and services sector. Apart from that, differences in the relative prices, technology and factor endowment also play vital role in determining the pace of deindustrialisation.

2. Evidence from the Developing World

There has been some pessimist view regarding the phenomenon of deindustrialisation in the developing part of the world. It is considered that deindustrialisation is a process of betrayal to the industrialist workers and the propaganda to deprive the developing world from its industrial power [Cowie and Heathcott (2003)].

Noorbakhsh and Paloni (1999) considered the Structural Adjustment Programme (SAP) of IMF and World Bank as responsible for the low per capita growth of Sub-Saharan Africa claiming that SAP has resulted in the declining performance of industrial sector as compared to the period before the adoption of SAP. And SAP could not lead towards a rise in the export competitiveness of industrial sector with presumably attached technology transfer.

According to Palma (2005 and 2008) the developing world has been facing the declining share of industrial sector in GDP/employment because of the policy shifts faced by most of the economies. Trade liberalisation along with the financial liberalisation has resulted in inverse relationship between the manufacturing employment and the income per capita. Dasgupta and Singh (2005) have provided the evidence of deindustrialisation at the low level of income, jobless growth and the development of informal sector. They used the concept of "premature deindustrialisation" because of its negative implications for growth as it lowers the capacity and hence growth of industrial sector.

For the Latin American countries, Brady, *et al.* (2008) suggested that de-industrialising took place in these countries despite the sheer need of strong industrial base because of the MERCOSUR trade agreement, dependency on the United States, inward FDI inflows, military spending and institutional problems.

This completes the review of literature. Next section presents an overview of Pakistan's industrial sector growth performance and energy crises.

III. DEINDUSTRIALISATION AND POWER CRISIS IN PAKISTAN: AN OVERVIEW

The industrialisation has been considered as engine of growth that has held true for almost 200 years, since the start of Industrial Revolution [Chenery (1960); Kaldor (1966)]. It is well established that industrial sector development is fundamental for overall economic development. The historical evidence portrays that currently developed countries have developed with the help of sound industrialisation strategies. The industrial sector of Pakistan is the second largest sector of the economy comprising of small, medium and large scale industries. Currently, industrial sector contributes 20.9 percent to GDP having sub-sectors: manufacturing, construction, mining and quarrying and electricity and gas distribution. According to *Economic Survey (2012-13)*, the growth of manufacturing sector is estimated at 3.5 percent compared to the growth of 2.1 percent last year. The employment share by manufacturing sector has increased from 13.2 percent in 2009-10 to 13.7 percent in 2010-11.

However, the fact remains that the performance of industrial sector has remained below potential and is impediment in the way of sustainable economic growth and development. There are various reasons for the poor performance of industrial sector but the concern of the current paper is to examine the role of acute power crisis in the industrial downfall in Pakistan. A detailed analysis of deindustrialisation and power crisis trend is made in this section.

1. An Overview of 1970s

The industrial performance of Pakistan was meander in the first two decades, in view of the negligible industrial base. The establishment of Pakistan Industrial Development Corporation (PIDC) in 1952 helped the economy to create an industrial base for self-sustained growth. In 1970s, Pakistan adopted the Indian development strategy of state-led and heavy industry based industrialisation. However, separation of East Pakistan, war with India, oil price shocks and the public deficits reduced the manufacturing growth in 1960s from 7.8 percent to 2.8 percent in 1970s [Federal Bureau of Statistics (2011)]. The dismal performance of industrial sector in 1970s cannot be attributed soley to the power shortage as the electricity situation was quite good that time. The cost of production and demand of electricity were quite low as the total consumption of electricity in 1970s was 7739 GWH against the generation of 11373 GWH on average [Pakistan (2010)].

2. Moving towards Denationalisation and Industrial Sector: 1980s

With the change in government, decade of 1980s witnessed the reversal in policies which moved towards the denationalisation with the mixed economy and import substitution.

The denationalisation took place in few industries but the public sector continued to invest in the heavy industries. The expansion in domestic demand led to the industrial growth in that period almost equal to that of 1960s. With the outbreak of Afghan war, the country had inflow of foreign capital in form of assistance from USA and other financial institutions. However, the industrial sector growth was unbalanced and most of the investment was concentrated in the textile and sugar industries. The value addition of industrial sector in GDP was 23.2 percent with a nominal rise from previous year's figure i.e., 22.7 percent [*World Development Indicators* (2010)].

On energy front, the need for additional power generation capacity was realised in the power sector in mid 1980s. The concept of Integrated Energy Planning and Policy Formulation (IEP) and the institutional structure was introduced in early 1980s but gradually lost its favour with international institutions on the presumption of market forces leading towards right policy choice. And the task was given to the private sector in the form of Independent Power plants (IPPs) instead of adding the additional capacity in public sector, the first step towards the power crisis emerged in the following years.

3. Declining Industrial Growth and Rising Energy Shortage: 1990s

The industrial sector performance was disappointing in the 1990s as the growth of large scale manufacturing sector that was 8.2 percent in 1989 reduced to 4.7 percent in the first half and 2.5 percent in the second half of the decade [Federal Bureau of Statistics (2011)]. The implementation of reforms suggested by "Washington Consensus" and Structural Adjustment Programme by International Monetary Fund (IMF) led to the deregulation which created an anti-industrial bias in the country and economy observed a sharp move towards services sector growth thereafter. The value addition of industrial sector in GDP was 24.3 percent for the decade against the 49.4 percent by the services sector. Following the reforms, the new power policy was announced in 1994. The policy was based on the cost-plus-return with 15-18 percent internal rate of return along with the repayment of fixed as well as variable cost of production in terms of US dollars irrespective of the efficiency by the Pakistan Electric Power Company (PEPCO)/WAPDA and Karachi Electric Supply Company (KESC) [Munir and Khalid (2012)]. The policy clearly marked the accumulation of the acute circular debt with the devaluation of the Rupee in the 2000s.

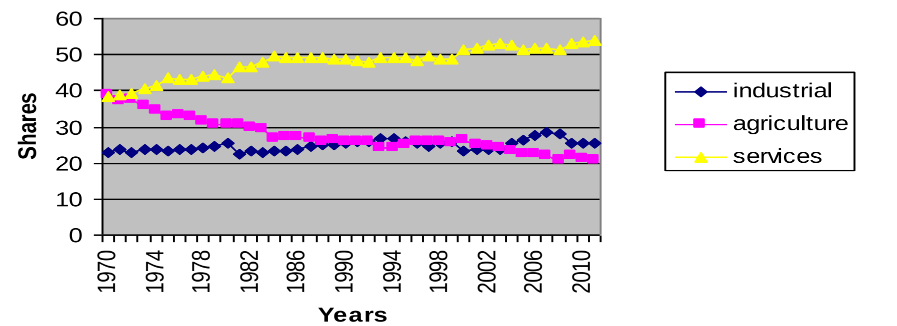
4. Sufferings of Industrial Sector and Energy Crises: 2000 Onwards

The industrial performance of Pakistan from 2000 till 2010 was highly volatile as the growth rate of industrial sector was as high as 12.1 percent in 2005 while it drastically declined to –3.6 percent in 2009. Similarly, the large scale manufacturing growth declined to –7.7 percent from 19.9 percent in the same time period. On the contrary, the growth rate of services sector was satisfactory at 3.6 percent in 2009 although lower than 2005s figure i.e., 8.5 percent [Pakistan (2010)]. The first half of the decade was accompanied by sound macroeconomic policies, strengthening domestic demand, suitable financial conditions and stable exchange rate that encouraged the industrial sector growth. However, in the later half, severe energy shortages, global recession of 2008, oil price hike and sharp depreciation in the local currency led to the decline of industrial sector growth [Jaleel (2012)].

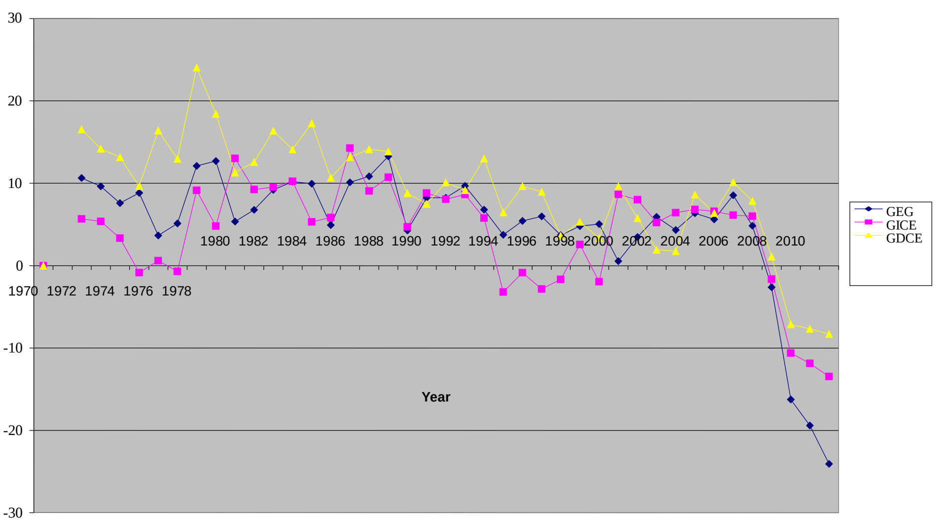
The decade of 2000s can be considered as the decade of power crisis as the economy faced such electricity problems which have never been experienced before. On the one hand, the demand of electricity is rising enormously and the number of electricity consumers increased from 7.9 million in 1992 to 19.9 million in 2008 while on the other hand, the shortfall was recorded to be 37 percent as demand for electricity was 11,509 MW against the supply of 7237 MW [Khan (2012)]. These issues are the direct outcome of poor power policy adopted in 1994 and 2002 power policy. Despite knowing the fact that Pakistan has advantage in hydropower, the fuel mix between hydro and thermal was modified from 60:40 in 1980 to 30:70 in 2000 which raised the cost of generating electricity from Rs 1.03 per kwh by WAPDA to Rs 9.58 per kwh by IPPs [Munir and Khalid (2012)]. Additionally, the fiscal crunch faced by the government has led to the inability to pay the debt to IPPs and further aggravated the situation as electricity generation is not meeting the demand and the industries are forced to be shut down or to move the entire set up elsewhere.

In short, industrial sector growth has gradually declined with the power shortage as represented by figures and facts discussed above. The comparison of sectoral share in GDP and growth trends in industrial and domestic consumption of electricity (gice, gdce) and power generation (geg) are displayed in Graph 1 and Graph 2, respectively. Graph 1 provides the sectoral share of industrial (ind), agricultural (agr) and services (serv) sector as percentage of GDP.

Graph 1
Sectoral Share in GDP



Graph 2: Electricity Generation and Consumption Growth



This portrays the emerging significance of services sector, which was taken up by traditional agricultural sector in Pakistan where agricultural sector's share declined over time while services sector's share increased on a sharp pace over the same time span. While the industrial sector has remained stagnant throughout the time period, maintaining a GDP share around 25 percent with nominal fluctuations. Such trends in sectoral shares in GDP indicate the industrial sector's status, which is functioning sub-optimally, on the one hand the services sector is replacing the other sectors of the economy.

