The Pakistan Development Review
33 : 4 Part I (Winter 1994) pp. 327–356

The Quaid-i-Azam Lecture

Markets, Technological Change and Economic Growth

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I am honoured to be invited to give this lecture before so distinguished an audience of development economists.

For the last 2½ years I have been director of a project financed by the Canadian Institute for Advanced Research and composed of a group of scholars from Canada, the United States, and Israel.[1] Our brief is to study the determinants of long term economic growth. Although our primary focus is on advanced industrial countries such as my own, some of us have come to the conclusion that there is more common ground between developed and developing countries than we might have first thought. I am, however, no expert on development economics so I must let you decide how much of what I say is applicable to economies such as your own.

Today, I will discuss some of the grand themes that have arisen in my studies with our group. In the short time available, I can only allude to how these themes are rooted in our more detailed studies. In doing this, I must hasten to add that I speak for myself alone; our group has no corporate view other than the sum of our individual, and very individualistic, views.

THREE MAJOR THEMES

The three major themes of my talk can all be traced back to the classical economists. I will first state their views and will then go on to suggest that our understandings of all of them need major reinterpretation.

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I. Markets Coordinate Decentralised Decision-making

The classical economists developed the understanding that the market was a social control mechanism that organised our economic activity *as if* it were centrally planned by an omniscient being, but more effectively than if any central planning actually occurred. This is Smith's famous "hidden hand".

Markets work by generating prices which publicly signal relative national scarcities without anyone having to calculate them, or even to know what they are, and then allowing self-interested individuals to respond to these signals, which they do by economising on relatively scarce things (because they are expensive) while making lavish use of relatively plentiful things (because they are cheap).

II. Diminishing Returns Limit the Income Gains Achievable by Accumulating Capital

In the classical view, the iron law of diminishing returns limits the gains to income that can be achieved by accumulating capital. Holding technology and labour constant, each new increment of capital must add less to total output than each previous increment until all investment opportunities are exhausted. Furthermore, given that land is limited, increasing population will lower per capita incomes as soon as labour is applied to land beyond the point of diminishing average returns.

Thus, (given constant technology) not only are sustained, long-term increases in per capita real income impossible, the law of diminishing returns applied to fixed stock of land and a growing population will eventually force living standards to fall to the subsistence level.

This analysis, plus the Malthusian theory of population, caused economics to become the gloomy science.

III. Technological Change Plays a Minor Role in Raising Living Standards

The majority of the classical economists saw no reason to believe that changes in technology were capable of overcoming the tendencies just described so as to produce sustained growth of per capita incomes over a couple of centuries, let alone more or less forever.

It should be recorded that Karl Marx was a major exception in understanding the vast power of technological change, unleashed by capitalism operating in a market economy. He saw capitalism taking modern economies to the point where there was no need for further growth. Then communism would take over and usher in the new society. According to this view, the communist revolution should have come in the most advanced capitalist countries, not in one of the least developed of them.[2]

MARKETS VERSUS CENTRAL PLANNING: THE BATTLE IS JOINED

Nonetheless, Marx's socialist and communist successors saw it differently. Whatever the circumstances, a communist society, with its planned economy, should be able successfully to supplant capitalism. That view was given major encouragement when the USSR achieved massive economic growth in the 1930s, while the Great Depression seemed to herald the failure of capitalism.

The great 20th century battle of ideologies was now on between market-driven and centrally planned economies–somewhat misnamed as a contest between capitalism and socialism. (Note that I am not talking about social security measures; it is quite possible to believe, as I do, that the market is the better organising principle for economic decisions, while still supporting, as I do, strong measures to alleviate some of the less desirable consequences of market determination.)

In a contest between the market and central planning, most economists should have been firmly lined up with Adam Smith on the side of markets. Although the majority no doubt were, fewer were initially on that side than might have been expected? One reason is that, as with most of society's great debates, the battle lines were never clearly drawn. For example, many saw it as a battle between social democracy and *laissez faire* capitalism–a contest that continues today. My concern here is with the great debate between the market and central planning as methods of organising economic activity. I will suggest two sets of reasons why more people, both among economists and those who looked to economists for guidance, were not on the side of markets. One is rooted in historical understanding and one is rooted in analysis.

Some Misreadings of History

Many 19th century social critics, and many latter-day economists, misread the lessons of the first Industrial Revolution.

One misreading was that the conditions of the majority of ordinary workers were initially made worse off by the Industrial Revolution.[3] In contrast, Braudel (1979) has documented in great detail the appalling conditions of the masses of lower class persons who lived in towns in pre-industrial Europe. Reviewing this, and other evidence, [Rosenberg and Birdzell conclude (1986), p. 173]:

[2]The details of this view are spelled out in Rosenberg (1991).

[3]The initial effects of the Industrial Revolution are still hotly debated, partly because the answer varies with the group being considered, such as displaced agricultural workers, skilled artisans and hand-loom weavers. My argument only requires that the conclusion, that the Industrial Revolution lowered lower-class living standards, is wide of the mark.

> The romantic view that workers in pre-industrial Europe lived well may safely be dismissed as pure fantasy.... The low wages, long hours, and oppressive discipline of the early factories are shocking in that the willingness of the inarticulate poor to work on such terms bespeaks, more forcibly than the most eloquent words, the even more abysmal character of the alternatives they had endured in the past. But this was not the way the romantics of the nineteenth century read the message of the factories.

A second misreading was that the ordinary working person gained nothing from the changes brought about by the first 50 or so years of the First Industrial Revolution. Rosenberg and Birdzell put the point this way (1986, p. 6):

> Over a year, or even over a decade, the economic gains [of the late eighteenth and the nineteenth centuries], after allowing for the rise in population, were so little noticeable that it was widely believed that the gains were experienced only by the rich, and not by the poor. Only as the West's compounded growth continued through the twentieth century did its breadth become clear. It became obvious that Western working classes were increasingly well off and that the Western middle classes were prospering and growing as a proportion of the whole population. Not that poverty disappeared. The West's achievement was not the abolition of poverty but the reduction of its incidence from 90 percent of the population to 30 percent, 20 percent, or less, depending on the country and one's definition of poverty....

A third, even more serious misreading, followed on the first two. Many 20th century observers misinterpreted the place of public policy in the 19th century. Believing that the First Industrial Revolution had reduced living standards compared with the pre-industrial age, and then left them static over time, it was an obvious next step to conclude that the working class was saved from poverty by the 19th century pro-labour legislation. Many went on to conclude that pro-labour legislation was all that was needed to create working class prosperity. This view guided public policy in many countries and brought misery to the very labouring groups the policies were meant to help. Argentina is a typical case in point. Even today, many observers in advanced industrial countries blame low incomes in poorer countries on the absence of advanced social legislation. In this, they neglect the fact that if total output is low, average living standards must be low. What alleviates low overall living standards is growth of total output, not redistribution of existing output (no matter how desirable some redistribution may be for other pressing reasons).

A fourth, and very important misconception, followed from a confusion between the market mechanism and the type of capitalism ushered in by the First Industrial Revolution. Modern industrial capitalism dates from the mid 18th century. The market system dates from the 3rd century BC! This point requires elaboration.

