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The Green Revolution and the Gene Revolution in Pakistan: Policy Implications

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Pakistan achieved high levels of Green Revolution Modern Variety (GRMV) adoption in the Green Revolution. Pakistan out-performed India and Bangladesh in the Green Revolution. Only China, among major countries, out-performed Pakistan in the Green Revolution. Pakistan does not have the food safety and environmental risk studies in place to support a regulatory environment for biotechnology. In effect, Pakistan is following the "precautionary principle" and applying it to science policy. This paper argues that this is a mistake. Pakistan is paying a "double penalty" for its inability to develop the regulatory systems required to take advantage of genetically modified (GM) crops. Not only does it lose the cost reductions enabled by GM crops, but because other countries have adopted GM crops, world prices are lower as a result and affect Pakistan's export crops.

Pakistan achieved a Green Revolution in the major Green Revolution crops. The adoption rates for the two major Green Revolution crops in Pakistan, wheat and rice were higher than the adoption rates for other countries in South Asia. The same was true for the adoption of potatoes and lentils. However, adoption rates in Pakistan for maize, sorghum, millets and groundnuts were lower than in other South Asian countries. Overall Pakistan had the best Green Revolution performance in South Asia.

Pakistan did not achieve a "Gene Revolution", i.e., a revolution based on "recombinant DNA" (genetic engineering) techniques. The Gene Revolution was initiated in 1953 by the work of Watson and Crick identifying DNA as the source of intergenerational transfer of heredity and traits. In 1973, Berg at Stanford had created recombinant DNA in his laboratory. The next year, 1974, Cohen at Stanford

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and Boyer at the University of California at San Francisco achieved the first "transformation" by taking "alien" DNA from a source organism and inserting it into a host organism. With this achievement, the field of genetic engineering was established.[1]

Pakistan has not had a Gene Revolution because it has not yet established the food safety and environmental safety regulations required for the Gene Revolution. Pakistan has approved laboratory/greenhouse studies of cotton and rice, but lags far behind India which has approved commercial production of cotton, field trials of canola and tobacco and laboratory/greenhouse studies of rice, potatoes and tomatoes (see the appendix for regulatory approvals). Bangladesh has approved laboratory/ greenhouse studies of rice, lettuce, papaya, tobacco and groundnuts. Nepal and Sri Lanka have not approved laboratory/greenhouse studies for any gene revolution crops (see the appendix).

Pakistan is paying a "double penalty" for its inability to develop the regulatory systems required to take advantage of genetically modified (GM) crops. Not only does it lose the cost reductions enabled by GM crops, but because other countries have adopted GM crops, world prices are lower as a result. For example, India produces "transgenic" cotton (using the *Bacillus thuriengensis*—Bt gene). Studies show that Bt cotton lowers production costs of cotton by as much as 15 percent. More than half of the world's cotton production is now Bt cotton. As a result, prices in world markets for cotton fibre are lower.

But the real tragedy of Pakistan's failure to achieve a Gene Revolution is that the Gene Revolution represents "modern" advanced science. By following the advice of European Union Countries to introduce the "precautionary principle" as a guiding principle for science policy, Pakistani scientists have probably slipped behind the scientific frontier.

In this paper, I will first cover the Green Revolution. Then I will cover the Gene Revolution, including an assessment of cost reduction potential for Pakistan. I will then restate the policy implications of following the precautionary principle.

I. THE GREEN REVOLUTION

(a) An Overview

Table 1 reports a summary of Green Revolution Modern Variety (GRMV) production by five-year period. This table shows that GRMV production has had increasing numbers of GRMVs produced in all crops.

Table 2 reports the IARC content of GRMV varieties. Thirty-six percent of all GRMVs were the result of an IARC cross (35 percent of all adopted varieties were the result of an IARC cross). Seventeen percent of NARS crosses had an

[1]See Cohen (1997) and Watson (1968).

Table 1

Average Annual Varietal Releases by Crop and Region

Crop	Average Annual Releases						
	1965-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-2000
Wheat	40.8	54.2	58.0	75.6	81.2	79.3	85.0
Rice	19.2	35.2	43.8	50.8	57.8	54.8	58.5
Maize	13.4	16.6	21.6	43.4	52.7	108.3	71.3
Sorghum	6.9	7.2	9.6	10.6	12.2	17.6	14.3
Millet	.8	.4	1.8	5.0	4.8	6.0	9.7
Barley	0.0	0.0	0.0	2.8	8.2	5.6	7.3
Lentils	0.0	0.0	0.0	1.8	1.8	3.9	4.0
Beans	4.0	7.0	12.0	18.5	18.0	43.0	45.0
Cassava	0.0	1.0	2.0	15.8	9.8	13.6	15.0
Potatoes	2.0	10.4	13.0	15.9	18.9	19.6	20.0
All Crops							
Latin America	37.8	55.9	65.9	92.5	116.2	177.3	140.0
Asia	27.2	59.6	66.8	86.3	76.7	81.2	80.0
Middle East and North Africa	4.4	8.0	10.2	12.2	28.4	30.5	85.0
Sub-Saharan Africa	17.7	18.0	23.0	43.2	46.2	50.1	55.0
All Regions	87.1	132.0	161.8	240.2	265.8	351.7	360.0