According to Graph 2, the power generation appears highly volatile and has remained lower than domestic use of electricity throughout the time. For industrial use a wide gap is observed between demand and supply underpinning the rising power crises over time. Besides, the growth touched negative digits in last years and so is the case for electricity consumption. This completes the overview of Pakistan's economy for power crises and industrialisation trends. Now we turn to the methodology.

IV. METHODOLOGY AND DATA DESCRIPTION

1. Model Specification and Data Description

In order to achieve the objectives of the research, the variables related to the power sector including power generation, domestic consumption and industrial consumption volatility, industrial imports and inflation are included in the deindustrialisation equation. Following is the equation for estimation.

$$IGDP_t = \alpha_0 + \beta_1 GEG_t + \beta_2 GDCE_t + \beta_3 VGICE_t + \beta_4 INF_t + \beta_5 GIIMP_t + \mu \quad \ldots \quad (1)$$

Where,

$IGDP_t$ = Industrial share in GDP (%)
GEG_t = Growth rate of electricity generation (Gwh)
$GDCE_t$ = Growth rate of domestic consumption of electricity (Gwh)
$VGICE_t$ = Volatility in Industrial consumption of electricity (Gwh)
INF_t = Inflation (annual CPI growth)
$GIIMP_t$ = Growth rate of industrial imports[2]

The share of industrial sector as % of GDP, dependent variable, is used to measure the deindustrialisation time path for Pakistan over the period of 1970–2010. The electricity generation and consumption are measured in Gwh and its growth rate is expected to have a positive relationship with industrial share in GDP. However, the disaggregated industrial and domestic need for electricity may yield variant effects as the electricity shortage makes the domestic and industrial sectors compete for energy. The industrial use may be significant in promoting industrial sector but domestic use may or may not be significant. The power generation is expected to affect industrial sector positively. The industrial consumption volatility is expected to affect industrial sector significantly.

[2]Trade liberalisation and industrial policy dummies were used in the model as exogenous variables. For trade liberalisation and industrial policy, a value 1 is assigned to post-trade liberalisation period i.e., 1988 onward and to the successful 5 year industrial plans compared with base category i.e., assigned value 0, pre-trade liberalisation period and unsuccessful industrial policies, respectively. The variable on electricity loss was also added but dropped in final model for being insignificant.

The industrial imports are measured in million rupees and the variable is expected to promote the industrial sector due to heavy reliance on imports, import intensity of industrial production and a meagre and less competitive export base. The data on all variables is collected from *Handbook of Statistics* (SBP) and *Economic Survey* (various issues).

In order to measure the uncertainty in power generation and consumption, volatility of the series was derived using Generalised Autoregressive Conditional Heteroscedasticity (GARCH) technique. Following Aizenman and Marion (1993), the forecasting equation is specified as below to determine the unexpected part as measure of uncertainty for industrial consumption.[3]

$$P_t = \alpha_1 + \alpha_2 T + \alpha_3 P_{t-1} + \alpha_4 P_{t-2} + \varepsilon_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(i)}$$

where P_t is the variable under consideration, T is time trend; α_1 is an intercept, α_3 and α_4 are the autoregressive parameters and ε_t is the error term. After estimating Equation (i), the Garch term (σ^2) will be regressed on one year lag of the error term square and its own lag. Following is the equation for that purpose:

$$\sigma^2 t = \gamma_0 + \gamma_t \varepsilon_{t-1}^2 + \delta_t \sigma_{t-1}^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(ii)}$$

2. Estimation Technique

The short and long-run effect of volatile industrial energy consumption and power generation on emerging phenomena of deindustrialisation is assessed through Johansen (1998) and Johansen and Juselius (1990) cointegration technique. The series is checked for stationarity purpose by Augmented Dickey Fuller (1979) that serves to identify the order of integration of all variables in the model. ADF test includes the estimation of following regression equation.

$$\Delta X_t = \alpha + \beta_t + \gamma_i X_{t-i} + \sum_{i=1}^{n} \varphi_i \Delta X_{t-1} + \epsilon_t \quad \ldots \quad \ldots \quad \ldots \quad \text{(iii)}$$

Where X_t is the variable under consideration, Δ is the first difference operator, t captures the time trend, ϵ_t is the random error term and n is the maximum lag length. The optimal lag length is determined to ensure that the error term is white noise, while α, β, γ and φ are the parameters to be estimated. The non rejection of the null hypothesis depicts the presence of unit root. Hereafter, the selection of an optimal lag length is essential at the onset of cointegration analysis because multivariate cointegration analysis is very sensitive to the lag length selection. This would be done with the help of two available criterions namely Akaike Information Criterion (AIC) and Schwarz Information Criterion (SC).

2.I. *Johansen Cointegration Test*

Next step in the estimation procedure is the application of Johansen Cointegration test. This proposes two tests namely; trace test (λ_{trace}) and maximum eigen test (λ_{max}) in order to determine the existence and number of cointegrating vectors in the model. The

[3]The volatility appeared to be statistically significant only for industrial consumption of electricity following Equation (2). The significance and graph of volatility series is given in Appendix Table A1 and Figure A 1.

null hypothesis under the trace test is that the number of cointegrating vectors is less than or equal to r where r = 0, 1, 2, 3…, etc. While in the null hypothesis for Eigen test, the existence of r cointegrating vectors is tested against the alternative of r + 1 co-integrating vectors.[4] The multivariate co-integration test can be expressed as:

$$Z_t = K_1 Z_{t-1} + K_2 Z_{t-2} + \ldots + K_{k-1} Z_{t-k} + \mu + v_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(iv)}$$

Where Z_t $(GEG_t, GDCE_t, VGICE_t, INF_t, GIIMP_t)$ i.e., a 6 x 1 vector of variables of I (1) where I (1) refers to the integration of order 1, μ is a vector of constant and v_t is a vector of normally and independently distributed error term.

2.2. Vector Error Correction Model

The next step is the application of the vector Error Correction Model (VECUM). The model yields the effects which are considered as the limit to which the behaviour of dependent variable will tend, ceteris paribus. The regulator of the behaviour of the variable in the short run is taken into account, up to a certain point, as shown by Engle and Granger (1987). Equation (ii) can be reformulated in a Vector Error Correction Model (VECM) as follows:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \ldots + \Gamma_{k-1} \Delta Z_{t-k-1} + \Pi Z_{t-1} + \mu + \nu_t \quad \ldots \quad \ldots \quad \text{(v)}$$

Where, $\Gamma i = (I - A_1 - A_2 \ldots - A_i)$, $i = 1, 2, 3 \ldots k - 1$ and $\Pi = -(I - A_1 - A_2 - A_3 \ldots - A_k)$. The coefficient matrix Π provides information about the long-run relationships among the variables in the data. Π can be factored into αβ' where α will include the speed of adjustment to the equilibrium coefficients while the β' will be the long-run matrix of coefficients. The presence of r cointegrating vectors between the elements of Z implies that Π is of the rank r, $(0 < r < 5)$.[5]

V. RESULTS AND INTERPRETATION

This section deals with the empirical findings and interpretation.

1. Test for Order of Integration

The stationary properties of the individual series are examined before proceeding to establish the long-run relationship. The results of ADF reported in Table 1 yields the existence of unit roots at level but stationary at its first order.[6] Hence, all variables in the model are integrated of order one i.e., I (1) and allow to proceed with the cointegration process.

As mentioned in methodology, Johansen's maximum likelihood approach is used for the cointegration test. The optimal lag length is one according to the both and is reported in Table A2.

[4]In case of divergence among the results of two tests, the λ_{max} test is recommended because it is more reliable especially in small samples [see Dutta and Ahmed (1997) for reference].

[5]It is important to point out that the long-run effects should be considered with some caution in that they are not the real measures, rather they can inform of what impact would be if economy had reached its equilibrium behaviour.

[6]It is done with the intercept and trend option.

Table 1

Unit Root Test

Variables	Level	First Difference	Order of Integration
IGDP	–2.895	–6.442	I (1)
GEG	–0.457	–5.88	I (1)
GDCE	–3.475	–8.080	I (1)
VGICE	–3.527	–7.229	I (1)
INF	–3.086	–6.100	I (1)
GIIMP	–0.217	–4.331	I (1)
1 % Critical Value	–4.219	–4.219	

2. Johansen Cointegration Test

Table 2 reports the findings for co-integration based on Johansen-Juselius co-integration test. The maximal eigenvalue (λ_{max}) traces two cointegrating vector, suggesting a stable long-run relationship among selected variables. This implies the existence of significant co-movement of selected variables in the long run. It is pertinent to mention that the results for error correction model are reported with 1 cointegrating vector keeping in view that; first, the 1st cointegrating vector has the highest eigenvalue and is therefore the "most associated with the stationary part of the model".[7] Second, the results yielded by the first cointegration vector are consistent with expectations and theory, as well. Hence, the first vector is normalised by the deindustrialisation variable and the results are reported in Table 2.

Table 2

Johansen's Cointegration Test Results

		Trace Test Maximal		Eigenvalue Test	
Null Hypothesis	Alternative Hypothesis	Statistics	95 % Critical Value	Statistics	95 % Critical Value
r = 0	r = 1	153.02*	95.75	59.47*	40.07
r ≤ 1	r = 2	93.54*	69.81	46.42*	33.87
r ≤ 2	r = 3	47.12	47.86	22.81	27.58

Note: *Implies that null hypothesis is rejected at 5 percent confidence level.

The short-run dynamics of the industrial share in GDP was estimated following general-to-specific modelling approach. The results for the Error Correction Model for deindustrialisation are reported in Table 3.

The results reported in Table 3 postulate a long-run relationship among the variables. A number of diagnostic tests are applied to the Error Correction Model. R^2 implies that model is a good fit. The serial correlation-Lagrange Multiplier test indicates no signs of autocorrelation of the residuals. Normality test, based on χ^2 statistic, does not reject the null hypothesis of residuals multivariate normality. The growth rate of electricity generation appeares as significantly positive, as expected and the coefficient is highest (0.46 percent) among all other parameters. It is obvious from the findings that

[7]See, Johansen and Juselius (1995) for fuller discussion on this issue.

the power shortage is partly responsible for de-industrialising Pakistan's economy in the long run as perceived in Section III. Pakistan has long been relying on imported coal and furnace oil for thermal power generation that kept on adding the energy bill.

Table 3

Error Correction Results for Deindustrialisation

Variables	ECM based on Johansen Technique (se in parentheses)
Constant	–18.13
GEG	0.46*
	(0.08)
GDCE	0.075
	(0.07)
VGICE	–0.05**
	(0.02)
INF	0.25*
	(0.03)
GIIMP	1.26E-05*
	(1.4E-06)
ECT	–0.3185
	(0.098)
Diagnostic Tests	
R^2	0.46
F statistic	3.00
Normality Test (Cholesky)	χ^2 (6) = 1.858 (0.932)
Serial Correlation (LM stat)	30.44 (0.729)

Note: 1. **, * indicates statistical significance at 5 percent and 1 percent, respectively.
2. p-values in parentheses of diagnostic tests.