The stone age city states of early Sumerian civilisation appear to have been run to a great extent on the common principle operated by the priesthood and working through kinship relations. With the invention of bronze, states expanded beyond the range of single cities and adjacent hinterland. To cope with such size, the command principle was ineffective and one of the most momentous developments in all of history occurred: the gradual shift from centralised, command to decentralised markets as the main device for coordinating economic activity.[4]

Markets did not arise with the First Industrial Revolution and will not disappear in the "Post-Industrial Society" which now seems to be evolving. For five millennia, markets have shown their superiority as an organising mechanism over all alternatives over a wide range of decisions, whenever the decisions to be coordinated are even moderately complex, and these conditions are changing.[5]

So our evaluation of the market as a coordinating mechanism needs to be separated from our evaluation of the First Industrial Revolution, or of any other single event in the long history of technological change.

Two Defences of the Market Economy

A second part of the answer as to why more economists did not line up on the side of the market against central planning, is to be found in the two types of analysis that economists have used to demonstrate the advantages of a market system.

The first, is informal in the sense that it is not laid out in equations leading to some formal mathematical result. But it does follow from some hard reasoning, and it has been subjected to some searching intellectual probing. This *informal defence* of the market economy is as old as Adam Smith, and is based on four points, which I can only mention but do not have time to elaborate. First and foremost, the market system coordinates economic decisions better than any known alternative. Second, markets tend to do this relatively efficiently by inducing decision-makers to economise on resources that are scarce and goods whose resource costs are high, while making lavish use of resources that are plentiful and goods whose resource costs are low. Third, the market tends to decentralise power and to involve less

[4]For a full account see Dudley (1991), Chapter 2.

[5]The qualification "over a wide range of decisions" is important. The determination of the boundary between decisions that are best mediated by intra-firm non-market mechanisms and those that are best mediated through inter-firm market mechanisms is a key issue–on which Ronald Coase said an important, but by no means the last, word.

coercion, and opportunities for corruption, than does any centrally administered type of organising mechanism. Fourth, the rewards and the flexibility of the market system are conducive to growth by encouraging the exploration of opportunities for innovation by decentralised, profit-seeking, decision-takers competing against each other and employing privately owned capital. (This last point is the one that is most sensitive to being wrong in certain social, and religious environments.) This defence is neutral with respect to the amount of government intervention that is desirable to improve static efficiency and/or to enhance growth; it merely says that any intervention that does occur should do so in the overall context of a market economy and should use, wherever possible, market rather than command incentives.

The *formal defence* dates back at least as far as Pigou and is currently embodied in the fundamental theorem of welfare economics. It arose because professional economists were not satisfied to rest their case on the intuitive defence alone. They wanted to be more precise about just what the market economy did so well. To do so, they developed the proof that an idealisation of the market economy called perfect competition would lead, in equilibrium, to an *optimum* allocation of resources. In this idealisation, not only is the market economy a better way of organising economic decisions than known alternatives, it is the best way: it achieves optimality; there can be nothing better. This defence is not neutral with respect to government intervention. If the unaided market achieves optimality, then all government intervention must make things worse.

Although the proof of the optimality of perfect competition was an intellectual triumph, basing the practical case for the market system on this proof had some unfortunate consequences. While professional economists went on studying and refining the model and their academically bound graduate students went on learning it, the great bulk of their students were sent out into the world with an intellectual defence of the market economy that would not stand up to five minutes' rough handling by anyone who knew anything about the actual behaviour of real markets. It was obvious to most non-economists, who were exposed to the economists' model, that the assumptions of perfect competition are not even remotely related to much of the world in which we live. Many people who would have accepted the proposition that market economies tended to be superior to other possible forms of economic organisation, were not willing to accept that, whatever misery and injustice it produced, a real-world market economy was the best of all possible economic worlds (i.e. the only *optimal* economy). Furthermore, those students who found the formal proof unconvincing were sent into the world of the 1950s, 1960s and 1970s believing that there was no strong case for the price system.

Possibly an even more important limitation was that the formal defence concentrated on static resource allocation and said nothing about economic growth. The static model deals with intertemporal issues by having dated inputs and outputs as well as futures markets, but it does not have endogenous, path dependant, technological change.

Growth versus Efficiency

Whatever professional economists thought about the relative merits of efficiency versus growth as ways of judging the great doctrinal debate between planned and market economies, the public was clear that the central issue was growth. Early observers were impressed with the USSR's rapid industrialisation. Although there was concern about the efficiency of the allocation of capital during the time that it was not allowed to be priced, the main interest was in the economy's growth performance. When Nikita Khrushchev challenged John F. Kennedy to a battle of the two economies, it was th USSR's superior growth potential to reach, and even surpass, U.S. per capita living standards to which he referred (a claim that many contemporary observers did not dismiss as the ridiculous boast that it is now seen to have been). In what follows, I will take up two strands of economics that seek to explain economic growth in advanced countries.

THE MICRO ECONOMICS OF TECHNOLOGY AND GROWTH[6]

Early in the century, Joseph Schumpeter emphasised the importance of growth over static efficiency in raising living standards. Correctly interpreted, the Schumpeterian viewpoint is not that efficiency in resource allocation is unimportant, but only that the real-world market economy produces sufficient organising efficiency without any need for policies designed to make it come closer to some hypothetical, perfectly competitive optimum. What matters for living standards in Schumpeter's view is growth, and growth will best be produced by the market left to itself with its large, transitory monopoly and oligopoly profits which provide the incentive for what he called "creative destruction"–the invention of new technologies to destroy the monopoly profits enjoyed by existing technologies. In all this Schumpeter was, in my view, right.

A minority of the profession followed Schumpeter's lead which made the key to understanding growth a study of the microeconomics of innovations designed to install technological change.

Technological Change Broadly Understood is the Key to Growth

Technology is our way of doing things. As I use the term, it includes: (i) the goods and services that are produced, (ii) processes by which products are designed, produced, financed, distributed and sold, (iii) basic materials, (iv) energy sources,

[6]Readers who know the writings of Nathan Rosenberg will be aware of the enormous debt that the views I express in this section owe to him.

(v) the organisations that coordinate economic activity within production units, and (vi) the institutions that provide the background structure for that activity. A study of history shows that growth is not driven by more of the same kind of capital and labour, but by new goods, new techniques, new institutions and new organisational structures. A major vehicle of growth is thus technological change understood in the broadest possible sense.

I was raised to disparage the study of technology as something for engineers not economists. I now think that without a reasonably detailed understanding of the elements of this important engine of growth, economists find it very difficult to deal with many of the most important issues in growth economics.

Technological Change is Endogenous

Nate Rosenberg's book *Inside the Black Box* was one of the decisive works in establishing from microeconomic observations that technological change is largely endogenous to the economic system. This does not mean that it is determined wholly by economic variables, only that it responds in significant ways to economic signals. Rosenberg makes a strong case that the development part of R & D is largely endogenous. Of course, this is as it should be, since R & D is a costly activity undertaken to a great extent by firms in the pursuit of profit. Perhaps more surprisingly, Rosenberg also argues persuasively that the pure research part is also endogenous.