Table 2

IARC Content by Crop and Region from 1965–1998

Crop	1965-1998 IARC Content			
	IX	IP	IA	IN
Wheat	0.49	0.29	0.08	0.14
Rice	0.20	0.20	0.07	0.48
Maize	0.28	0.28	0.04	0.53
Sorghum	0.16	0.16	0.06	0.71
Millet	0.15	0.15	0.09	0.35
Barley	0.49	0.49	0.01	0.30
Lentils	0.54	0.54	0.01	0.40
Beans	0.72	0.72	0.01	0.19
Cassava	0.53	0.53	0.01	0.31
Potatoes	0.17	0.17	0.02	0.75
All Crops				
Latin America	0.39	0.39	0.04	0.43
Asia	0.18	0.18	0.10	0.43
Middle East and North Africa	0.62	0.62	0.04	0.12
Sub-Saharan Africa	0.45	0.45	0.07	0.27
All Regions	0.36	0.20	0.06	0.38

IX: IARC Cross
IP: IARC Crossed Parent
IA: IARC Crossed Ancestor
IN: NARS Crossed Variety

IARC-crossed parent and an additional 5 percent had a non-parent IARC-crossed ancestor.[2] Private sector firms produced 5 percent of GRMVs.[3] Developed country programmes produced no GRMVs for developing countries. No GRMVs were produced by Non-government Organisations (NGOs).

(b) The Green Revolution in Pakistan

Table 3 reports adoption rates by five-year periods for Pakistan and for South Asia (in parentheses). These adoption rates show that Pakistan adopted wheat and rice GRMVs at a faster rate than was the case for South Asia generally. This was also the case for lentils and potatoes. But for maize, millets, sorghum and groundnuts, Pakistan adopted GRMVs more slowly than other South Asian countries. Overall, however, Pakistan had very high rates of GRMV adoption.

Table 3

Adoption Rates by Green Revolution Crop: Pakistan and South Asia (South Asia in Parenthesis)

Year	Wheat	Rice	Maize	Millets	Sorghum	Lentils	Ground-nuts	Potatoes	All Crops
1965	5	0	0	0	0	0	0	10	
	(1.7)	(0)	(0)	(0)	(0)	(0)	(0)	(18.4)	3
1970	15	30	0	0	0	0	0	20	
	(10.0)	(10.2)	(0)	(0)	(0)	(0)	(0)	(37.2)	35
1975	50	40	0	0	0	0	0	45	
	(39.6)	(26.6)	(26.3)	(28.7)	(14.6)	(0)	(0)	(41.8)	49
1980	88	45	0	0	7	0	0	50	
	(78.2)	(36.3)	(34.4)	(38.7)	(19.4)	(0)	(0)	(47.1)	64
1985	90	55	0	0	10	0	0	60	
	(82.9)	(44.2)	(42.5)	(47.5)	(34.4)	(0)	(4.9)	(48.6)	67
1990	91	70	5	5	15	3	1	70	
	(87.3)	(52.6)	(47.1)	(52.3)	(44.3)	(.8)	(9.8)	(57.6)	71
1995	92	85	10	10	20	15	3	75	
	(90.1)	(59.0)	(48.8)	(56.6)	(58.6)	(27)	(29.5)	(58.1)	75
2000	95	99	15	15	21	33	5	80	
	(94.5)	(71.0)	(53.5)	(75.7)	(68.3)	(3.7)	(46.3)	(74.6)	81

Table 4 reports crop yields by five-year periods from 1960 to 2000. The ratio of crop yields in 2000 to crop yields in 1960 is also reported. These ratios show that wheat yields tripled, rice and potato yields more than doubled and other crop yields, except for groundnuts, increased as well. As a result, the Dietary Energy Sufficiency (DES) a measure of calories consumed per capita, for Pakistan increased from 1748

[2]A study reported in Evenson and Gollin (2003) concluded that the availability of IARC-crossed GRMVs made NARS programmes more productive.

[3]These were all hybrid varieties.

Table 4

Crop Yields in Pakistan

Year	Wheat	Rice	Maize	Millets	Sorghum	Lentils	Groundnuts	Potatoes
1960	.82	1.39	1.03	.44	.48	.42	1.39	8.45
1965	.86	1.42	.99	.44	.46	.42	1.39	9.28
1970	1.17	2.19	1.12	.47	.59	.34	1.26	10.51
1975	1.32	2.30	1.29	.49	.59	.35	1.47	10.45
1980	1.51	2.42	1.26	.53	.58	.42	1.41	10.54
1985	1.61	2.46	1.26	.46	.59	.53	1.23	9.97
1990	1.83	2.32	1.40	.40	.57	.44	1.15	10.40
1995	2.08	2.75	1.60	.40	.61	.51	1.10	13.94
2000	2.49	3.03	1.75	.51	.62	.65	1.12	16.90
Y2000/ Y1960	(3.0)	(2.7)	(1.7)	(1.2)	(1.3)	(1.5)	(.9)	(2.0)

in 1960 to 2462 in 2000.This had major implications for child mortality in Pakistan. Infant mortality declined from 18 percent in 1960 to 8.5 percent in 2000. Child mortality declined from 23 percent in 1960 to 11 percent in 2000. These indicators show that the Green Revolution was very favourable for Pakistan.