According to 'US Department of Energy Estimates 2012', published in Energy Outlook, the price of electricity has gone up approximately 530 percent for the average consumer since 1990 due to the switch in the energy mix from cheaper hydropower to the thermal power in Pakistan.

In the 1980s, the country's electricity generation was based on a fuel mix of approximately 60:40 percent in favour of hydropower versus thermal. A dramatic change was observed in 90s in fuel mix and was switched to a fuel mix of 30:70 percent for hydropower versus thermal by the end of 2010. According to a recent World Bank Report, oil accounts for nearly 40 percent of electricity generation with gas and hydropower at 29 percent each.[8]

[8]C.f., Trimble, Yoshida, and Sakib (2011).

Munir and Khalid (2012) provided,

> "the dramatic shift in generation source occurred because the 1994 power policy (and later the 2002 power policy) did not discriminate on the fuel source being employed and made the country hostage to fluctuations in international oil prices".

The incentives were given to Independent Power Producers in energy policy 1994 for thermal power units but the economy faced a sharp rise in the price of electricity afterwards in 90s. The gap between growth rate of supply and consumption of electricity has widened afterwards till today. In this regards Asian Development Bank's Energy Outlook (2013) expressed, "despite economic rebound, the energy shortages have been constraining economic growth. Pakistan is faced with domestic energy supply shortages of coal, oil and natural gas, as well as a shortage of hydro generation capacities. These fuel constraints have severely affected the power sector, resulting in a significant decline in the power production". The lack of concern for the proper source of fuel for electricity generation has added to the existing shortage. To this end, it has raised the overall cost of electricity generation and created acute power shortage.

The power generation shortfall makes the industrial power consumption uncertain. According to our findings, volatile industrial consumption has declined industrial share by 0.05 percent in total GDP over 1970-2010.[9] The high energy prices, power breakdowns and relentless load shedding made industrial consumption highly uncertain and have long been upsetting the industrial production. The gap in growth of power demand and supply is expanding due to rising population pressure and hinders the steady power flow to the most critical sector of the economy i.e., industrial sector. While the supply of power is required to be continuous and price competitive for industrial sector growth. If not done so, it can hard hit the overall economy. The figure says that 44 percent of thermal fuel resources make electricity expensive and 25–28 percent loss occurs due to mismanagement in power transmission, theft and poor infrastructure.[10] Regarding the emergence of services sector in Pakistan, the historic and momentous role of industrial sector in economic development can't be abandoned.

According to the findings, the industrial imports have positive impact on the industrial share in GDP. The result shows a nominal but significant role of industrial imports in industrial growth. The industrial sector needs imported material and advanced technology due to the import-intensive nature of domestic production and consumption with a narrow export-base. Although, the industrial imports appeared as positively significant in affecting industrial sector's share in GDP but they are generally considered as an impediment to the economic growth by deteriorating its external balance. With the every rise in the import bill, the economy can face imbalance in trade. However, the

[9]The Appendix Table A1 and Figure A1 depict the significant volatility measure from GARCH in industrial energy consumption. Besides, the domestic power consumption appeared insignificant in results.

[10]In this study, the electricity loss in distribution appeared as insignificant to industrial share in GDP, hence dropped from the model.

positive impact is quite negligible and dependence on imports can be overcome by additional and dedicated efforts to expand export base.[11] This is worth mentioning that purpose is not only to re-industrialise the economy; it is also to enhance the capacity and growth of industrial sector to promote employment generation.

The relationship between industrial share and inflation appeared as positive. The findings are consistent with the theory of inflation indicating a link between rising cost of production and rising inflation of consumer goods. The rising prices of consumer goods can serve as an incentive to the producers to enhance industrial production and its share in GDP, consequently. Such behaviour can also be explained by the 'misperception theory' on the part of producers and also by 'Tobin effect' that explains a positive link between inflation and higher output.

From the experience of countries, the literature on inflation presents a positive impact of inflation on economic growth at low or moderate level of inflation whereas negative at higher level of inflation. Similarly, literature suggests positive impact for single-digit inflation while negative for double-digit inflation [Phillips (1958); Nell (2000); Chowdhury and Mallik (2001)]. Such evidences suggest that whenever the economy enters into double-digit inflation it will hit the industrial sector hard.

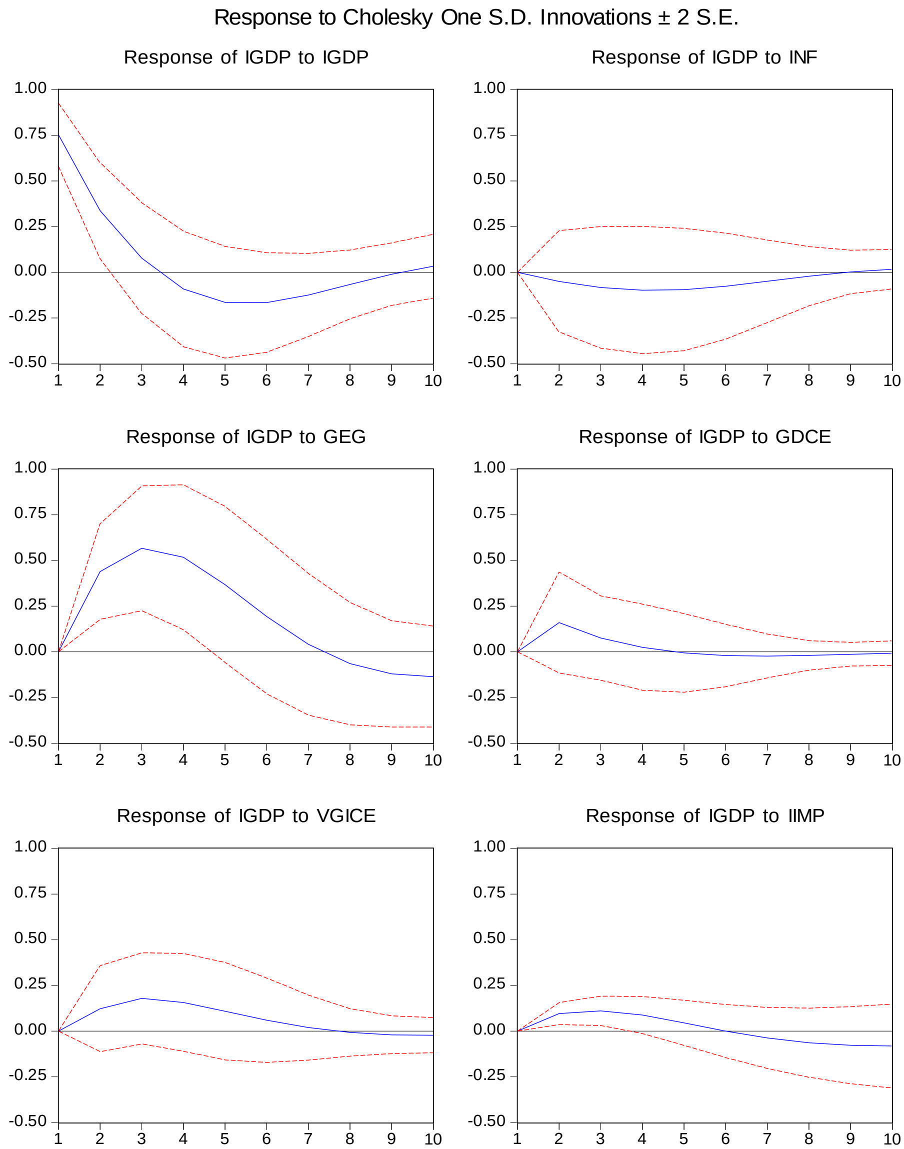
The Error Correction Term (ECT) represents the percentage of correction to the deviation in the long-run equilibrium in deindustrialisation and also represents how fast the deviations from the long-run equilibrium will be adjusted. According to the result reported in Table 3, the error correction term, measuring the speed of adjustment, appears to be negatively significant i.e., –0.318, reflecting the model stability. The value of ECT implies a marginal rate of convergence to equilibrium over a period of 10 years and implies that in any disturbance in the industrial share in GDP in the long run, 0.318 percent correction to disequilibrium will take place each year.

3. Impulse Response Function (IRF) and Variance Decomposition

The responses of deindustrialisation to one standard deviation shock to the selective variables are presented in Graph 3. The first graph shows model's stability and displays that one time shock to industrial share will eventually converge to its equilibrium in next 10 years. The response of inflation, volatility of industrial consumption of electricity and domestic consumption growth have appeared as insignificant whereas the response of industrial share to one s-d shock to power generation and industrial imports is significant. Notwithstanding, the electricity generation shows a rising trend in industrial share in GDP till 3rd year and than declines, touching negative zone, but does not show tendency to converge till the end of 10th year. This implies that electricity generations shocks have long-run impact on the industrial sector. The one time shock is persistent and sequel for deindustrialisation. According to IRF, the response of industrial share in GDP to one time shock to inflation, domestic consumption of electricity and industrial consumption volatility is likely to be converged towards the equilibrium after 9 years of shock.

[11]Hypothetically, industrial imports may have bidirectional relationship with industrialisation but the empirical findings from the Granger Causality between IIMP and IGDP suggested only one-way pass through to industrial share of GDP from industrial imports.

Graph 3. Response of De-Industrialisation to Power Generation, Domestic Consumption and Industrial Consumption Volatility, Inflation and Industrial Imports



Similar are the findings from variance decomposition reported in Table 4. Thais identifies electricity generation growth (geg) as the major contributor to industrial sector's share in the economy. It is worth mentioning that its contribution in forecasted error increases gradually over the time. The electricity generation and industrial consumption volatility contributes to the industrial share's standard error negligibly but in the long-term horizon it explains around 50 percent of the forecasted error variance of industrial share in GDP. The industrial share is contributing 73 percent in 1st year but then declines to 40 percent. Industrial consumption volatility is contributing around 4 percent of variations while the rest of the variations in the forecasted error of deindustrialisation are due to other selective variables.

Table 4

Forecast Error Variance Decomposition (%)

Period	Forecasted Standard Error	Industrial Share in GDP	Electricity Generation Growth	Industrial Consumption Volatility	Inflation
1	0.752941	100.0000	0.000000	0.000000	0.000000
2	0.961956	73.55454	20.81417	1.615167	0.264892
3	1.143897	52.47500	39.20005	3.590812	0.712668
4	1.275434	42.72156	47.96662	4.405961	1.157688
5	1.346050	39.84180	50.52904	4.615723	1.532751
6	1.373335	39.72425	50.50973	4.621744	1.779320
7	1.381248	40.07852	50.02002	4.588492	1.884827
8	1.386109	40.02647	49.88767	4.558937	1.894833
9	1.393718	39.59599	50.09299	4.529756	1.874369
10	1.403368	39.10992	50.34025	4.492912	1.863517

VI. CONCLUSIONS AND POLICY SUGGESTIONS

The paper endeavoured to assess the role of electricity demand, supply and industrial consumption volatility on the industrial share in GDP. The declining share of industrial sector has raised questions about the reasons of such trends. Some regarded it as pathological problem, where it stops the economy from being able to achieve its full potential of growth, employment and resource utilisation while some other considered it as premature de-industrialisation. Kaldor (1966, 1967) in his seminal contribution, emphasised on the spillover effects of industrial development due to its dynamic economies of scale.[12] The industrial sector has long been considered as an engine of growth, in that regards. Kaldor (1966) materialised,

> "on the supply side, industrial sector has greater potential for productivity growth and hence, for employment generation as compared to services sector. While on the demand side the income elasticity of demand for manufacturing products was greater than that for agriculture".