Here are a few of the most obvious examples of direct causation from economic problems to discoveries in pure science.[7] Torricelli's demonstration of the weight of air in the atmosphere was of utmost scientific importance and came out of his attempts to design an improved pump. Carnot's creation of the science of thermodynamics was an outgrowth of attempts to explain the determinants of the efficiency of steam engines. Joule's discovery of the law of conservation of energy came from work on alternative sources of power for his father's brewery. Pasteur's development of the science of bacteriology came out of his studies of fermentation and putrification in the French wine industry. Solid state physics was not even taught in most US universities until the transistor was invented; today it is one of the hottest areas for teaching and pure research.

Rosenberg makes a persuasive case that there are many more subtle causal forces that make the course of pure science respond partially to economic incentives.

Here are just three of the profound implications that follow from this recognition of endogeneity. First, firms' responses to shocks are very different from what standard theory predicts. Standard I. O. textbooks predict the response of a firm to a shock, such as an increase in input prices, to occur over two "runs". In the short run, the response is in prices and outputs. In the long run, the response is in factor substi-

[7]These examples are quoted from Rosenberg (1982), Chapter 8.

tution and capacity decisions within the framework of known technology. For example, in the long run, firms may substitute their way out of some of the effects of input-price shocks by using less of the input whose relative price has risen. Evidence shows, however, that a major response over even a few years is in induced technological change.[8] Faced with an unfavourable shock, firms often innovate their way out of that shock in ways that are usually neglected in micro-theory textbooks.

Second, the common use of comparative static equilibrium analysis as a predictive device may be misleading. Once a shock-induced, technological change has occurred, the removal of the shock will not cause firms to return to the original pre-shock situation. Technological change is a cumulative, largely irreversible process, to which it is difficult to apply static equilibrium models successfully.

Third, optimality ceases to be well defined because static adjustment to the current set of prices may not be optimal. Faced with a change in input prices, the firm that uses its scarce R & D resources to innovate its way out of the shock may do better than the one that devotes its scarce resources to substituting within the confines of known technology. As Rosenberg often points out, both efforts use resources and the firm must decide how to allocate its available resources.[9] Given an infinite set of possible ways in which attempts may be made to alter technology, there is no way to say *ex ante* which response is optimal.[10] This is one of the many strands from this type of investigation that force us to reconsider the formal defence of the price system which is based on the proof of the optimality of perfectly competitive, static equilibrium.

Massive Uncertainties

Innovative activity is subject to massive uncertainties in Frank Knight's sense of the term. On the one hand, the outcome of attempts to make major technological breakthroughs cannot be predicted or even assigned a well-defined probability. Because innovation is a costly and uncertain activity, large sums of money often must be expended in going up an alley to see if it is blind or has a pot of gold at the end. On the other hand, major breakthroughs often happen more or less costlessly as a result of attempts to do something quite different. Since the pay off may be zero, or a vast sum, or almost anything in between, the simple maximisation of probable

[8]For myriad examples see Dertouzos *et al.* (1989) and Porter (1990).

[9]"...the notion that is so deeply embedded in the neoclassical theory of the firm, that one can draw a sharp and well-delineated distinction between technological change and factor substitution...the D of R&D encompasses a wide range of diverse, information-acquiring activities, it also includes many expenditures that are essential to make possible what economists have in mind when speaking of factor substitution" [Rosenberg (1994), p. 13].

[10]Critical to this argument is the subsequent point that there is often no way to put a probability number on the possible expenses of, or the expected returns to, each of these possible explorations into altering technology.

pay offs is often not a fruitful way to model choices concerning major innovations.

Endogeneity plus uncertainty give rise to all sorts of possibilities when several new technologies are competing with each other–as when reciprocating steam engines, steam turbines and diesels competed to be the power source of steam ships after the First World War; as when internal combustion engines and steam engines competed to be the power source of the automobile in the first two decades of the 20th century; and when light-water and gas-cooled designs competed to be the method of harnessing nuclear power for peacetime uses after 1945. As Arthur (1988) has argued in detail, such competition does not always produce what looks *ex post* to be the best result. If one competing technology gets ahead of another for any one of a number of quite trivial reasons–e.g., the personalities of the persons making key decisions at the critical moments, better software or improved networking–the more successful technique attracts more research money and has a good chance of increasing its lead. After a while, it can get so far ahead of its competitors that everyone wants it. An absorbing barrier has then been crossed and the technology is locked in. There is no guarantee, however, that the technology so chosen by the market is the one with the highest long-run potential to do the required job at the lowest cost. If we knew everything in advance, the "wrong" technology would never be chosen. Because we must spend money on each technology to learn its capabilities over time, and because we do not go all the way to proving discarded technologies, we may never know if, in the end, the losing technology would have been more economical than the one chosen by the market.

This is yet another reason why the proof of the optimality of perfect competition under known technology is irrelevant in judging how real markets perform. It cannot evaluate market behaviour in this frequently encountered competition among new technologies.

Massive Externalities

Innovations typically confer major benefits, many of which are not captured by the innovating firm, or even by the innovating industry. Sometimes, these externalities (i.e., effects that fall on bodies other than those who created them) are massive–consider for example those of the silicon chip and the integrated circuit.

The products that are characteristic of one technological regime are *mutually reenforcing*, so that the total set of these products produces much more additional value than the value that would be produced if each were introduced in isolation. For example, rail, shipping, refrigeration, and telegraph around the end of the 19th century all reenforced each other's productivity in the US. This implies, among other things, that the first investments in a new fundamental technology are more risky, and yield lower returns, than subsequent investments. This may account for the slow way in which revolutionary technological changes show up as increasing productivity at the aggregate level. What is going on here may be called *historical increasing returns* to investment as a new basic technology is slowly developed over time (and is quite different from the increasing and decreasing returns about which economists normally theorise).

A second source of externality is that many benefits of increased productivity flowing from an innovation are captured by other industries. For one reason, a radical new innovation will give rise to many new industrial groupings and patterns of specialisation. Also, the technical problems in one industry are often solved by innovations in another industry.

Diffusion is Slow and Costly

In Schumpeter's model and in the classic article by Kenneth Arrow, any new technological advance is freely available once it is developed. Research on diffusion shows otherwise. Diffusion is a slow and costly matter. It is slow because much knowledge is *tacit* in Polyani's sense: it cannot be written down and learned from books; it must be learned by doing and by using. Diffusion is costly because generic technologies that are of equal use to everyone seldom exist. Instead, most technologies need to be adapted for each specific use.

This has immediate implications for policy in countries at all stages of development. Diffusion of technologies is an important economic variable which can be helped or hindered by market structures, institutions, and government policy. Within one national industry there is often a wide divergence of technologies in use. Some of this divergence is due to the long lifetime of equipment which embodies technology, some is due to the slow rate of diffusion of tacit knowledge. Canada has an apparently successful policy in which agents assist firms to identify where there are better technologies than the ones now in use and then help management to adapt these technologies so that they can adopt them.