(c) The Diffusion of GRMVs in Pakistan

Azam and Evenson (2002) undertook an analysis of factors affecting GRMV diffusion for wheat and rice in Pakistan. The data available for the analysis were for the crop year 1969-70 to 1999-2000 at the district level for the Provinces of Sindh and Punjab. The dependent variable recognised the logistic or s-shaped function of diffusion.

Table 5 reports estimates of the diffusion specification for wheat and rice. These estimates show:

(1) That higher literacy rates for rural males facilitates GRMV diffusion for both wheat and rice.
(2) That more paved roads per unit of cultivated area does not facilitates GRMV diffusion.
(3) That nearby markets facilitate GRMV diffusion but distant markets do not.
(4) That crop research in the public sector facilitates GRMV diffusion, because it results in higher levels of GRMV production. Over the 1965–2000 period 122 wheat varieties were released. More than half of these releases were produced by the Pakistan research programme. Over the 1965–99 period, 40 rice GRMVs were released. Of these 30 were produced in the Pakistan rice research programme.
(5) That the ratio of GRMV yields to traditional yields (an index of favourable conditions), led to higher GRMV diffusions.

Table 5

Estimates: Diffusion Specification

Dependent Variable ln(pctGRMV)/(100-PCTGRMV)
t-Ratios in Parenthesis.

Independent Variables	Wheat	Rice
Literacy (Rural Males)	0.750	0.021
	(8.94)	(2.84)
Road Surface (Paved)/Cultivated Area	–0.195	0.119
	(3.80)	(1.18)
Markets Within 0-5 km	0.013	0.008
	(1.75)	(0.95)
Markets Over 5 km	–0.037	–0.010
	(3.18)	(0.70)
Crop Specific Research (Public Sector)	0.049	0.034
	(9.78)	(11.73)
Percent GRMV in 1969	0.014	0.012
	(3.46)	(5.61)
Yield Traditional Varieties 1969	1.59	–2.20
	(2.43)	(6.01)
GRMV Yields/Traditional Yields 1969	0.229	0.661
	(0.95)	(2.99)
Percent Irrigated Area 1969	0.242	
	(5.58)	
Percent Basmati Area 1969		0.008
		(4.13)
Constant	–4.24	3.29
	(4.34)	(3.74)
Number of Observations	612	649
R^2	0.533	0.367
Prob>F	0.000	0.000

(6) That conditions favourable to early adoption of GRMVs were also favourable to GRMV diffusion.
(7) That irrigation facilitated wheat GRMV diffusion. Virtually all rice area was irrigated.
(8) That conditions favourable to Basmati GRMVs for rice facilitated GRMV diffusion for rice.

(d) The Unequal Delivery of the Green Revolution

Figure 1 lists 87 countries classified according to aggregate Green Revolution Modern Variety (GRMV) adoption rates. The 12 countries in the first column report

Fig. 1. Green Revolution Clusters by GRMV Adoption Level

LT 2%	2-10%	10-20%	20-30%	30-40%	40-50%	50-65%	GT 65%
Afghanistan	Burkina Faso	Bolivia	Colombia	Cuba	Dominican Republic	Algeria	Argentina
Angola	Cambodia	Benin	Costa Rica	Egypt	Iran	Bangladesh	Chile
Burundi	Chad	Botswana	Ecuador	Mexico	Kenya	Brazil	China
Central African Republic	El Salvador	Cameroon	Ghana	Namibia	Morocco	Myanmar	India
Congo (B)	Gabon	Congo (Z)	Laos	Paraguay	Nepal	Tunisia	Indonesia
Gambia	Guatemala	Côte d'Ivoire	Madagascar	Peru	Thailand		Malaysia
Guinea Bissau	Guinea	Ethiopia	Mali	Saudi Arabia	Turkey		Pakistan
Mauritania	Haiti	Liberia	Sierra Leone	South Africa			Philippines
Mongolia	Jamaica	Honduras		Syria			Sri Lanka
Niger	Libya	Mauritius					Vietnam
Somalia	Malawi	Nicaragua					
Yemen	Mozambique	Nigeria					
	Panama	Rwanda					
	Senegal	Sudan					
	Swaziland	Tanzania					
	Togo	Uruguay					
	Uganda	Venezuela					
	Zambia	Zimbabwe					

no GRMV adoption at all in the year 2000. All other classes are based on area weighted GRMV adoption rates for the 11 crops included in the GRMV study.[4]

Table 6 lists indicators by Green Revolution cluster. Two sets of indicators are provided. The economic indicators show the following:

(1) Crop value (in US dollars) per hectare is very low for countries not realising a Green Revolution and rises to a level more than six times that for countries realising the highest levels of GRMV adoption.
(2) Fertiliser application per hectare is negligible for the first four clusters and significant for the highest GRMV adoption.
(3) Crop TFP growth is negligible for countries not realising a Green Revolution and highest for countries with highest levels of GRMV adoption.
(4) Countries without a Green Revolution did have both agricultural scientists and extension workers. Scientists per million hectares of cropland rise with higher levels of GRMV adoption.
(5) Extension workers per million hectares of cropland are roughly 20 times as great as scientists per million hectares of cropland. The number of extension workers increased in every cluster. No correlation between extension workers per million hectares of cropland and GRMV adoption exists.
(6) None of the countries without a Green Revolution has industrial competitiveness. A UNIDO index of .05 indicates industrial competetiveness. Only countries in 30-40 percent GRMV clusters and above have industrial competitiveness. Improvement in industrial competitiveness is highest for the highest Green Revolution cluster.[5]

The social indicators show the following:

(1) Sixty-three percent of the 4.65 billion people living in developing countries in 2000 are located in the ten countries in the highest Green Revolution cluster. Countries without a Green Revolution make up less than 2 percent of the population in developing countries.
(2) The average population of countries in 1960 and 2000 rises as GRMV adoption rises. This suggests a strong bias against small countries.

[4]The 11 crops were rice, wheat, maize, sorghum, millets, barley, groundnuts, lentils, beans, potatoes and cassava.

[5]UNIDO Indexes for South Asia were:

	1985	**1998**
India	0.034	0.054
Pakistan	0.028	0.031
Sri Lanka	0.008	0.017
Nepal	0.001	0.006
Bangladesh	0.008	0.011

Table 6

Green Revolution Cluster Indicators

Economic Indicators

Clusters by GRMV Adoption	Crop Value per Hectare (dollars)	Fertiliser per Hectare (kg/ha)	Crop TFP Growth (1961-2000)	Scientists per Million Hectare Cropland		Extension Work per Million Hectare		Industrial Competitive-ness (UNIDO)	
				1960	2000	1960	2000	1985	1998
LT 2%	78	2	.09	.019	.030	.230	.461	.002	.002
2-10%	128	22	.72	.018	.093	.392	.402	.020	.028
10-20%	94	6	1.07	.013	.033	.149	.220	.028	.029
20-30%	112	12	.87	.033	.076	.245	.416	.037	.051
30-40%	180	40	1.30	.033	.179	.070	.371	.050	.076
40-50%	227	52	.96	.023	.063	.287	,827	.038	.072
50-60%	300	68	1.36	.050	.063	.070	.140	.060	.080
GT 65%	488	166	1.56	.079	.120	.150	.442	.047	.111

Social Indicators

Clusters by GRMV Adoption	Countries in Class	Population in 2000 (Millions)	Population (Millions)		Birth Rates (Millions)		Child Mortality Rates (Millions)		Dietary Energy Sufficiency		GDP Per Capita	
			1960	2000	1960	2000	1960	2000	1960	2000	1960	2000
LT 2%	12	75	2.2	6.1	47	41	293	160	2029	2192	361	388
2-10%	18	153	3.1	8.5	45	36	236	118	2074	2387	815	1291
10-20%	18	385	7.0	21.4	44	36	214	134	1983	2282	866	1295
20-30%	8	115	9.0	14.3	46	32	238	124	2070	2384	695	1156
30-40%	9	337	14.3	37.4	42	26	156	27	2050	2574	1169	3514
40-50%	2	284	15.5	40.3	46	26	221	61	2084	2506	805	1660
50-60%	5	385	34.9	76.7	46	23	240	50	2038	2391	1096	2153
GT 65%	10	2886	135.1	288.6	39	22	165	43	2100	2719	1049	2305

(3) In 1960, birth rates were similar across GRMV clusters. By 2000, birth rates had declined in all GRMV clusters, with highest declines in the highest GRMV clusters.

(4) Child mortality rates in 1960 were similar in most GRMV clusters. By 2000, they had declined in all GRMV clusters with highest declines in the highest GRMV clusters. In the top two GRMV clusters, child mortality rates in 2000 were only 24 percent of their 1960 levels.

(5) Dietary Energy Sufficiency (DES) was similar for all GRMV clusters in 1960. By 2000, improvements were achieved in all clusters with highest improvements in highest GRMV clusters. DES improvement is highly correlated with child mortality reduction.