This perspective classifies industrial sector as a critical sector of the economy. The industrial exports are a major source of foreign exchange earnings in Pakistan. The share of industrial sector in GDP and in employment is not only declining in Pakistan but also Shafedin (2005) suggested that, "a premature decline in industry value added as percentage of GDP without recovering is due to re-orientation of the production structure of the economy from import substitution strategies towards production on the basis of

[12]Faster the growth of manufacturing output, faster will be the growth of manufacturing productivity.

static comparative advantage due to trade liberalisation". The findings by Dasgupta (2006) suggested that manufacturing sector continues to be a critical sector in economic development, but services sector also made a positive contribution in a number of developing countries like India. Conclusively, the services sector can be considered as an additional engine of growth provided that a well-developed and diversified industrial base has already been developed in the economy.

The findings of this study connote the role of electricity generation and industrial consumption volatility to the industrialisation in Pakistan. The power generation and volatile industrial consumption have significant impact on the industrial share in GDP. The electricity generation will have the highest contribution to the forecasted variations in industrial sector's share in GDP in next 10 years according to variance decomposition and will have a persistent and long lasting effect of its own shock. In view of the gravity of power crises and intensity of the issue that made industrial sector vulnerable to internal and external shocks, an adequate and pertinent power policy is still awaited to be implemented in Pakistan. The policy target should be focused on finding cheaper and sustainable energy alternate to electricity like small hydropower projects, lower reliance on imported oil and better provision of gas and coal to efficient power firms and extraction of new coal sources to end the power shortage. Consequently, it will make industrial consumption of electricity more certain and industrial output can come out of energy crises trap rendering a U turn in industrial sector performance.

APPENDIX

Table A1

Volatility of Industrial Consumption of Electricity

*GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)*			
Variable	Coefficient	Std. Error	Prob.
C	7.137974	6.913685	0.3019
RESID(-1)^2	–0.225884	0.154326	0.1433
GARCH(-1)	0.850106	0.323772	0.0086

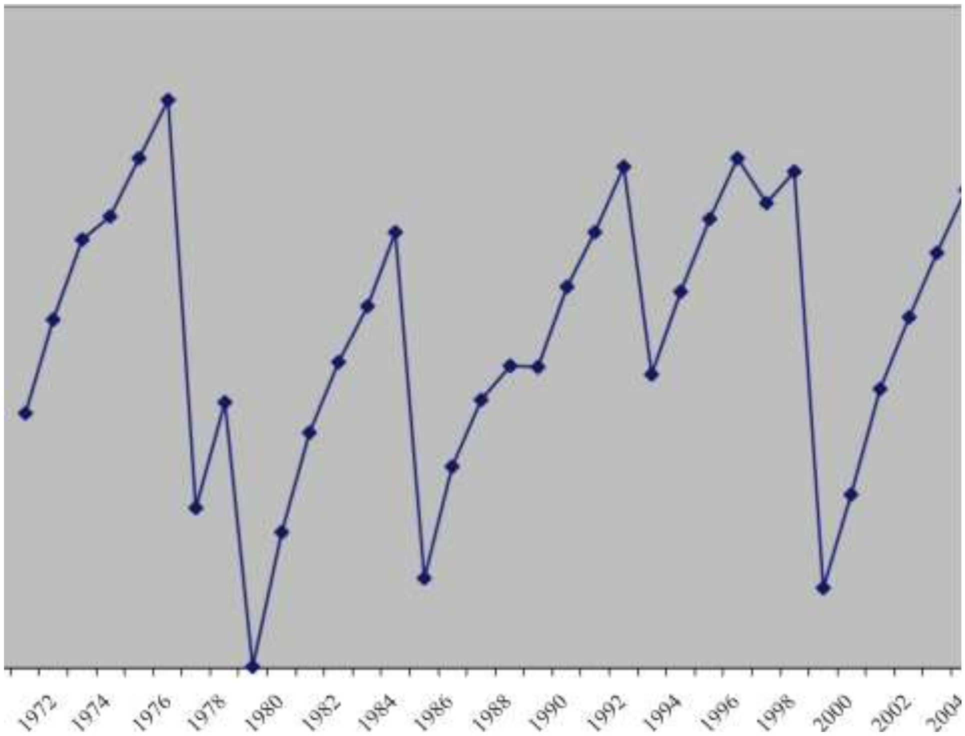
Table A2

VAR Lag Order Selection

Lag	SC
0	36.126
1	35.667*
2	51.97
3	52.38

* Indicates lag order selected by criterion.

Fig. 1. Industrial Power Consumption Volatility



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Comments

The paper titled "The Role of Power Generation and Industrial Consumption Uncertainty in De-industrialising Pakistan" is an interesting paper in the where the authors explores the reasons for reduction of manufacturing industry share in the GDP and having a lesser employment share in Pakistan.

Following are some of the observations which if incorporated may improve the quality of paper and in terms of contribution to the academic knowledge on the subject.

(i) Using terminologies like "de-industrialisation" needs a clear explanation at the very outset to make the reader more aware of what is to follow. Especially if the paper is going to extend the existing knowledge on that subject. In terms of how it should be accounted for. May be some cross country and Pakistan data tables could help more in terms of taking into account what is proposed.

(ii) When we talk specifically about the "premature de-industrialisation" then what exactly it means in terms of the variable we are referring to. e.g. if it is the industrial share in the GDP, then does that mean that some other sector is improving and why is it bad?

(iii) There are specific studies on the losses of employment and economic loss due to the load shedding. For example see our study titled " The Cost of Unserved Energy: Evidence from Selected Industrial Cities of Pakistan" published in *PDR*.

(iv) Using qualifiers such as …*as a rule of thumb, industrial sector has to face 33 percent...* needs citation. Referencing is in general weak.

(v) Data for 2014 publication needs an update especially if used from Economic Survey.

(vi) The Literature review is devoid of any study which studies the "premature de-industrialisation" the present study is discussing. I doubt it, it may be with some other name, such as the cost of unserved energy etc.

(vii) The variables in graph needs to be explained in terms of what they are referring to.

(viii) Some theoretical model has to be referred to.

(ix) The selection of variables seems arbitrary and without explanation. E.g. VGICE: volatility in industrial consumption of electricity, is not an exogenous variable or a variable of choice for the firms to take, its an out come variable, which may be due to one of the explanatory variables such as the growth of electricity generation and domestic use etc.

(x) Some other variables are missing in the specification for control such as the openness and law and order situation.

(xi) Uncertainty may not be the case here, its simply and excess demand situation with prices capped. Supply increases so will the utilisation increase.

(xii) The results for unit root test are not provided for inclusion of intercept and trend or there is no plot of the data. Further for robust results especially for data sets with structural breaks often PP test is also applied but not in this case.

(xiii) Results need a proper validation through cross referencing.

(xiv) Results such as *cost push inflation…consumer prices increase… incentives to producers…* is a bit A-theoretical. Like stagflation, but micro is more of a settled thing I guess.

(xv) Take the later half of first para and 2, 3rd paragraph in the situation analysis.

(xvi) Random thoughts should not be placed in the conclusion. References to be placed in the conclusion also needs a careful revisit. Conclusions such as employment share (it could be the absolute value) declining needs some evidence and not hard to get. Further basing policy recommendations which are not arrived at from the authors estimation should not be put forth.

(xvii) Editing is required.

Mahmood Khalid

Pakistan Institute of Development Economics,
Islamabad.

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The Effect of Oil Price Shocks on the Dynamic Relationship between Current Account and Exchange Rate: Evidence from D-8 Countries

SYEDA QURAT-UL-AIN and SAIRA TUFAIL

1. INTRODUCTION

The effect of oil price shocks on global economy has been a great concern since 1970s and has instigated a great deal of research investigating macroeconomic consequences of oil price fluctuations. Later on, the instability in the Middle East and recent oil price hike confirmed the enduring significance of the issue. Though a voluminous body of literature has evolved examining the bearings of oil prices for internal sectors of economies [to name a few, e.g., Barsky and Kilian (2004); Kilian (2008a,b); Hamilton (2008)], the studies analysing the external sector response to oil price shocks are very few [see, e.g. Kilian, *et al.* (2007)].

The determination of current account and exchange rate—the two major indicators of external sector—has been studied widely in theoretical and empirical literature but mostly the discussion of the two variables largely remained separate [Lee and Chinn (1998)]. Similarly, investigation of simultaneous response of these two variables to an oil price shock remained relatively less ventured avenue of research. Initial work done on the relationship between current account and oil price could not ascertain conclusive link between these two variables.[1] Recent work on the issue revealed the diversity of responses of current account of different countries to an oil price shock. For instance, oil price increase deteriorates current account balance of developing countries [OECD (2004); Rebucci and Spatafora (2006); Killian, *et al.* (2007)] but may improve it if the country happens to be a net oil-exporter. This implies that the relationship depends on the number of factors among which oil dependency of country, oil-intensity of production process[2] and responses of non-oil trade balance[3] and sources of oil price fluctuations[4]are of particular significance.

In this context exchange rate attains pivotal importance due to its role for adjusting current account imbalances as advocated by both traditional [Mundell (1962);

Syeda Qurat-ul-Ain is Graduate Student, Department of Economics, Fatima Jinnah Women University Rawalpindi. Saira Tufail <beatingmind@gmail.com> is Lecturer, Department of Economics, Fatima Jinnah Women University, Rawalpindi.

[1]See, for instance, Lafer and Agmon (1978), Marion and Svensson (1984).

[2]See, IMF (2000).

[3]See, Gruber and Kamin (2007).

[4]Buetzer, *et al.* (2012).

Flemming (1962)] and advance open economy macroeconomic approaches [Obstfeld and Rogoff (2000)] to current account determination. However, the potency of exchange rate for smoothing current account imbalances may be considerably affected in circumstances where oil prices are volatile in nature. There exists a strand of literature ascertaining the relationship between oil prices and exchange rate for both oil importing and exporting countries. However, research examining the effect of oil price innovations on the effectiveness of exchange rate to lessen current account imbalances is in fact scant.