It follows that developing countries cannot assume that relevant new technologies will easily flow to them across international borders. Nor can they assume that, even if it is installed locally by multinationals, the knowledge will flow over to other local users. Technology transfer policies, between nations and within one nation, may be important parts of a development strategy–something that would never have been suggested by the formal defence of the price system.

The above are all *characteristics* of technological change. I now consider the *process* of such change.

Understanding Growth through Technological Change Requires Understanding History

Efficiency and distribution can be studied in equilibrium models using classical mathematics in the tradition of Isaac Newton. Were it not so, these methods would not have stayed around for so long. Growth and technical change, however, are different. They take place in real and irreversible time. They display lock in effects, absorbing barriers, irreversibilities, and many other aspects that can only be modelled with non-linear dynamics. Because of this, they are influenced by all kinds of historical accidents and may be best viewed as evolutionary rather than as static maximising processes.

Technoeconomic Paradigms

Innovations, running from minor to revolutionary, are constantly changing our technologies. To deal with these, researchers at the Science Policy Research Unit (SPRU) at Sussex England distinguish four levels: (i) incremental innovations each one of which is small but whose cumulative effect is large; (ii) radical innovations which are discontinuous events such as the development of a new power source, such as atomic energy, or a new material, such as rayon; (iii) changes in the technology system which are a related cluster of changes facing several branches of the economy, such as the late nineteenth century changes in and around the chemical industry; (iv) technological revolutions, which are changes in the whole underlying technoeconomic paradigm.[11]

A technoeconomic paradigm is defined as a systemic relationship among the products that are produced, the methods of producing them, the organisation of productive units, and the institutions that support this activity. A typical paradigm is based on: (i) a few *key products* with wide application, (ii) a few *key materials* whose costs are falling over time, (iii) a way of *organising economic activity*, (iv) a *supporting infrastructure*, (v) a typical pattern of *industrial concentration*, (vi) typical *patterns of efficient locations.*

The value of the concept of a technoeconomic paradigm is hotly debated. Whatever position one takes in this debate, it seems clear to most students of the microeconomics of technological change that there are occasional, revolutionary changes that have deep and far reaching effects across the whole society. If one wishes, one can just read "changes in technologies that have deep and far-reaching effects" wherever I talk about "shifts in the technoeconomic paradigm".

Such technological revolutions occur intermittently in our society, stretching as far back as the Neolithic Agricultural Revolution, which turned us from hunter-gatherers to food producers. Many dramatic shifts can be located between that time and the First Industrial Revolution, including those associated with the invention of writing, the introduction of bronze, the adoption of printing, the development of efficient sailing vessels, the invention of wind and water wheel which removed the

[11]The concept of a technoeconomic paradigm is due to Carlotta Perez and is expounded in detail in Freeman and Perez (1988) and Lipsey (1993).

need for slaves as motive power, and the passing from wood to coal as the major source of heat for domestic and industrial uses.[12]

In the 18th century, the First Industrial Revolution took production out of the cottage and into the factory; the widespread use of steam power in the early 19th century created massive scale economies in production; the introduction of electric motors in the late 19th century allowed much small-scale production to be efficient and laid the basis for the system that is still with us whereby small, decentralised parts manufacturers produce components that are assembled in large, centralised assembly plants; the spread of Fordist mass production in the 1920s, which could not have happened without electricity, brought durable consumers goods within the range of ordinary consumer's budgets. At that time, the automobile and the Hollywood movie changed how and where citizens in the developed world lived and worked, how they saw the world, how their young courted (they were taken by the automobile away from the eyes of parents and chaperons), and their value systems in quite fundamental ways.

Some investigators have sought to establish a 50 year cycle of changes in the technoeconomic ,paradigm. That is contentious, but the fact of such underlying changes that periodically revolutionise our way of doing things seems very well established. Furthermore, we are currently living through one of these fundamental and profound changes in paradigm.

The new paradigm which is taking over in the 1980s and 1990s is built around the transmission, retrieval, and analysis of data and falling transport and communication costs. It is now possible to communicate, coordinate and move across the world information and goods at low (and falling) cost. This has led to many changes. In the words of Freeman and Perez (1988, p. 61):

> "The skill profile associated with the new technoeconomic paradigm appears to change from the concentration on middle-range craft and supervisory skills to increasingly high- and low-range qualifications, and from narrow specialisation to broader, multi-purpose basic skills for information handling. Diversity and flexibility at all levels substitute for homogeneity and dedicated systems. The transformations of the profile of capital equipment is no less radical...The deep structural problems involved in this change of paradigm are now evident in all parts of the world. Among the manifestations are the acute and persistent shortage of the high-level skills associated with the new paradigm, even in countries with high levels of general unemployment, and the

[12] For a fascinating study of the major technological changes that took place in medieval Europe see Gies (1994).

persistent surplus capacity in the older 'smokestack', energy-intensive industries such as steel, oil and petrochemicals."

A new paradigm does not burst fully developed onto a waiting world. Instead, it is developed tentatively alongside of the existing paradigm and only slowly, as more and more new applications are made, is its full potential revealed. In short, a new paradigm begins more as an agenda for future R & D than as a fully developed new technology. It takes time, experience, and money before even the agenda is reasonably mapped out, let alone before the possibilities are well explored.

Many disagreements about the current behaviour of the advanced economies can be traced to differences between structuralists, such as Freeman, Perez and myself [Lipsey (1993)], and those who hold that change occurs all the time and is little different from one decade to another.[13] Structuralist believe that the economy is going through one of its occasional wrenching set of changes as one technoeconomic paradigm is replaced by another, after which a new secular boom is likely to occur as the new technology comes into full bloom and is ripe for profitable exploitation. Not all structuralists accept the concept of a technoeconomic paradigm.

Productivity Slowdowns

The current productivity slowdown in OECD countries has perplexed economists. A detailed knowledge of how changes in underlying technoeconomic paradigms have played out in the past may help in understanding what seems so perplexing today. In an important article, Paul David investigates the introduction of electricity around the turn of this century and finds much that is similar to our current experiences. As David puts it (1993, p. 315):

> "Each of the principal empirical perceptions of a "productivity paradox," had a striking historical precedent in the conditions that obtained less than a century ago in the industrialised West. In 1900 contemporaries might well have said that the electric dynamos were to be seen "everywhere but in the economic statistics." Exploring the reasons for that state of affairs, and the features of commonality between computer and dynamo–particularly in the dynamics of their diffusion and their incremental improvement, and the problems of capturing their initial effects with conventional productivity measures–provides some clues to help understand our current situation."

[13] Many hold this latter view; Madison (1991), for example, explicitly rejects the structuralist explanations.

I have time only to mention a couple of the points made by David.

At first, the electric motor was used to do what steam did, only to do it a bit cheaper and more reliably–which was to turn the main drive shaft of a factory from which belts went off to power each machine. In this system, the layout of the factory was dictated by the power demands of each machine. Those that used most power had to be closest to the central drive shaft because of the large friction loss in belt transmission. For the same reason, factories were built as multistorey structures.