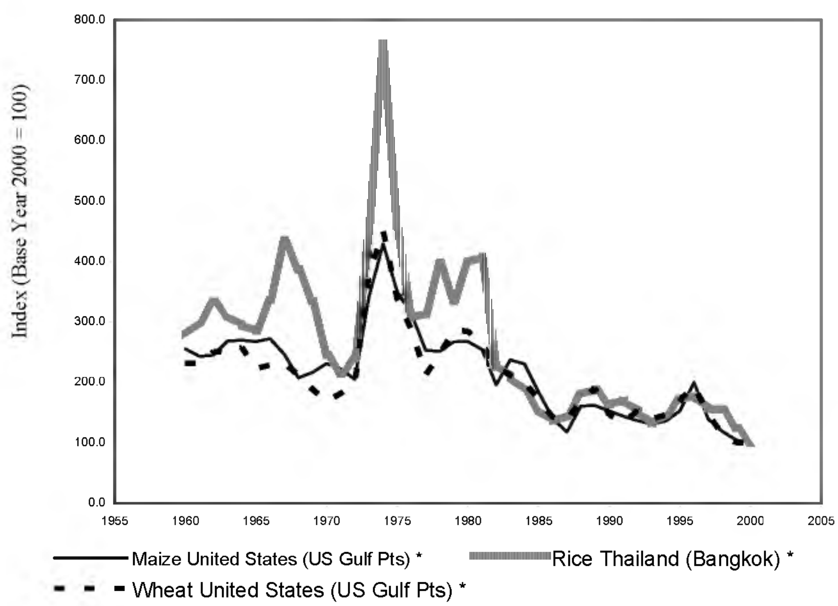
(6) GDP per capita (using exchange rate conversion to dollars, Atlas Method) was lowest in countries without a Green Revolution in 1960 and did not improve in 2000. GDP per capita for the next three GRMV clusters rose from 1960 to 2000 by 56 percent. GDP per capita for the highest four GRMV clusters rose by 140 percent from 1960 to 2000.

Why did twelve countries fail to produce a Green Revolution? A closer examination suggests three explanations. The first is the "failed state" explanation. The second is the "small state" explanation. The third is the civil conflict explanation. Most or all of the countries failing to deliver a Green Revolution to their farmers are effectively failed states. They cannot manage to "deliver the mail" much less produce a Green Revolution. But they are also small states with an average population of 2.2 million people in 1960. None have universities to train agricultural scientists. All have been in civil conflict for much of the past 40 years. Given their incomes and taxing power, it is not surprising that they did not produce a Green Revolution.

The second GRMV cluster did have a small Green Revolution, but they too are small countries (Mozambique and Uganda being largest with populations around 7 million in 1960). Most of these have also been in civil conflict. Few have noted universities to train agricultural scientists, but they did manage a small Green Revolution.

Figure 2 depicts "real" prices for the 1960 to 2000 period (a 5-year moving average). The prices of rice, wheat and maize in 2000 were approximately 45 percent of their 1960 level (35 percent of their 1950 level). Thus, the real prices of the world's major cereal grains have been declining by roughly 1 percent per year for the past 50 years.

Fig. 2. World Grain Prices, 1960–2000



In the OECD developed countries, it is estimated that Total Factor Productivity rates (a measure of cost reduction) have been roughly 1 percent per year higher than in the rest of the economy. For developing countries, crop TFP growth rates have been high except for the lowest GRMV clusters. Only a few of the industrially competitive countries have had industrial TFP growth rates that are higher than agricultural TFP growth rates.

Why then do we have "hunger in a world awash with grain?" For this we need only look at crop value per hectare in Table 6. With low crop yields, crop value per hectare is low. The highest GRMV cluster produces about five times as much crop value per hectare as do the lowest four clusters. At 1960 prices, farmers in Sub-Saharan Africa with 1.2 hectares could earn $2 per day per capita. At 2000 prices with .8 hectares, farmers in Sub-Saharan Africa can earn only $1 per day per capita.

II. PAKISTAN AND THE GENE REVOLUTION

The Gene Revolution is characterised by Genetically Modified (GM) products in both the health and agricultural crops sectors. Roughly 40 percent of GM products are GM crop products and 60 percent are GM health products.[6] The GM crop products fall into three categories:

(a) Herbicide Tolerant products.
(b) Disease Resistant products.
(c) Insect Resistant products (chiefly from *Bacillus thurengiensis* (Bt) engineered into the plant.

As noted above, Pakistan has not benefited from the Gene Revolution. It should be noted that the GM crop products available on the market today have cost-reduction potential. For example, herbicide tolerant soybeans (Roundup-Ready) have been incorporated in roughly 1500 soybean varieties produced by 150 companies and public sector breeding programmes.[7] For some crops (e.g., maize) GM traits can be stacked (herbicide tolerance and insect resistance). This may enhance cost reduction, but only Green Revolution breeding can produce continuous breeding gains as reflected in wheat yield gains for Pakistan. GM products can only reduce costs of production.

(a) Mechanisms to Achieve Cost Reductions

Five mechanisms are specified in this section.

(1) *GMOs for Rent: Developed Country Suppliers*

This mechanism entails negotiations between private agro biotech suppliers of crop GMOs and farmers in developing countries. The suppliers provide the GM

[6]See Zohrabian and Evenson (2001).

[7]Monsanto will actually install the GM trait in the soybean variety if the country lacks the skills to do so.

products in return for a technology fee or a seed price premium. The suppliers may incorporate the GM product (e.g., a Bt product) in more than one crop variety (e.g., several cotton varieties). These varieties may have been developed by public NARS or IARC-NARS programmes or by private seed companies. The supplier may even provide the rDNA technical services, so that little or no rDNA technical skills are actually required in the host economy.