The paper bridges this gap by utilising the data for D-8 countries. As a first step the existence of Marshal-Lerner condition and J-Curve phenomenon is explored for each country. Following Lee and Chinn (2006) a bivariate vector autoregressive model is employed as it minimises the arbitrariness and helps to get several presumptions of open economy macroeconomics validated with least possible restrictions. However, unlike Lee and Chinn (2006) who employed reduced form model, our study assumes identification by Cholesky factorisation considering exchange rate is unaffected by contemporaneous innovations in current account. This is justifiable as former is conducted for G-7 countries where the exchange rate and current account are determined jointly, while later is conducted for D-8 countries where assuming exchange rate relatively exogenous seems more plausible. Given the information from the first exercise, model is extended to allow the inclusion of oil prices to achieve two objectives; (a) to examine the effect of oil prices on the effectiveness of exchange rate to improve current account balance, and (b) to examine the simultaneous response of both current account and exchange rate to changes in oil prices. For both of these objectives lower triangular identification scheme is followed ordering oil prices ahead of exchange rate and current account.

The choice of countries is very critical to our objectives due to a number of reasons. The countries not only differ as far as their trade in oil is concerned, but also with respect to oil intensity of production. Moreover, being the host of not only oil exporting (Iran, Nigeria and Egypt) and importing countries (Pakistan, Turkey, Bangladesh), but also countries transiting from being oil exporter to importer (Indonesia and Malaysia), the group is expected to provide very insightful and diverse outcomes for the targeted variables given the oil price shock of same magnitude and direction.[5]

The rest of study is organised as follows. In Section 2, a review of related literature is presented. In Section 3, descriptive analysis of data is given. Section 4 reports the empirical results and Section 5 concludes the study.

2. RELATED LITERATURE

The relationship between current account balance and exchange rate is explicitly established in elasticity approach to balance of payment determination. Even the deviations from the basic model in the form of Marshal-Lerner condition and J-Curve phenomenon could not prove the authenticity of approach. Empirical evidence on this issue is not only ample but also evolutionary. For instance, initial work on this issue including Cooper (1971); Laffer (1974) and Salant (1974) provided evidence in support of J-curve phenomenon using bivariate models of exchange rate and trade balance.

[5]In the analysis part Indonesia is treated as oil importing country while Malaysia as oil exporting country.

However, according to Miles (1979) the inclusion of additional determinants of trade balance and balance of payment nullified the favourable contribution of exchange rate for trade balance while Bahmani-Oaskooee (1985) reinforced the existence of J-curve phenomenon even in a multivariate framework. Rose and Yellen (1989), Rose (1991) conducted studies for both developed and developing countries by using time series econometric techniques and could not find the evidence of cointegrating relationship between exchange rate and current account. Obstfeld and Rogoff (1995), on the other hand, assuming an infinite horizon monetary model of monopolistically competitive world economy showed that elasticity approach is valid if nominal prices in producer country are rigid and exchange rate pass-through is complete. Recently, by incorporating the standard assumptions of intertemporal macroeconomic models in vector autoregression framework, Lee and Chinn (2006) showed that the relationship between exchange rate and current account depends largely on the nature of shocks. For instance, temporary shocks depreciate the real exchange rate and improve current account balance while permanent shocks though appreciate the exchange rate but the effect on current account balance is not consistent.

Inclusion of oil prices in the modeling of exchange rate and current account is not only in concordance of elasticity approach but also consistent with both absorption and monetary approaches to balance of payment determination. This eminence arises from the fact that oil prices affect macroeconomy through a variety of channels most of which either emanate from current account and exchange rate or have direct or indirect effects on these variables. For instance, Lafer and Agmon (1978) showed in context of monetary approach to balance of payment that oil price shocks deteriorate trade balance markedly. This relationship is also reported in OECD (2004); Killian, Rebucci and Spataforta (2007). However, the size of the effect of oil price shock on trade balance is subject to the response of non-oil trade balance to oil price shocks [Lafer and Agmon (1978); Gruber and Kamin (2007)]. Amano and Norden (1995), Backus and Crucini (2000) Chen and Rogoff (2003), Cashin, *et al.* (2004) and Tokarick (2008) showed that effect of oil prices are transmitted to exchange rate through changes in terms of trade. According to Krugman (1983), Golub (1983) and Rasmussen and Roitman (2011) this effect occurs through the transfer of wealth from oil importing to exporting countries and is largely determined by the oil dependence of oil importing and import patterns of oil exporting countries. Recently, Bodenstein, *et al.* (2007: 2011) showed that in order to stabilise the net foreign assets in face of positive oil price shock exchange rate depreciates (appreciates) for oil importing (exporting) countries. On the other hand, effect on current account depends on the rate of depreciation of non-oil terms of trade and adjustment of non-oil trade balance in face of oil price hike. The magnitude of effect of oil price increase vitally depends on the level of financial integration and efficiency of asset market.

The brief survey of literature strengthens the case for our research as none of the study reported above takes into account the relative effectiveness of exchange rate for adjusting current account imbalances with and without oil price changes. Moreover, joint response of current account and exchange rate for both oil importing and exporting countries has not been assessed yet. The methodology to address these issues is discussed in forthcoming sections.

3. MODEL SPECIFICATION

3.1. Model Construction

In present study two systems of equations are constructed to be estimated by VAR. Initially two-variables-system including current account (ca) and exchange rate (rexr) is constructed. Structural shock includes one standard deviation positive shock to exchange rate in order to observe the impact of current account. In the second step three-variable system of equations is developed and oil prices (oil) are included as third variable. The model is given as follows:

$$X_t = A(L)X_{t-1} + U_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Whereas for the first model X_t is the 2 × 1 vector of endogenous variables, i.e. X'_t [$rexr_t$, ca_t]. $A(L)$ is 2 × 2 matrix of lag polynomials and U_t is the 2 × 1 vector reduced form innovation, i.e., $U_t \equiv [u_t^{rexr}, u_t^{ca}]$. While for second model, X_t is the 3 ×1 vector of endogenous variables, i.e. X'_t [oil, $rexr_t$, ca_t]. $A(L)$ is 3 × 3 matrix of lag polynomials and U_t is the 3 × 1 vector reduced form innovation , i.e., $U_t \equiv [\mu_t^{oil}, u_t^{rexr}, u_t^{ca}]$. These innovations are independently and identically distributed with variance covariance matrix, where

$$E(U_t) = 0\,;\, E(U_t U_t') = \sum u_t$$

Amisano and Giannini (1997) suggested the following relationship between reduced form and structural shocks in the form of AB-model:

$$AU_t = BV_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

V_t are the structural shocks, whereas, A and B are 2 × 2 and 3 × 3 matrices for two models respectively, which show the instantaneous relationship between variables and linear relationship between shocks and reduced form innovation respectively. The remaining steps involved in the construction of model are presented in Appendix A.

We employed recursive scheme of identification given the fact in our system variables can be arranged according to degree of endogeniety. In first system of equations including exchange rate and current account, exchange rate is considered relatively more exogenous than current account. This scheme of identification is considered more appropriate for developing country due to its limited ability to affect the value of dollar in international market. In the second system of equation oil prices are considered most exogenous variable for both oil-exporting and importing countries. Exchange rate is expected to be effected by oil price and its own innovations. While current account is considered to be affected by both exchange rate and oil prices and its own innovations.

These identification schemes are presented as follows:

$$\begin{bmatrix} 1 & 0 \\ -\alpha_{21} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^{trex} \\ \varepsilon_t^{ca} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^{rexr} \\ u_t^{ca} \end{bmatrix}$$

For three variable VAR it is given as:

$$\begin{bmatrix} \alpha_{11} & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 \\ \alpha_{31} & \alpha_{31} & \alpha_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{oil} \\ \varepsilon_t^{rexr} \\ \varepsilon_t^{ca} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^{oil} \\ u_t^{rexr} \\ u_t^{ca} \end{bmatrix}$$

Along with these short run restrictions, the same identification is used for the long run restrictions.

3.2. Data Description

The annual data for D-8 countries; Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey from the year 1981 to 2011 is collected. The data set comprises of three main variables: current account, real exchange rate and oil price. All data has been retrieved from the World Development Indicators (2013) issued by World Bank, except of world oil price. The data for oil price was retrieved from International Financial Statistics issued by International Monetary Fund. Exchange rate and oil price are taken in log form and current account as percentage of GDP. The exchange rate is made real by multiplying it with consumer price index (2005=100) of USA and dividing it with consumer price index of each country.

4. ESTIMATION AND DISCUSSION OF RESULTS

4.1. Test of Stationarity

Due to the adoption of multiple exchange rate regimes and trade reforms, it was intuitive to assume the presence of structural instability in the exchange rate and current account balance for all D-8 countries. To affirm our assertion, the model for each country was checked for structural stability using Chow break point test (results are reported in Appendix B). Given the presence of significant structural breaks for all countries, the power of conventional Augmented Dickey Fuller test becomes dubious. In order to overcome this problem Clemente, Montanes and Reyes (1998) test is applied that allows for two structural breaks. By applying both innovative outlier and additive outlier schemes, it was found that all series for each country are integrated of order one, i.e. *I(1)*. The results are reported in Table 1.

4.2. Lag Order Selection

Schwartz information criterion (SIC) is used to select appropriate lag length. The Table 2 shows appropriate lag length selected for model with and without oil price for D-8 countries.

4.3. Marshal Lerner Condition and J-Curve in D-8 Countries

Table 3 shows that J-curve phenomenon exists in all oil importing countries of the group. Among oil exporting countries, J-curve phenomenon exists for Egypt and Nigeria while for Iran Marshal Lerner condition holds both in short and long run. The case of Malaysia is opposite to that of Iran where depreciation could not stimulate current account improvement even in long run.

After including oil prices in the model, J-curve phenomenon continues to exist in Bangladesh and Turkey, though, it dampens the long run favourable effect of depreciation for current account for both of the countries. The case of Pakistan presents the extreme example of oil price repercussions for the relationship between exchange rate and current account. In presence of oil prices exchange rate depreciation not only deteriorates current account in short run, this deterioration exacerbates in long run. In contrast, for Indonesia the inclusion of oil prices in the model makes the existence of Marshal Lerner condition possible in both short and long run.