The key step in really utilising the potential of electricity required reengineering. It took a long time to see this and then to give it effect. Eventually, however, one electric motor came to be attached to each machine tool. This permitted a host of changes, all summarised in rearranging the factory to facilitate the flow of production rather than on some other organising principle. This laid the basis for the mass production techniques later introduced by Henry Ford.

The first generation of computers have had an analogous experience in doing a little cheaper what people, or simpler machines, used to do, and doing it in an unchanged organisational context. In the second generation of adjustment to the new technology, production, product design, firm organisation, and other activities, are being redesigned from the bottom up to fit into new, more efficient forms that computers make possible. As this happens, the much delayed productivity gains are beginning to show up.

Electricity also led to much deskilling. The machine operator in the steam plant had to be a skilled mechanic and often spent up to two hours a day repairing his machine. With more reliable, electrically operated machines, repair and maintenance became a specialisation while the operator required much less skill.[14]

And so David's analysis goes on through a number of parallels between then and now. It seems to me that it is very difficult to make sense of what happened then and is happening now from aggregate data alone, without a detailed knowledge of the technical changes that are the cause of our overall growth, or lack of it.

Sustainable Growth: Technology as Part of the Solution not Part of the Problem

An important current debate concerns the extent to which continued growth is compatible with environmental protection. My own view is that to try to stop growth by freezing technology at its existing levels would, were it possible, condemn much of the world's population to unnecessary suffering, and many developing nations to perpetual poverty. Technological developments, and the economic

[14]Eventually, electric power also transformed the household, releasing women in electrified homes from the dawn to dusk drudgery that had been the lot of all but a privileged few throughout history–truly one of the greatest transformations in living styles of all time.

growth that comes in their wake, are the main hope for reducing pollution, and saving the environment, as well as for raising living standards of the developing nations to levels near those currently found in developed nations.

Many detailed calculations made in the 1970s, including those of the Club of Rome, showed that any attempt to raise the GDPs of the developing countries to those of the developed countries, using only existing technologies, would result in unsupportable environmental degradation. This leaves only two alternatives for those who wish to see the lower-income countries reach high living standards.

The first is to stop economic growth and redistribute existing income and resource use from the richer countries to the poorer ones. Say that we froze GDPs and resource use at their present levels and redistributed income to equalise it across the world. In 1985, this would have given a family of four an income of about $11,000, which was just below the U. S. Department of Commerce's estimate of the poverty level for an American non-farm family of four in that year.[15] Thus any feasible redistribution of existing incomes would leave most of the rest of the world well below what is currently regarded as poverty in advanced industrial countries.

The second alternative is to rely on further economic growth, constrained by effective environmental controls, to solve the poverty problem by raising output. The environmental problems are then to be dealt with through, among other methods, the creation of effective incentives, both to use existing pollution-reducing technology and to develop further such technology (which is developed fairly quickly whenever market incentives are created by making pollution a costly activity for those who produce it).

Those who think only of today's commodities and today's technologies, do not see the enormous possibilities for raising living standards, and dealing with pollution, through technological advance, which is the way charted by the Bruntland Commission. Technological advance transforms our lives by inventing new undreamed of products, and new undreamed of ways of making them. 1980s technologies, based on fossil fuels, fish caught from the sea, and food grown on land, in ways not greatly changed since the dawn of history, and goods produced in noisy, pollution-creating production facilities, will seem crude beyond measure to our great grandchildren, providing only that technological change precedes at its present rate.

This environmental optimism is not shared by everyone. For myself, however, contemplating technological change over the past 12 millennia leaves me relatively optimistic about the *possibilities*–although not so optimistic about our ability to manage those possibilities. While I would not discourage those who would lead

[15]The calculation is made a bit tricky because the UN does not have data for countries covering around 10 percent of the world's population, most of which are in the poorer brackets. If these are ignored, the result is around $ 2,800 *per person*, while if an estimate is made for the missing population based on data for the reporting poorer countries, the result is about $ 2,600 *per person*.

some of us back to a simpler life, I do not see the overall solution coming from that direction. Either technological change continues to do what it has done in the past, which is to produce more and more per unit of resource input, or the bulk of the world's population will be left with incomes that are very much lower than they aspire to.

Nonlinear Models

The relations we have been discussing obviously cannot be accommodated in the typical equilibrium framework, or in one that assumes linear dynamic relations. In many of the circumstances described above, there is often no equilibrium or several. Forces interact with each other in nonlinear, path-dependant ways. There is no way to define a unique, optimal, equilibrium or an optimal dynamic path.

This is an evolutionary view of the world. Economic theorists have recently been writing down many nonlinear models and showing that each has the characteristics typical of such systems. There is, however, not much to be gained from multiplying such models if they do no more than illustrate the already well-known characteristics of such systems.

The real issue is, as Dosi and Orsenigo (1988) argue, to understand how a world that appears to be full of these nonlinear relations, each with its potential for unstable behaviour, manages to behave in a relatively stable way. Of course, change and oscillations do occur, some of which are large and some prolonged. But economic variables do not constantly shoot off in wild cycles or degenerate into chaotic behaviour. Given that so many micro relations appear to be non-linear, the real puzzle is what imparts relative macro stability to the whole system most of the time. This issue is analogous to the issue of how the price system organises a static world of given tastes and endowments and it will become a key issue in the future. Until it does, we will probably have to go through a period in which nonlinear models are multiplied and their general properties displayed over and over again in many specific contexts. What needs to be done, however, is to accept the instabilities inherent in such relations and study the reasons why they interact to produce stable behaviour most of the time, and instability or low level equilibria only occasionally.

This discussion has taken us a very long way from Arrow-Debreu optimality, but not a long way from the informal defence of the market as a reasonably effective coordinating mechanism, an issue that Adam Smith understood.

The Hidden Hand and the Evolutionary Hand

Given the high degree of uncertainty described above, firms cannot be classical maximisers–profit seekers, yes; but profit maximisers, no. They may best be viewed as groping towards improved results in a hunch-judgement-trail-error process, as studied by Nelson and Winter (1982) in their evolutionary theory.

Rapid technological change alters many relations in the economy, including the best forms of business organisation. Given the new situation, no one is quite sure what changes are called for. This ushers in a period of trial and error and, over time, the market rewards the successes with profits and punishes the failures with bankruptcy.

Such, for example, was the trust and merger movement around the turn of the century in the US.[16] The technological innovations that transformed the US production process in the late 19th century, conferred scale economies on some industries and made small sizes efficient in others. However, no one was quite sure which industry fell into which category. So mergers were tried more or less throughout the whole economy–they became the latest fad of the day. After a couple of decades, the dust settled. Some giants prospered where there proved to be large and durable scale economies, while for others, when scale economies did not appear, the giants could not prevent the entry of smaller efficient firms.