(2) *GMOs for Rent: Developing Country Suppliers*

This mechanism is similar to mechanism 1 except that a private firm or public NARS programme in a developing country is the GM product supplier. Public NARS suppliers may choose to set different technology fees for domestic and foreign purchasers.

(3) *GMOs for Rent: International Agency Purchase*

For this mechanism, an International Donor Agency negotiations with a GM product supplier to provide specific GM products to farmers in specific countries. The International Donor Agency makes payments to the GM product supplier. Farmers may then utilise the GM product without paying a technology fee.

(4) *GM Product Germplasm Conversion*

Most GM products being marketed today can be converted to germplasm in the form of "breeding lines". Once the initial "transgenic" incorporation of rDNA into a breeding line is made, the GM product is expressed in the breeding line and in most cases will be expressed in progeny varieties where the transgenic line is utilised as a parent in a conventional cross. This effectively converts the Gm product into a form where "conventional" breeding methods can be utilised by IARC programmes in much same way that wide crossing methods were used to incorporate "wild (i.e., uncultivated) species" DNA into breeding lines.

(5) *Quantitative Enhancement: Genomics, Proteconomics Research*

This mechanism entails "quantitative" trait breeding. Some prospects for quantitative trait locus (QTL) breeding have been developed to date, but the science of genomics and proteconomics is still in its infancy. There are, however, prospects for important gains in achieving gains in photosynthetic efficiency in plants. This research is very demanding of skills and creativity.

It should be noted that at present. GM products are basically "qualitative trait" products. And qualitative trait products endow plants with specific cost advantages that vary from environment to environment, but are "static" in nature. That is, the cost advantage gains are of a "one time" nature. They do not grow over time. It is possible to "stack" more that one GM product in a crop variety and this produces further cost reduction, but stacking does not produce cumulative gains.

It is sometimes said that the Gene revolution will replace Green Revolution. But this will not happen until and unless mechanism 5 enables breeders to produce "dynamic" gains in generations of varieties. Until such time the Gene Revolution GM products can only complement conventional Green Revolution breeding. This complementarity takes the form of installing "static" GM products on the dynamic generations of varieties produced by conventional Green Revolution methods.

It should be noted, however that Marker Aided Selection (MAS) techniques enable conventional breeders to achieve breeding objectives faster. There is a need to "upgrade" breeders in the use of these techniques.

(b) Cost Reduction Estimates

Table 7 reports estimates of cost reductions from the two major GM products, herbicide tolerance and insect resistance.

As Table 7 notes, cost reduction depends on adoption levels. For maize, both herbicide tolerance and insect resistance GM products can be "stacked".

Table 7

Cost Reduction Potential

		Adoption Level		
Crop	Country	0–30	30–60	60–80
1. Herbicide Tolerance				
Soybeans	US	15	12	10
	Argentina	15	12	10
Canola	Canada	12	10	8
Maize	US	12	10	8
2. Insect Resistance (Bt)				
Maize	US	13	10	6
	South Africa	10	8	6
Cotton	US	15	13	12
	China	30	25	20
	India	30	20	10
	Mexico	30	20	10
	South Africa	30	20	10
Rice	All Regions	8	8	6

(c) Cost Reduction Potential and Cost Reduction Realised as of 2004

Table 8 reports cost reduction potential based on cotton, soybeans, canola, maize and rice production. In addition cost reduction gains realised as of 2004 are reported by country.

Table 8

Cost Reduction Potential by Country and Estimates of Potential Realised

	Potential Cost Reduction (Percent)	Realised as of 2004
I. Developed Countries		
Canada	5	2
USA	9	7
Northern Europe	Less than 1	0
Southern Europe	2	0
Eastern Europe	4	1
Japan	2	0
II. Developing Countries		
Latin America		
Argentina	9	7
Brazil	7	3
Mexico	3	1
Venezuela	2	0
Africa		
Egypt	3	0
Kenya	3	0
Chad	8	0
Benin	11	0
Mali	12	0
Nigeria	2	0
Mozambique	4	0
Malawi	4	0
South Africa	5	2
Zimbabwe	11	0
South Asia		
Bangladesh	5	0
India	3	1
Nepal	4	0
Pakistan	5	0
Sri Lanka	2	0
West Asia		
Syria	2	0
South East Asia		
Cambodia	4	0
Indonesia	3	0
Laos	6	0
Philippines	2	0
Thailand	3	0
Vietnam	4	0
East Asia		
China	4	1

Table 8 offers several conclusions. The first is that the countries of the European Union countries have little or nothing at stake in the Gene Revolution. This is because they produce little acreage of four of the five GM crops currently produced. That is they produce little cotton, soybeans, canola or rice. Maize production is significant in southern Europe but not in Northern Europe. Yet it is the European Union countries that urge adoption of the "precautionary principles". And while the adoption of the precautionary principle makes some sense for regulatory policies, it certainly does not make sense to adopt the precautionary principle as a guide to science policy more generally.

The second point is that North America and Latin America have actually realised much of their cost reduction potential. The only country in Africa to do so is South Africa. This further exacerbates the inequities of the Green Revolution. In South Asia, India has approved Bt cotton production and China has approved Bt cotton and had recently released a Bt rice.