Table 1

Clemente-Montanes-Reyes Unit Root Test (Double Mean Shift)

		Innovative Outlier				Additive Outlier			
		Level		Difference		Level		Difference	
Country	Variables	*(rho)*	*Break*	*(rho)*	*Break*	*(rho)*	*Break*	*(rho)*	*Break*
Bangladesh	*ca*	–0.83	1988, 2004	–1.79**	1988, 2004	–1.0	1987, 2003	–1.96**	1984, 1993
	lrexr	–0.49	1998,1995	–0.92**	1994, 2005	–0.43	1995, 2003	–0.83**	1995, 2004
Egypt	*ca*	–0.7	1988, 1993	–1.74**	1988, 1993	–0.6	1987, 1994	–1.43**	1992, 2001
	lrexr	–0.4	1984, 1988	–0.82**	1988, 1990	–0.5	1986, 1992	–0.82**	1988, 1990
Iran	*ca*	–0.90	1989, 1992	–8.01**	1993, 1999	–0.61	1989, 1995	–2.89**	1992, 1998
	lrexr	–0.37	1991, 2000	–0.89**	1992, 2000	–1.0	1994, 2003	–1.8**	1994, 2004
Indonesia	*ca*	–1.0	1996, 2002	–3.0**	1996, 1999	–0.91	1997, 2003	–1.87**	1996, 2000
	lrexr	–0.31	1997, 2000	–1.31**	1986, 1997	–0.42	1995, 2003	–1.60**	1988, 1996
Malaysia	*ca*	–0.62	1986, 1996	–1.30**	1986, 1997	–0.50	1995, 2000	–1.29**	1985, 2006
	lrexr	–1.0	1984, 1996	–1.54**	1991, 1997	–0.76	1987, 1999	–1.05**	1990, 1996
Nigeria	*ca*	–1.01	1982, 2002	–1.69**	1992, 2004	–1.0	1990, 2001	–1.70**	1991, 2007
	lrexr	–0.62	1984, 1997	–0.89**	1991, 1998	–0.22	1988, 1998	–0.66**	1992, 1997
Pakistan	*ca*	–1.0	1982, 2002	–1.69**	1992, 2004	–0.78	1990, 2001	–1.79	1991, 2007
	lrexr	–0.43	1997, 2002	–1.02**	1994, 2000	–0.60	1986, 1998	1.67**	1997, 1999
Turkey	*ca*	–1.18	1986, 2003	–2.7**	2003, 2007	–1.06	1986, 2003	–2.05**	2002, 2006
	lrexr	–0.67	1988, 2003	1.06**	1993, 2000	–0.79	1987, 2004	–1.2**	1992, 1999

** Denotes rejection of null hypothesis at 5 percent level of significance.

Table 2

*Lag Length Selection**

Countries	Without Oil Price Lags	With Oil Price Lags
Bangladesh	1	1
Egypt	2	1
Iran	1	1
Indonesia	3	1
Malaysia	1	1
Nigeria	2	1
Pakistan	3	1
Turkey	2	1

*Selection is based on the minimum value of SIC.

Table 3

Marshal Lerner Condition and J-Curve in D-8 Countries

Bangladesh	Without Oil Prices		With Oil Price		Percentage Change[6,7]	
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run
	Ca	Ca	Ca	Ca		
Rexr	–4.02***	6.09***	–4.14***	4.79***	–0.03	–0.21
	(–19.17)	(29.83)	(–20.27)	(23.44)		
Egypt						
	Short run	Long run	Short run	Long run		
	Ca	Ca	Ca	Ca		
Rexr	–10.76***	4.38***	–12.60***	9.39***	–0.17	114.38
	(56.94)	(23.18)	(–67.86)	(50.57)		
Iran						
	Short run	Long run	Short run	Long run		
	Ca	Ca	Ca	Ca		
Rexr	0.3*	1.49***	–0.07	2.54***	–123.3	70.47
	(1.69)	(8.07)	(–0.42)	13.4		
Indonesia						
	Short run	Long run	Short run	Long run		
	Ca	Ca	Ca	Ca		
Rexr	–4.88***	3.63***	0.39**	2.54***	107.99	–30.02
	(–25.36)	(18.86)	2.11	13.4		
Malaysia						
	Short run	Long run	Short run	Long run		
	Ca	Ca	Ca	Ca		
Rexr	–18.96***	–14.5***	–19.75**	5.59***	–4.17	138.55
	(–102.08)	(–78.18)	(–106.36)	(30.11)		
Nigeria						
	Short run	Long run	Short run	Long run		
	Ca	Ca	Ca	Ca		
Rexr	–8.609***	6.211***	–1.905**	7.932***	77.87	27.70
	(–45.55)	(32.866)	(–10.258)	(42.715)		
Pakistan						
	Short run	Long run	Short run	Long run		
	Ca	Ca	Ca	Ca		
Rexr	–8.13***	6.82***	–10.93**	–18.28***	–34.4	–368.03
	(–42.29)	(35.44)	(–58.89)	(–98.48)		
Turkey						
	Short run	Long run	Short run	Long run		
	Ca	Ca	Ca	Ca		
Rexr	–14.69***	9.47***	–7.88***	1.759***	46.35	–81.42
	(–77.74)	(50.126)	(–42.47)	(9.47)		

***Denote significance at 1 percent level, **Denotes significance at 5 percent level.

[6]It's calculated as difference in coefficient of exchange rate for current account with and without oil prices model as percentage of coefficient of exchange rate for current account for model without oil price. The exercise is done for both short and long run.

[7]A negative value is showing decrease in the effectiveness of exchange rate for improving current account balance while a positive sign is showing the percentage increase.

Many interesting results stand out when oil prices are included in model for oil exporting countries. In short run, effectiveness of exchange rate depreciation for current account improvement deteriorates for Egypt, Iran and Malaysia respectively and increases for Nigeria. However, for all exporting countries the role of exchange rate for improving current account balance strengthens in long run after the inclusion of oil prices. The improvement is significant for Malaysia, which is 139 percent. These interesting results are well consistent with the Malaysian policies of subsidising oil prices [Arshad and Shamsuddin (2005)].[8]

4.3.1. Impulse Response Functions and Variance Decomposition

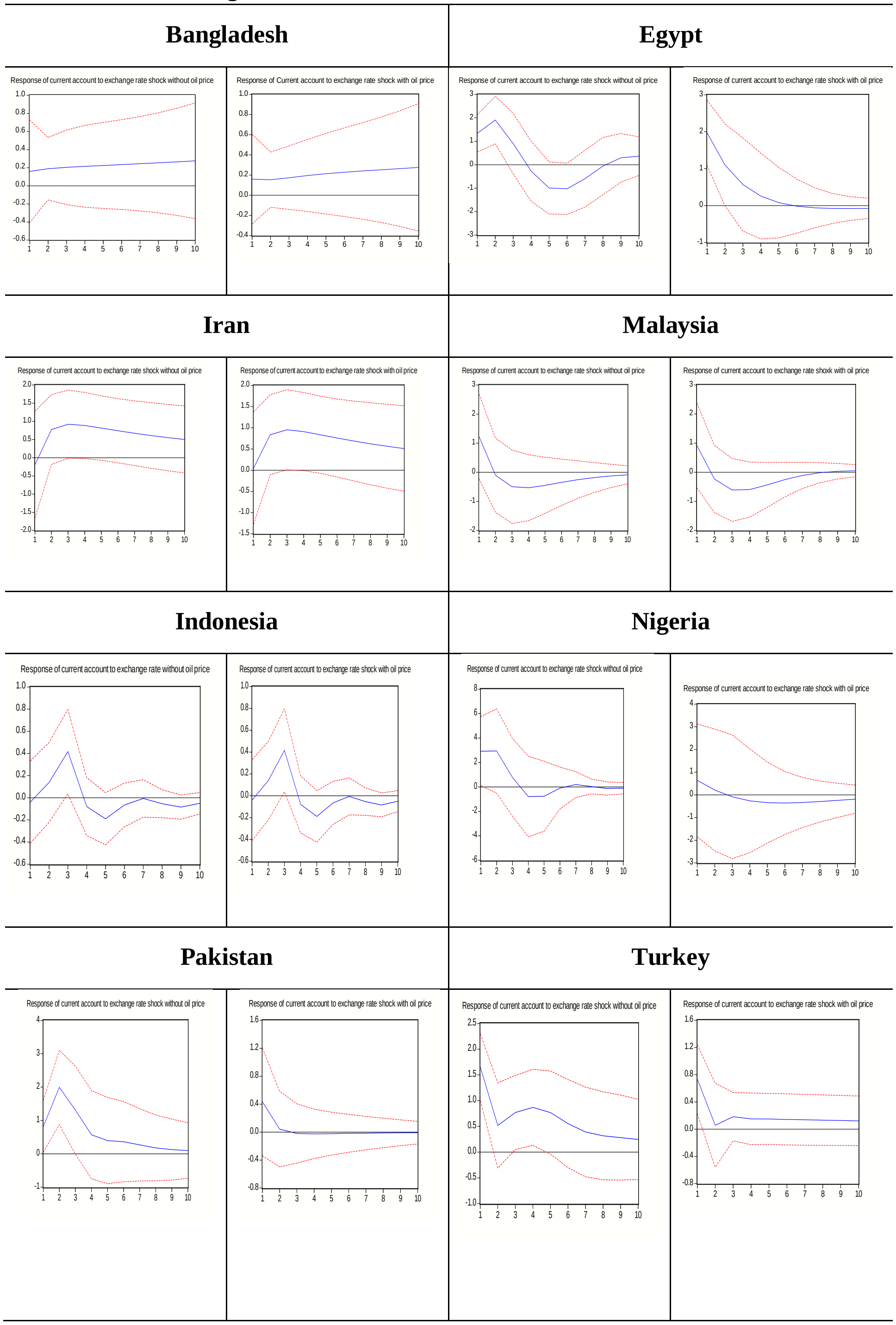
The relationship between exchange rate and current account for both models (with and without oil prices) is also forecasted with the help of impulse response functions. These impulses are derived on the basis of above specified identification scheme, in which Cholesky one-standard deviation shocks are given to exchange rate and response of current account balance is estimated over a period of ten years, 2012-2021, following the initial occurrence of the shocks. The impulses for all countries are plotted in Figure 1.

Among oil importing countries an obvious difference can be observed in response of current account to one standard deviation positive shock to exchange rate in models with and without oil price for Pakistan and Turkey. This also holds for Egypt and Nigeria among oil exporting countries. These results are also consistent with the exercise done and results obtained in Section 4.3.

Along with derivation of impulse response function, variance decomposition analysis is also conducted to analyse the contribution of each shock to the variance of n-period ahead forecast error of the variables. Table 4 presents the variance decomposition of current account balance with and without oil prices. For all oil importing countries, oil prices are contributing more than exchange rate in forecasted error of current account balance. For Indonesia, Turkey and Pakistan contribution of exchange rate reduces drastically after the inclusion of oil prices in model. However, for Bangladesh contribution of exchange rate after including oil prices remains almost same. This is also the case of Nigeria among oil exporting countries. However, for Egypt and Iran exchange rate is contributing more to the standard error of current account balance as compared to oil prices.

[8]The cost of oil price subsidy in Malaysia increases with the increase in oil price which is not compensated by increased export revenues. Subsidised oil prices also encourage oil consumption leading to mounting oil bill and current account worsening. However, with a long run increase in oil prices oil export revenues increase to more than compensate initial mounted import bill leading to the existence of J-curve phenomenon.

Fig. 4.1. Impulse Response Function of Current Account Balance in Response to Exchange Rate Shock With and Without Oil Prices



Source: Authors' own generated.