Neoclassical economists, working with a model of market optimality are inclined to argue that something would not have happened if it were not optimal. In this view, if a merger boom occurs and is subsequently reversed, the conditions must have changed since both situations must have been optimal. My study of history leads me to support the evolutionary economists who argue that, in the wake of a major technological shift, no one can be sure what new forms of organisation will prove profitable *until they are tried.*

This conflict of views reveals a very basic difference in the understanding of the place of the price mechanism in organising economic activity. According to the neoclassical "hidden hand" view of the formal defence, the market merely generates the prices that reflect relative scarcities and firms do everything else. According to the "evolutionary hand" view (Nelson and Winter's term), agents experiment under great uncertainty and the market encourages the success and weeds out the failures. This is a much more powerful function for the market than merely generating prices that allow all-seeing firms to behave optimally.

GROWTH IN AGGREGATE MODELS

The first generation of modern aggregate models designed to help economists understand growth grew out of Robert Solow's pioneering work. From that time on, mainline growth theory has been the province of macro economics using an aggregate relation whose generic form is: $Y = Af(L^{\alpha}K^{1-\alpha})$. In its 1960s and 1970s version,

[16]For a good discussion see Rosenberg and Birdzell, *op cit*, Chapter 7, "Technology, Trusts and Marketable Stock".

technological change was exogenous and measured as the residual from the stable relation between the aggregate capital stock and the aggregate labour force on the one hand, and GDP on the other hand. The micro underpinning of the model was perfect competition. The key assumptions were diminishing returns to one factor and constant returns to scale.

On the theoretical front, a whole generation of growth economists worked on this model, dealing elegantly with its properties of a steady state growth path in which labour (measured in efficiency units), capital and income all grew at the same rate. The Classical economist's iron law of diminishing returns carried its influence powerfully on through these models. Because of it, continued per capita income growth cannot be caused by continued capital accumulation.

Many economists were influenced by the model's key property that the equilibrium rate of growth is uninfluenced by the saving rate. Such is the power of models, that many accepted this as a policy-relevant conclusion even though the model displayed non of the economic characteristics such as positive feedback loops, that research into the micro-economics of technological change suggested were important.

The second front on which this model had influence was in focusing attention on technological change. The massive unexplained residual when the model was first fitted to data was taken to measure technological change and this led to further measurements of such change at the micro and macro levels.

In the 1980s, the aggregate model was given a new burst of energy in which Paul Romer was a pioneer. The new work, which made technical change endogenous, represented an important attempt to incorporate the main, growth-driving force into aggregate growth models.

This work has two far-reaching implications. The first concerns perfect competition. In the neoclassical growth model with constant returns to scale and perfect competition, there is no output left to remunerate those who supply R & D after paying capital and labour their marginal products. This did not bother people as long as technological change was assumed exogenous. But once technical change became endogenous, R & D had to be paid for. After some attempts to handle this with Marshallian-type external economies e.g., Romer (1986), the position was accepted that endogenous R & D could only be paid for if there were increasing returns in equilibrium. However, increasing returns are incompatible with perfect competition. (This is shown in any introductory text book and follows because perfectly competitive firms are price takers and would not leave unexploited any chance to lower costs by raising output that is always presented by increasing returns.) Thus endogenous technology and perfect competition were held to be logically incompatible.

The least revolutionary way of handling this problem was to assume monopolistic competition. This saved everything else in the neoclassical growth model, including equilibrium. The change should not have bothered any Industrial Organisation economists, since no one working at the micro level believed that perfect competition existed in much of the manufacturing or service sectors. In those sectors, product differentiation is usual and many industries contain small numbers of firms. Most I. O. economists would have preferred to see perfect competition replaced by oligopoly rather than monopolistic competition in these models. But analytical tractability called for the use of monopolistic competition and that at least seemed to be an improvement over the even more unrealistic perfect competition.

Personally, I find it difficult to understand how anyone who has studied the historical evidence could for one moment doubt that economists needed to develop models in which technological change is endogenous and in which industries are typically not perfectly competitive. But that was not the reaction of many economic theorists, particularly in the United State. Opinions differ as to why there was so much resistance to abandoning perfect competition as the underpinning of the aggregate growth model. My own opinion is that the optimality of perfect competition fulfils an important ritualistic position in neoclassical economics. Take it away, and the quasi-religious doctrine of the perfection of the price system is destroyed since the formal case for optimality requires perfect competition.

The second important implication is that we must incorporate into our theories the economics of ideas rather than just the economics of things. This, which is a persistent theme of Paul Romer's, is revolutionary e.g., Romer (1993, 1993a). Ever since economics began, diminishing returns to the accumulation of one factor, and constant returns to scale, have dominated the landscape of economic models. Ideas, however, are not like goods. If you have an idea, you can use it and so can everyone else; whereas if you use your machine, no one else can use it at the same time. In technical language, goods are rivalrous while ideas are not.[17]

Thus the accumulation of ideas with labour constant is not subject to decreasing returns as is the accumulation of capital with ideas (technological knowledge) constant. Investment need not be subject to decreasing returns, as long as it embodies technological change. The long-run steady state in growth models needs not be associated with zero increases in per capita output. Instead, with ideas (technological knowledge) as the key factor in growth, incomes can go on growing forever. Nor do we need to worry within any foreseeable time horizon about running out of good ideas. Furthermore, the usual diminishing returns argument, that we use the best ideas first then go on to less productive ones, does not apply to technological

[17]Some people have sought to equate ideas and human capital. As Romer points out, the two are significantly different in that human capital is rivalrous (if I visit your firm and use my skills to help you today, I cannot simultaneously visit some other firm and use my skills to help them), while ideas are not (once developed, everyone can use an idea simultaneously).

change. some case, albeit a rather weak one, can be made for the "diminishing returns" argument within the latter stages of one technoeconomic paradigm. But in the shift from one paradigm to another, there is no reason to expect diminishing returns because there is no reason to believe that the increment to total output coming from a succession of totally new ways of doing things will decrease over time. There is no reason, for example, why the increment in going from the water wheel to the steam engine had to be more than the increment in going from the steam engine to electricity, or that the increment in going from the putting out system to the factory system had to be more than the increment in going from the old factory system to the Fordist mass production system, or that this increment had to be more than the increment in going to lean production. *In the realm of fundamental new ideas, there is neither theory nor evidence to support the view of the diminishing economic returns to the accumulation of knowledge.*

Under the impact of the new growth theory, economics is shedding its dark mantle of the dismal science. It is now donning a new bright mantle of the possibility of continued, sustained growth through technological change without diminishing returns.

EVENTS IN THE LATE 20TH CENTURY

While economists were doing the work described above, experience of actual economies was accumulating. The rise of the Asian Tigers, often called newly industrialised countries (NICs), South Korea, Taiwan, Singapore and Hong Kong, was one of the first strong signs that the advantage in the great doctrinal battle might be shifting towards the market economies. Then came the dramatic fall of communism in eastern Europe, combined with the even more dramatic growth in those parts of communist China which were left free to market forces.[18] The 20th century battle of those particular ideologies was over. The market system was the conclusive winner over the centrally planned system of economic organisation. Rarely in human history has so decisive a decision been accepted on a great social issue.

Out of these experiences has come a measure of agreement which Williamson (1990) calls the Washington consensus. Rather than follow Williamson, I will quote from the UN's symposium on policies for developing nations in the 1990s. This symposium was held in the Hague in March 1992 and, as its rapporteur, I reported on the consensus reached at the conference (UN, pp. 20–22).