The third point is that many countries in Africa have significant cost reduction potential. This is particularly true for cotton producing countries. These countries are generally not prepared to approve commercial production of GM crops. As a result they experience a double penalty. Not only do they lose the cost reduction potential, but because other countries have approved commercial production of GM crops, prices in world markets are lower.

The fourth point is that Pakistan has significant cost reduction potential because Pakistan is a major cotton producing country. But Pakistan is not realising this potential.

III. SCIENCE POLICY IN PAKISTAN

Many scientists will recall that in 1936, Joseph Stalin appointed T. D. Lysenko to be the genetics "czar" of the Soviet Union. Lysenko first used his position to attack V. I. Vavalov, ultimately, leading to Vavalov's death. But more significantly, Lysenko convinced Stalin that with appropriate techniques (including vernalisation) the laws governing inheritance could be altered. He argued that with proper preparation, genetic change could be forced. In this he was wrong. But Lysenko continued to have influence in the Soviet Union with Stalin and later with Khrushchev. As a result of Lysenko's influence the Soviet Union was relegated to a "second class" position in the sciences of genetics and crop sciences.

There is a kind of "political Lysenkoism" in Europe today. The opposition to GM foods in Europe is not based on scientific studies. Studies of food safety, including many done in Europe, conclude that no evidence has shown that GM foods are less safe than their non-GM counterpart foods.[8] Similarly, for environmental

[8]In the United States there are approximately 5200 deaths each year and 275,000 hospitalisation from "food borne illnesses" many of these deaths and hospitalisations are due to allergic reactions. Some are due to e. coli contaminations. But all foods whether GM or not are subject to allergic reactions and to e. coli contamination.

concerns, scientific studies show no unusual environmental issues requiring specific management techniques.[9]

The leading opponents of GM crops in Europe are activist groups with little or no interest in scientific studies. It appears that European crop science has already lost significant ground to North American crop science. Is this likely to happen in Pakistan?

As noted above, the precautionary principle could be applied to regulatory policy. The application of the principle, however, is problematic in the sense that it places a burden on agencies to demonstrate that a food is safe or the environment is safe before approval. This is a kind of "guilty until proven innocent" stance that is inconsistent with practical reality. For example, the Food and Drug Administration is faced with roughly 10,000 "new food" approvals each year. The FDA's stance on new food is that unless a new food has new ingredients it should be "generally regarded as safe" (GRAS).[10]

It is self obvious, however that the precautionary principle should not govern science policy whether in Pakistan or elsewhere. Yet the decline in European crop science influence suggests that there is a real danger that science policy is affected.

Will Pakistan fall into the trap that has affected European crop science/ Pakistan led the charge in the Green Revolution. But it is in danger of dropping the "ball" in the Gene Revolution.

IV. IMPLICATIONS FOR PAKISTAN

European countries (the original EU members) send the following message to developing countries. They suggest following the "precautionary principle" in regulatory policy. Strictly speaking, the precautionary principle places a burden on a country to show that GM crops (foods) are safe and that they have low environmental risk. Several scientific studies have examined this issue.

It is now well known that an unusual degree of "political" opposition to the GM crops and GM foods has emerged over the past decade. The FAO 2003-04 State of Food and Agriculture provides a survey of the scientific literature on food safety and environmental safety.

Chapter 5 of the *2003-04 SOFA* is based on a critical review of several recent scientific assessments of health and environmental impacts of GM crops. The first is the International Council for Science (ICSU) report which itself is based on 50 scientific assessments by national science academies and other independent

[9]Genetic drift or contamination occur with all species and can occur between a species and or closely related species. This does raise issues with "organic" production technology. For example, an organic maize producer may experience Gm contamination from GM maize.

[10]GM foods have been carefully scrutinised in scientific studies by the FDA.

researchers.[11] Other reports surveyed in the *SOFA* chapter were prepared by the Nuffield Council on Bioethics,[12] the United Kingdom GM Science Review Panel,[13] and the Royal Society[14] farm-scale evaluation report. FAO expert consultations and decisions of the FAO/WHO Codex Alimentarius Commission and the International Plant Protection Convention are also reviewed in the SOFA.

The *2003-04 SOFA* concluded that the scientific evidence for food safety showed no exceptional food safety problems associated with any GM foods currently on the market. There are two main food safety concerns associated with GM foods: (i) the potential introduction of allergens and toxins, and (ii) possible negative effects from the consumption of antibiotic resistant marker genes and viral promoter genes used in the transformation process. Levels of allergens and toxins can increase through conventional breeding as well as genetic engineering, although only the latter are routinely tested. So far no allergenic or toxic effects from the consumption of GM foods have been confirmed anywhere in the world. Any risks associated with the use of antibiotic resistant and viral genes in the development of GM foods are very small, nevertheless their use has been discouraged and scientists have developed "clean" methods of genetic transformation that eliminate these substances. Scientists generally agree that existing GM foods are as safe as their conventional counterparts and new foods should be tested on the basis of their product characteristics rather than the method used to develop them.