Table 4

Percentage Contribution of Exchange Rate in Standard Error of Current Account Balance

Bangladesh

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.03	1.24	98.75
2	0.05	2.73	97.26
9	0.14	16.68	83.31
10	0.16	18.83	81.16

Percentage Contribution to Standard Error of Current Account With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.21	9.24	1.93	88.82
2	0.25	21.97	3.02	75.00
9	0.27	29.88	16.71	53.40
10	0.27	28.96	19.164	51.86

Egypt

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.12	33.77	66.22
2	0.19	58.88	41.11
9	0.23	69.31	30.68
10	0.23	69.63	30.36

Percentage Contribution to Standard Error of Current Account With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.26	5.23	48.28	46.48
2	0.35	4.44	46.12	49.42
9	0.56	5.59	42.25	52.15
10	0.57	5.86	42.15	51.98

Iran

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.61	0.23	99.76
2	0.85	3.76	96.23
9	1.40	21.96	78.03
10	1.43	22.87	77.12

Percentage Contribution to Standard Error of Current Account With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.22	20.52	0.014	79.46
2	0.28	18.91	4.046	77.03
9	0.35	18.96	21.63	59.40
10	0.35	18.95	22.46	58.57

Indonesia

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.16	15.78	84.21
2	0.18	27.06	72.93
9	0.20	36.67	63.32
10	0.20	36.67	63.32

Percentage Contribution to Standard Error of Current Account With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.25	15.03	0.13	84.82
2	0.29	18.35	1.68	80.00
9	0.41	31.44	11.20	57.35
10	0.41	31.84	11.22	56.925

Continued—

Table 4—(*Continued*)

Malaysia

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.06	9.37	90.62
2	0.07	7.56	92.43
9	0.08	10.90	89.09
10	0.08	10.92	89.07

Percentage Contribution to Standard Error of Current Account With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.22	0.11	5.34	94.53
2	0.29	0.12	4.27	95.56
9	0.36	1.69	7.78	90.52
10	0.36	1.76	7.78	90.44

Nigeria

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.33	14.21	85.78
2	0.47	20.03	79.96
9	0.58	19.87	80.12
10	0.58	19.87	80.12

Percentage Contribution to Standard Error of Current Account With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.23	39.06	0.55	60.37
2	0.28	34.96	0.51	64.51
9	0.33	34.06	1.05	64.87
10	0.33	34.08	1.09	64.81

Pakistan

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.04	14.80	85.19
2	0.07	50.45	49.54
9	0.12	60.33	39.60
10	0.12	60.41	39.58

Percentage Contribution to Standard Error of Current Account With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.22	28.04	3.07	68.88
2	0.27	35.43	2.34	62.22
9	0.33	40.90	1.96	57.12
10	0.33	40.91	1.96	57.12

Turkey

Percentage Contribution to Standard Error of Current Account Without Oil Price

Period	Forecasted Standard Error	Exchange Rate	Current Account
1	0.11	63.56	36.43
2	0.15	65.29	34.70
9	0.24	76.14	23.85
10	0.24	76.33	23.66

Percentage Contribution to Standard Error of Current Accounts With Oil Price

Period	Forecasted Standard Error	Oil Price	Exchange Rate	Current Account
1	0.25	38.60	15.60	45.79
2	0.33	41.78	13.86	44.35
9	0.58	60.33	11.02	28.63
10	0.60	61.46	10.84	27.68

Source: Author's Calculations.

4.4. Impact of Oil Prices on Exchange Rate and Current Account

The above exercise calls for further investigation of the issue by analysing the response of exchange rate and current account to oil price hike. Results are reported in Table 5. Increase in oil prices improves current account balance for all oil importing countries in short run and deteriorates it in long run except Bangladesh. It causes depreciation of exchange rate for Indonesia, Pakistan and Turkey but appreciates the exchange rate for Bangladesh in short run and other way round in long run.

These results are supported by Wijnbergen (1984) who postulated that oil price hike may induce recessionary pressures in oil importing countries leading to investment cuts. This will lead to decreases in demand of imported goods—mostly of which are energy and capital—leading to temporary improvement in current account. These improvements may take a permanent path depending on the availability of alternative use of energy as in case of Bangladesh. The permanence of improvement in current account also depends on the elasticity of substitution between oil and other energy sources. This is also true for Bangladesh where oil can be easily substituted with natural gas and other non commercial sources of energy consumption.[9] Moreover, Razzaqi and Sherbaz (2011) stated that growth of energy use is less than growth of GDP for Bangladesh showing the less reliance of production structure on oil and other sources of energy.

This fact is further supported by their findings that Bangladesh has also experienced negative growth in the use of energy delineating the highly elastic demand of energy with respect to energy prices. The same argument can be put forward for exchange rate appreciation which is occurring due to increase in oil price in Bangladesh. Unlike Bangladesh current account position worsens after long run increase in oil price in other oil importing countries. However, this worsening is insignificant for Pakistan. This insignificance of oil price for current account balance of Pakistan cannot be justified by the arguments posited for Bangladesh. Contrary to Bangladesh, Pakistan has not specialised in production of other sources of energy rather the results are pointing toward the alarming situation in Pakistan. It is evident from results that efforts to increase the investment or overcome the recessionary shock of oil price hike are not enough in Pakistan leading to vicious circle of poor investment declining demand for goods needed to encourage investment leaving insignificant effect of oil price on current account.

On the other hand, all oil exporting countries experience deterioration of current account in response to oil price shock both in short and long run except Malaysia whose current account improves in long run. For Egypt, with one percent increase in oil price current account deteriorates by 1.67 percent and exchange rate appreciates by 0.06 percent. However, the effect of oil price on exchange rate merits less consideration due to its insignificance. Even in long run though insignificant yet negative effect of high oil prices prevails for both current account and exchange rate. This means that country’s oil exports to world have not risen much asto compensate fully for rising import bill leading to worsening of current account and appreciation of exchange rate. However long run adverse effect of oil price is less severe than its short run counterpart. The results are consistent with the actual situation prevailing in the county as growth rate of oil consumption has been more than that of production in the many years of sample selected.

[9]About 66 percent of commercial energy demand is met by natural gas and more than 50 percent of household energy demand is met by non commercial resources.

Table 5

Impact of Oil Prices on Current Account Balance and Exchange Rate

Bangladesh				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	1.684***	–0.01	6.48***	0.97***
	(8.25)	(–0.04)	(6.49)	(4.76)
Egypt				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	–1.67***	–0.06	–0.81	–0.02
	(–9.01)	(–0.33)	(–0.46)	(–0.12)
Iran				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	–8.07***	0.44***	–0.69**	–0.12
	(–39.84)	(2.34)	(–1.96)	(–0.64)
Indonesia				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	1.75***	0.27	–2.32***	–0.39
	8.91	1.44	–4.5	–2.09
Malaysia				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	–2.12***	0.14	3.84***	–0.16
	(–11.31)	(0.46)	(3.64)	(–0.84)
Nigeria				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	–22.87***	–0.153	–1.293***	–0.79
	(–121.00)	(–0.824)	(–0.871)	–4.256
Pakistan				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	4.96***	0.07	–5.30	–0.28
	(26.66)	(0.38)	(–1.56)	(–1.50)
Turkey				
	Short-run		Long-run	
	Ca	Rexr	Ca	Rexr
Oil	2.98***	0.197	–3.267***	–0.36***
	(15.79)	(1.06)	(–8.69)	(–1.977)

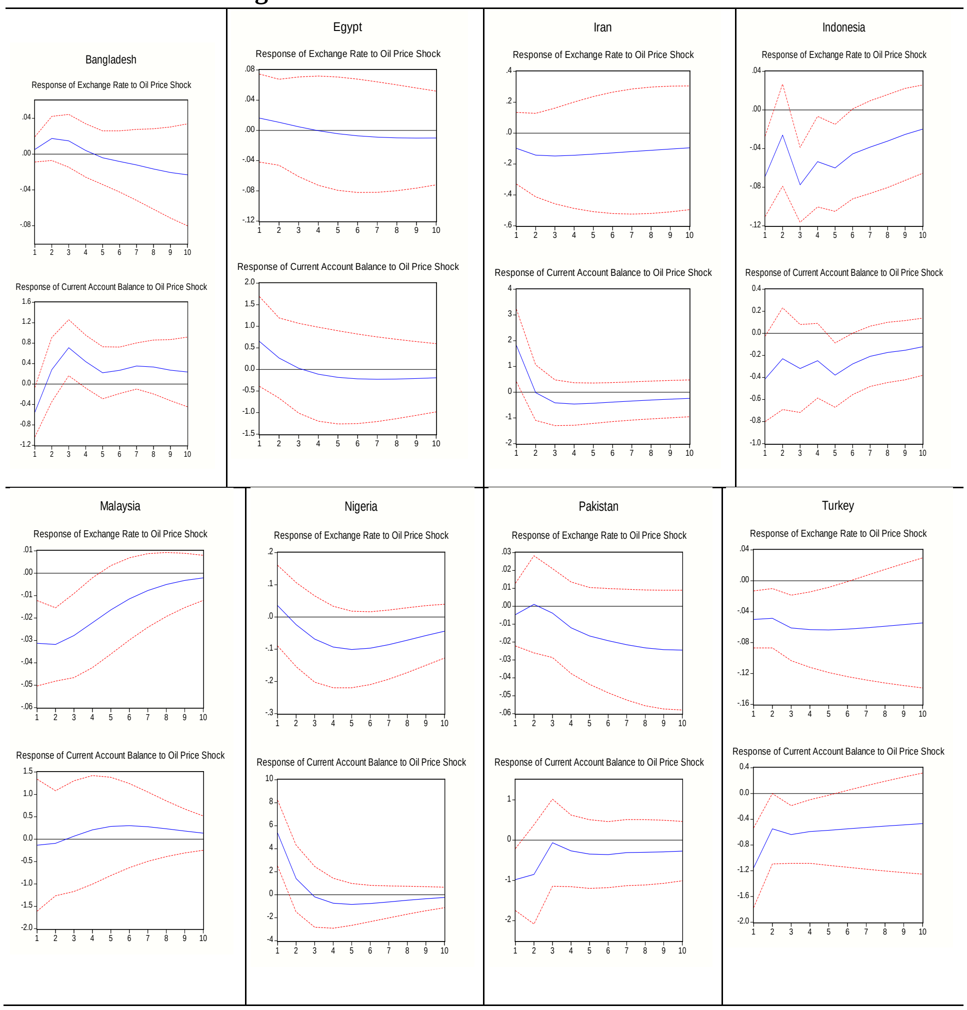
***Denote significance at 1 percent level.

The effect of oil prices on current account in case of Iran is similar to that of Egypt, however, for Iran growth rate of oil production still exceeds than that of consumption. Farzanegan and Markwardt (2009) providing more plausible reason for these results for Iran. They showed that it's not the mounting import bill of oil as compared to oil-export receipts which leads to current account worsening rather these are the supply side wealth effects of increase in oil price that stimulate real imports of variety of other goods leading to the worsening of current account position in Iran. Morsy (2009) showed that with the increase in oil price major oil exporting countries experience surpluses that constitute an average of 23 percent of GDP. However, given the increased wealth these countries spend significantly more on imports of goods and services, amounting to an average of 37 percent of GDP leading to the worsening of current account balance. Moreover, appreciation of exchange rate due to long run increase in oil price is providing strong evidence of Dutch disease phenomenon among oil exporting countries.