> ...policies that ignore or work against market forces are usually coun-

[18]China may develop dreadful problems, but that will not be because it increasingly uses market determination rather than central planning but because its government is unable to deliver the necessary background institutions and infrastructure, including effective environmental protection, and measures to alleviate growing income inequalities.

> terproductive–although there is room for proactive policies as long as they work through market forces and take them as their criterion of success. For developing countries, the consensus involves a major alteration of the older development model that was inward-looking, import substituting, state monopoly centred, and heavily interventionist in subsidisation, price setting and resource allocation. The revised model calls for a more outward-looking, trade-oriented, market-facilitating-based route to development....
> Part of the consensus concerns three basic classes of activities that are key roles of the Government: To provide a systematic framework within which markets can operate efficiently...to create appropriate factors of production...to resolve conflicts of interest, to handle market failures, and to redistribute income in line with currently accepted ideas of social justice. Redistributive policies must be constantly scrutinised for their impacts on growth and vice versa.... Poverty reduction is an important part of the consensus....

All of those sentiments are in line with the informal defence of the price system. It would appear that the price system has won the day and won it in the form that is suggested by the informal rather than the formal defence.

This consensus has been followed not by "the end of history" but, just as one should have expected, by a new battle of ideologies. Both of the ideologies that are now competing accept the informal defence of the price system, but they divide over the importance, and policy-relevance, of the views on technological change that I have reported on in this lecture. Here is how it appeared in the UN symposium (UN, p. 23):

> A crucial and much debated issue, is whether the conditions of the basic consensus are sufficient (or just necessary) to encourage the kinds and volumes of both domestic and foreign investments in physical and intangible capital needed to develop dynamic comparative advantages in higher-value-added industries.... The issue of whether or not more active government policies are required is related to newer views on economic growth in which endogenous technological change is the mainspring of growth. For developing countries, one of the most important of the many insights stemming from research into the growth process is that substantial R & D capacity is needed to adapt other people's technology to one's own purposes, and to learn how to use it.... The aim of targeted innovation and technology transfer policies is to provide incentives for creating structural competitiveness

based on adequate supply capabilities.

The first of the two competing ideologies advocates a basically *laissez fair* approach to economic (but not necessarily social) policy, such as is espoused (but not always followed) in the US and the UK. The second advocates what I call "massaged market economies". In this approach, while the market is the final test of success or failure, substantial, coordinated government assistance is given to the forces of technological change in a way that is systematically oriented towards innovation and growth. Policies such as these are found in some European countries, in Japan and in some of the NICs.

The evidence from theory and practice is that there is scope for a "massaged" approach to be productive, but that there is also potential for misuse. My reading of the evidence, as presented by such economists as Pack and Westphal (1986); Westphal (1990); and Wade (1990), is that at least two key conditions are necessary for the massaged approach to work.

First, there must be a market test to eliminate failures rapidly. In the highly uncertain world of fundamental innovation, governments can sometimes pick winners, just as the private sector can sometimes pick monumental losers. What is needed is a reliable mechanism for getting rid of the mistakes. In the market system, the bottom line provides the mechanism. The export orientation of the development policies of the NICs did the same for government selection–products that could not make it in the tough world of international competition had their assistance cut off. In contrast, Western democracies suffer from the difficulty that all vote-maximising governments have in getting rid of losers.

Second, there must be a single-minded pursuit of economic growth on the part of governments. Japanese policy, from the time of that country's opening, was dominated by the desire to catch up to the U.S. and, in the early stages, to avoid the fate of so many other Asian countries in becoming colonies of European nations. Similarly, policies in the NICs were dominated by growth considerations.

No one knows how this new clash of world views will play out, although many have suggested answers.[19] Books such as Lester Thurow's *Head to Head* outline the nature of the conflict from a policy perspective. From an economist's perspective, much of the issue turns on the new views of economic growth. No longer can the *laissez faire* market economy be supported because it produces optimality in the world in which we live. The informal defence of the market is a strong one; one that has been generally accepted in the new consensus. But the markets that are being accepted as regulating mechanisms contain many types of

[19]See, for example, Thurow (1992), and the three, views presented by Dornbusch, Krueger, and Tyson in Lawrence and Schultze (1990).

behaviour that cannot be defended as optimal: they are full of externalities that accompany most technologies and give rise to massive market failures, making them replete with opportunities for successful intervention (a necessary but not sufficient condition for justifying intervention). Successful interventions will not normally resist market forces but will assist the market in its dynamic path driven by evolving technologies.

Economists who support a *laissez faire* style economic policy are hostile to the suggestion of a valid case for the massaged market approach. In Western democracies such as the US and the UK, they may be right.[20] The potential for such policies to be diverted to political rather than economic gain is as great as is their potential to do harm when improperly applied. Nonetheless, the evidence of many countries, including some of the NICs, is that such policies cannot be dismissed as being inevitable failures.

Only time will tell how the two approaches of *laissez faire* economic policy and massaged markets will play out in practice.

One interesting test case is about to be undertaken. By entering a NAFTA, Mexico is tying its future to the *laissez faire* view. Many of the market-assisting interventions practised in the successful NICs, and in Japan, are prohibited by the NAFTA. Giving up such traditional levers as infant industry protection and technology transfer policies in return for more or less unlimited access to US market and to US capital, is a brave gamble.[21] Other developing countries, as well as advanced ones, will watch the experiment with great interest. Will the growth of the less developed Mexican economy be stifled by its economic union with the advanced US and Canadian economies, or will Mexican growth be stimulated? It is a big-stakes game for Mexico, and its outcome will influence the judgement, to be rendered sometime well into the 21st century, on the clash between the advocates of a *laissez faire* economic policy and those of a massaged market policy–both being applied within the general consensus that a market system is the best overall organising principle for any economy.

So where does all this leave us with respect to the three views of the classical economists with which we began? First, markets are still the best game in town as a device for organising economic activity, but they must be defended by the informal defence since the formal one is largely irrelevant to an economy with endogenous technological change. Second, the curse of diminishing returns is exorcised in a

[20]Most detailed interventions in Canada and the United States fail on both of the counts discussed above.

[21]Canadian and US opponents to the NAFTA argued ridiculously that the manufacturing sectors in their two countries were in danger of being wiped out by Mexican manufacturing! Although a few industries in which unskilled labour is a major part of cost may be in danger, the bulk of the real risks are all on the other side: that the emerging Mexican industrial sector, which contains many small and relatively inefficient firms, would be severely harmed, even if it were not totally wiped out.

world of continuously growing technological knowledge. Ideas, unlike goods, are not subject to diminishing returns. They have driven growth and change since the Neolithic Agricultural Revolution. They will continue to do so into the indefinite future and there is no reason to think that diminishing returns to knowledge accumulation is about to set in. Finally, technological change (broadly defined as I have done) is the driving force in sustained growth and a force that can be understood through detailed microeconomic and historical analysis.

Economic analysis will no doubt be used in the future to analyse many dismal economic events. But the days when the underlying basis of the subject justified the title "dismal science" are over. The modern title should become "the optimistic science"–not because economics predicts inevitable growth or the arrival of universal bliss, but because its underlying structure, altered to incorporate the economics of knowledge, implies no limit to real-income-creating, sustainable growth, operating in a basically market-organised society. If we cannot achieve sustained and sustainable economic growth, the fault dear Brutus must lie with ourselves not with some iron-clad economic law that dictates failure before we start.

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Comments on
"Markets, Technological Change and Economic Growth"

I can be brief since I agree almost wholly with Professor Lipsey's stimulating lecture, apart from a few differences of emphasis.

I agree that necessity is mostly the mother of invention, which is perhaps the old-fashioned way of saying that technological change is endogenous. I also agree that diffusion may be slow and costly. In the distant past improvements and dissemination seem to have been almost incredibly slow. The breast-plate harness of horses, which tended to throttle them, reduced their efficiency, as compared with a padded collar, from 15 manpower to 4 manpower. It took 3,000 years or more for a rudimentary padded collar to evolve: and another 1,000 years for it to develop and become general.[1]

But nowadays diffusion is usually fast. In this connection I think Lipsey exaggerates the need for adaptation. In the first decade of their industrial revolutions, S. Korea and Taiwan mostly used 'off the shelf' or generic technologies. This is not to say that some encouragement of diffusion may not be useful, especially in the later stages of industrialisation.

When he comes to 'Technoeconomic paradigms' Lipsey becomes quite romantic and visionary. Perhaps economics needs a whiff of poetry. But I think we should guard against a mood of complacency induced by contemplation of the full blooming of the chip. I recall attending in 1955 a Geneva conference on the peaceful uses of atomic energy. Several papers proclaimed a major contribution to the problems of poor countries. I would not be surprised if some spoke of a new paradigm. I think it is clear that the poor of the world would be better off if nuclear power had never been developed. I do not suggest that this will be true of integrated circuits. At the same time I do not think that they will do much to solve the problems of poverty.

On 'The hidden hand and the evolutionary hand', I cannot myself see that great uncertainty and trying to maximise profits are incompatible, as Lipsey implies. Of course, attitudes to risk complicate matters, but that is another story.

The discussion of 'Growth in Aggregate Models' is important, and I am in agreement with most of what is said. But I am sorry that no reference was made to M. FG. Scott whose work on endogenous growth preceded that of Romer, and is

[1] Ian M. D. Little in Herbert Giersch (ed) *Towards an Explanation of Economic Growth.* Institut für Weltwirtschaft an der Universität Kiel, J.C.B. Mohr (Paul Siebeck), Tübingen.

both more radical (the validity of the concepts of stocks of capital, static production functions, and hence total factor productivity are denied), and more operational.[2] One theoretical point of difference arises. Lipsey states that there is no output left to pay for indigenous R and D if perfect competition and constant returns are assumed. But Scott shows that even with perfect competition, in a steady growth situation, the present discounted value of the owners' interest is maximised when labour is paid less than the value of its marginal product. This is not to say that Scott or I disagree with the view that perfect competition does not apply in industry.

Finally on the NICs, especially Korea, I do not think that the markets were massaged. 'Massaging' suggests to me trying to eliminate natural distortions or market failures. I think that the impetus for the heavy and chemical industry drive came more from a bee in the bonnet of President Park, and from his (mis)understanding of the Nixon doctrine of disengagement. It was more punching than massaging, with which latter treatment even those devils, the neoclassical economists, would agree.

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[2]See M. FG. Scott, *A New View of Economic Growth.* Clarendon Press, Oxford, 1989; and earlier articles on the subject dating back to 1976.

Comments on "Markets, Technological Change and Economic Growth"

Professor Lipsey has done a signal service to development economists working on contemporary developing countries. He has done so by reminding us of what the classical economists had to say about their economies when they were in a similar structural state, helping us understand why much of our part of the profession may have strayed from some useful aspects of what the classicists had to say, and bringing us up to date on what contemporary historical analysis has to say about the sources of economic growth. I will comment on his paper with emphasis on its implications to the agricultural sector and its linkages to growth in other sectors.

Of particular importance in Professor Lipsey's paper is the emphasis on technological change. He notes early in his paper that the classical economists, excepting Marx, gave little importance to technological change. Since Solow's early work contemporary economists have recognised its central place in the growth of developed countries. It is surprising that it has not, in general, been central to the thinking of most economists working on contemporary developing countries. I think there are three reasons for that.

First, in the short run, technological change will have its largest impact on sectors which are already large. But agriculture, the dominant sector in early stages of growth, has generally been seen as dominated by small, illiterate producers who could not be easily envisaged as "modernising". Of course, the green revolution showed that such entrepreneurs were ready to innovate if technology came along. Second, the other side of the same coin, industry was seen as modern, and since there was not much, the emphasis was on increasing the size of the capital stock rather than increasing the productivity of existing resources. Third, it is only more recently that it has been clearly understood, a point Professor Lipsey makes, that technology change occurs little by direct transfer, but, rather, requires an indigenous R and D system even for transfer.

The conclusion is that we need to pay more attention to agriculture, to strengthening R and D for agriculture and to strengthening R and D for the other sectors as well. It also follows that economies must be open to technology flows, which probably means they must be generally open.

Professor Lipsey makes a very interesting point, that in the early days of the industrial revolution it was generally believed that the process was not helping the poor–that is the benefits were skewed to the rich. It is now self evident that economic growth of contemporary developed countries resulted in massive decline in poverty. It is striking that the initial view of the green revolution in developing countries was that it not only failed to assist the poor, but that it actually helped to impoverish them! As in the data cited by Professor Lipsey, so for the green revolution, given a little time poverty has been sharply reduced. Indeed, we now know that the bulk of poverty reduction in developing countries must come from processes of rural led growth, and that the growth in technology based growth in incomes in agriculture provide the initial burst of purchasing power that gets going the process of employment intensive expansion of non-agricultural goods and services that is central to rapid reduction in poverty.

Pushing on to the latest technological changes, and speculating about the future, Professor Lipsey notes the transport and communication revolution. There is a current in thinking about contemporary developing countries that is isolationist, partly on political grounds, but partly on the grounds that transport costs are rising due to limits to fuel availability. Professor Lipsey reminds us that transport costs continue to decline. The world is becoming smaller, the opportunities to tune production systems to micro differences in ecology and human skills is increasing. Thus for agriculture as for the rest of the economy, there is greater scope for the gains from specialisation and trade now than a few decades ago and those changes continue.

Finally Professor Lipsey, after having made so much of the importance of market forces, takes us back to the key roles of government in growth. He emphasises that the useful role of government is not in competition with market forces, but to the contrary, the market test is critical to effective government action to speed technological processes and related growth.

We are grateful not only to Professor Lipsey for his perceptive and thoughtfull review, but to the organisers of the conference, who saw that we must take advantage of the large set of resources studying the history of growth in developed countries to enrich our capabilities to minster to the contemporary processes in the developing countries. They made the right choice and Professor Lipsey rewarded us all.

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