4.4.1. *Impulse Response*

Exchange rate of all oil importing countries is depreciating significantly in response to oil price shock except of Bangladesh whose currency is appreciating insignificantly. As far as current account balance is concerned, all oil importing countries are expected to experience significant improvement in their current account balance with one standard deviation shock to oil prices. Among oil exporting countries, Malaysia's exchange rate is depreciating significantly, however improvement in current account happens to be insignificant. For all other oil exporting countries the effect of one time positive oil price shock is appreciation of currency but insignificantly. However, current account balance is deteriorating significantly in Iran and Nigeria, insignificantly in Egypt. In Malaysia current account balance is improving insignificantly in response to one standard deviation positive shock to oil prices.

Fig. 4.2. Impulse Response Function of Current Account Balance in Response to Exchange Rate Shock With and Without Oil Prices



Source: Authors' own generated.

5. CONCLUSION AND RECOMMENDATIONS

The objective of this study is to explore the dynamic relationship between current account and exchange rate and to analyse the effect of oil price innovation on their relationship for D-8 countries. For achieving this objective Vector Autoregression (VAR) approach is employed. Impulse responses are also used to analyse the response of current account to exchange rate shocks with and without oil price innovations. A variance decomposition analyses is then conducted to determine the contribution of exchange rate and oil price in the forecasted errors of current account. The annual data for each country is collected from 1981 to 2011 for current account, exchange rate and oil price.

The results revealed that J-curve phenomenon exists in all oil importing countries of the group. Among oil exporting countries, J-curve phenomenon exists for Egypt and Nigeria while for Iran Marshal Lerner condition holds both in short and long run. The case of Malaysia is opposite to that of Iran where depreciation could not stimulate current account improvement even in long run. After including oil prices in the model, J-curve phenomenon continues to exist in Bangladesh and Turkey. For Pakistan, in presence of oil prices exchange rate depreciation not only deteriorates current account in short run, this deterioration exacerbates in long run. Current account balance of Indonesia happens to improve with depreciation of exchange rate after inclusion of oil prices both in short and long run. For all oil exporting countries the role of exchange rate for improving current account balance strengthens in long run after the inclusion of oil prices.

As far as the effect of oil prices on exchange rate and current account balance is concerned, increase in oil price improves current account balance for all oil importing countries in short run and deteriorates it in long run except Bangladesh. It causes depreciation of exchange rate for Indonesia, Pakistan and Turkey but appreciates the exchange rate for Bangladesh in short run and other way round in long run. On the other hand, all oil exporting countries experience deterioration of current account in response to oil price shock both in short and long run except Malaysia whose current account improves in long run. Moreover, appreciation of exchange rate due to long run increase in oil price is providing strong evidence of Dutch disease phenomenon among oil exporting countries.

The recommendations drawn from present study are that for the oil exporting countries' exchange rate appreciates in face of oil price hike which results in Dutch Disease phenomena. As current account balance declines with exchange rate appreciations so these countries should maintain stability in their exchange rates and they should diversify their export base from oil to non-oil exports as well. Nigeria, Iran and Egypt should reduce their dependence on oil and natural resources and they should move towards industrial development as well.

Bangladesh emerged as a role model for other oil importing and developing countries through its results. Current account of Bangladesh shows improving trend both in face of high oil price hike and with exchange rate appreciation. It means Bangladesh has adopted alternative resources and lowered its reliance on oil resources. Pakistan and Turkey are oil importing countries; excessive increase in oil demand is causing reserve depletion in these countries which in turn causes imbalance in their current account. In order to improve current account balance, these countries should lower their demand of crude oil by discovering its alternatives like coal and gas reservoirs. These countries are also in dire need of widening their export base through proper planning and through building new infrastructure that can attract foreign investment in these countries.

The research can be extended in number of ways. For instance, study on exploring the transmission mechanism of oil prices to exchange rate and analysing the relationship between exchange rate and current account by incorporating exchange rate regimes and institutional and structural changes taking place during the sample period can be undertaken.

APPENDIX A

Recursive form of VAR can be obtained from reduced form by pre multiplying equation 1 with A as

$$AX_t = AA(L)X_{t-1} + AU_t \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

Replacing AU_t by BV_t to get,

$$AX_t = AA(L)X_{t-1} + BV_t \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

$$\begin{bmatrix} 1 & -\alpha_{12} \\ -\alpha_{21} & 1 \end{bmatrix} \begin{bmatrix} rexr_t \\ ca_t \end{bmatrix} = \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} rexr_{t-1} \\ ca_{t-1} \end{bmatrix} + \begin{bmatrix} 1 & \gamma_{12} \\ \gamma_{21} & 1 \end{bmatrix} \begin{bmatrix} u_t^{rexr} \\ u_t^{ca} \end{bmatrix}$$

Solving the Equation 4 for X_t we get

$$X_t = A^{-1}A(L)X_{t-1} + A^{-1}BV_t \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (5)$$

$$\begin{bmatrix} rexr_t \\ ca_t \end{bmatrix} = \begin{bmatrix} 1 & -\alpha_{12} \\ -\alpha_{21} & 1 \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} rexr_{t-1} \\ ca_{t-1} \end{bmatrix} + \begin{bmatrix} 1 & -\alpha_{12} \\ -\alpha_{21} & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & \gamma_{12} \\ \gamma_{21} & 1 \end{bmatrix} \begin{bmatrix} u_t^{rexr} \\ u_t^{ca} \end{bmatrix}$$

Summarised form of equation 5 can be written as:

$$X_t = A(L)X_{t-1} + \varepsilon_t \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (6)$$

Where as,

$$C(L) = A^{-1}A(L)$$

$$\varepsilon_t = A^{-1}BV_t$$

$$\begin{bmatrix} \varepsilon_t^{trex} \\ \varepsilon_t^{ca} \end{bmatrix} = \begin{bmatrix} 1 & -\alpha_{12} \\ -\alpha_{21} & 1 \end{bmatrix} \begin{bmatrix} 1 & \gamma_{12} \\ \gamma_{21} & 1 \end{bmatrix} \begin{bmatrix} u_t^{rexr} \\ u_t^{ca} \end{bmatrix}$$

Equation 6 conveys autoregressive representation of the model in which each variable is expressed as the function of the past values of itself and of the other variables of the system. Secondly, it shows that reduced form innovations are the linear combination of recursive innovations.

In next step model is extended to allow for inclusion of oil prices (oil). The above given steps are replicated and three variable system of equation is constructed and final form is given as follows:

$$\begin{bmatrix} oil_t \\ rexr_t \\ ca_t \end{bmatrix} = \begin{bmatrix} 1 & -\alpha_{12} & -\alpha_{13} \\ -\alpha_{21} & 1 & -\alpha_{23} \\ -\alpha_{31} & -\alpha_{32} & 1 \end{bmatrix}^{-1} \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \begin{bmatrix} oil_{t-1} \\ rexr_{t-1} \\ ca_{t-1} \end{bmatrix} +$$

$$\begin{bmatrix} 1 & -\alpha_{12} & -\alpha_{13} \\ -\alpha_{21} & 1 & -\alpha_{23} \\ -\alpha_{31} & -\alpha_{32} & 1 \end{bmatrix}^{-1} \begin{bmatrix} 1 & \gamma_{12} & \gamma_{13} \\ \gamma_{21} & 1 & \gamma_{23} \\ \gamma_{31} & \gamma_{32} & 1 \end{bmatrix} \begin{bmatrix} u_t^{oil} \\ u_t^{rexr} \\ u_t^{ca} \end{bmatrix}$$

$$\begin{bmatrix} \varepsilon_t^{oil} \\ \varepsilon_t^{rexr} \\ \varepsilon_t^{ca} \end{bmatrix} = \begin{bmatrix} 1 & -\alpha_{12} & -\alpha_{13} \\ -\alpha_{21} & 1 & -\alpha_{23} \\ -\alpha_{31} & -\alpha_{32} & 1 \end{bmatrix}^{-1} \begin{bmatrix} 1 & \gamma_{12} & \gamma_{13} \\ \gamma_{21} & 1 & \gamma_{23} \\ \gamma_{31} & \gamma_{32} & 1 \end{bmatrix} \begin{bmatrix} u_t^{oil} \\ u_t^{rexr} \\ u_t^{ca} \end{bmatrix}$$

APPENDIX-B

Chow Break Point Stability Test

F-statistics	Probability	Log Likelihood Ratio	Probability
Bangladesh (2003)			
5.99	0.01	11.28	0.003
Egypt (1991)			
9.14	0.00	15.98	0.000
Iran (1999)			
5.99	0.08	5.73	0.05
Indonesia (1998)			
8.31	0.0016	14.82	0.0006
Malaysia (1998)			
5.52***	0.009	10.63	0.0049
Nigeria			
4.92	0.001	9.63	0.01
Pakistan (2000)			
12.64	0.000	20.38	0.000
Turkey (1989)			
3.85	0.03	7.78	0.02

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Comments

The paper titled "The Effects of Oil Price Innovations on the Dynamic Relationship between Current Account and Exchange Rate: Evidence from D-8 Countries" is an excellent and systematic effort to explore the relationship in the shocks in oil prices and their impact on the current account and exchange rates in the D-8 countries. The case study of D-8 countries is carefully selected so as to represent both the oil exporting and oil importing countries and the relative dynamics thereof.

However the following are some of my comments which the authors may like to consider before the final submission of their papers:

(i) The title says *oil price innovations*….in my opinion since the authors have presented an empirical paper and it's not a pure econometrics/statistics paper hence the term innovation which in economics represents more of a controlled intervention sense, may be changed to *shocks.*

(ii) The sample period is taken upto 1981-2010, since the paper will be published in 2014, so if its not of a big hassle the authors may like to increase the no of years to be taken as the sample period.

(iii) Since the authors are exploring the impact of shocks in one of the components in the current account, a natural question arises would the analysis change if it was some other component say for developing countries the import of technology products, or the export of the agro-based products. Or is it the oil specifically, then in this case authors need to present a proper transmission mechanism of how the shock in oil prices will lead to an impact. I am saying this because in there results the results have some outliers on both the oil importing and oil exporting countries. So may be we need to generalise some results as to saying those imports which have a larger share in the imports/exports would follow this pattern.

(iv) Since we are exploring the dynamics through the adjustments in the exchange rates, there are a number of other institutional and structural changes which have taken place over the sample period. Such as (1) exchange rate regimes (authors have pointed it out in the literature but not used it) (2) remittance from the oil exporting countries to the oil importing countries being the origin country (3) BOP controls such as capital account convertibility (4) active monetary policy etc.

(v) Finally the difference in results across countries such as Bangladesh being an outlier needs more clarification in terms of either a theoretical justification or an administrative one.

The paper makes an interesting case and presents the results in accordance with the theoretical understanding. Over all the paper is a good contribution to the existing knowledge on the subject.

Mahmood Khalid

Pakistan Institute of Development Economics,
Islamabad.