The environmental safety of GM crops is also considered in *SOFA 2003-04*. Scientists generally agree on the types of hazards that are associated with GM crops, although they differ regarding their likelihood and potential severity. Most of these hazards can also occur with conventionally bred crops, and scientists generally agree that GM crops should be evaluated on a case-by-case basis depending on the crop, trait and ecosystem where it will be used. Three main environmental hazards are potentially associated with GM crops: (i) outcrossing or gene flow to related crops or wild species, (ii) harm to non-target organisms, and (iii) the emergence of resistant pests.

Gene flow occurs naturally between varieties of the same crop and between crops and sexually compatible wild species. This has occurred ever since farmers began selecting seeds to improve crop performance thousands of years ago. It occurs, therefore, with GM crops as well. In purely scientific terms, such gene flow

[11]The International Council for Science (ICSU) is a non-governmental organisation representing the international scientific community. The membership includes both national science academies (101 members) and International scientific unions (27 members). Because the ICSU is in contact with hundreds of thousands of scientists worldwide, it is often called upon to represent the world scientific community.

[12]The Nuffield Council on Bioethics is a British non-profit organisation funded by the Medical Research Council, the Nuffield Foundation and the Welcome Trust.

[13]The GM Science Review Panel is a group established by the United Kingdom Government to conduct a thorough impartial review of the scientific evidence regarding GM crops.

[14]The Royal Society is the independent scientific academy of the United Kingdom, dedicated to promoting excellence in science.

is a cause for concern only when the resulting hybrid achieves a “competitive advantage” that would enable it to invade natural ecosystems or other agricultural fields. Since a trait like herbicide tolerance confers an advantage only in the presence of a specific herbicide, it is highly unlikely that this trait would survive in nature, and in any case other herbicides could be used to control it. Furthermore, GM crops have no wild relatives in many production areas so gene flow into natural ecosystems would be impossible. Similar reasoning based on the trait, crop and location can be used to assess the risk of gene flow associated with other GM crops.

Gene flow from GM crops could pose an economic problem, especially for crops produced and certified as organic if such “contamination” results in the loss of organic status. Since GM pollen drift is distance limited, it is expected that this problem can be handled by imposing minimum distances between GM crops and organic crops, although the cost of doing so will depend on the tolerance limits for the accidental presence of GM traits in organic products.

The second environmental concern involves the potential for GM traits or associated farming practices to harm non-target organisms. The potential for Bt corn to harm Monarch butterfly larvae or for herbicide tolerant crops to reduce the presence of weeds in farmers’ fields—and hence the availability of food for farm land birds—are examples of such concerns. So far these traits have not caused serious harm to non-target organisms; on the contrary, compared with conventional cropping practices, they can be beneficial depending on how they are managed. Nevertheless, much remains unknown about the potential ecosystem effects of GM crops, and scientists recommend continued monitoring.

A final concern is that insects may develop resistance to Bt crops, leading to the emergence of “super-pests”. This has not happened to date, in part because of the use of “refugia” where some proportion of a GM crop is planted to non-GM varieties and to the development of second-generation GM crops that contain two Bt genes (which dramatically reduces the probability that resistance will develop). The emergence of pests that are resistant to Bt crops would not necessarily cause an ecological problem since other insecticides could be used against them.

The danger for Pakistan is that the precautionary principle is applied to science policy instead of regulatory policy. It may be appropriate for regulatory policy, although that is in some question. But it clearly is inappropriate for science policy. European crop science has probably already been harmed by the controversies associated with GM crops as noted in the discussion of Political Lysenkoism.

The application of the precautionary principle to applied science fields such as crop science “smothers” and limits the science. Watson and Crick changed the way biological science is done more than 50 years ago. And numerous scientific advances have been made since then. Pakistan had an excellent record in the Green Revolution. Reluctance and hesitancy in applying Gene Revolution techniques is not in Pakistan’s best interest.

Appendix. Status of Ag-Biotech Regulations

Fig. 3. Global Biotech Activity: Field Crops—Highest Level of Biotech Development

Field Crops by Country	Soybean	Cotton	Maize	Canola	Sugar Beet	Rice	Flax	Wheat	Sugarcane	Barley	Alfalfa	Cassava	Sunflower	Clover	Safflower	Sorghum
Canada	P	A	P	P	A	A	A	F		F	F		F	F	F	
United States	P	P	P	P	A	A	A	F	F	F	F				F	
Australia	a	P	a	a	a			F	F	F				F		
West Europe (15/15)	a	F	P	a	F	F		F		F	F		F			
Argentina	P	P	P		F			F	L	L	F		F			
Mexico	A	P	F	F		F	F	F								
China	F	P	F	L	L	F		L		L						L
Japan	a	a	a	a	a	F		L								
South Africa	P	P	P	F					F							
Brazil	P	F	F			F			F	L						
East Europe (8/13)	P		A	F	L		L	F		L	F		F			
Indonesia	F	a	F			L			L							
Uruguay	P		P													
Egypt		A	F	A				F	F	L						
India		P		F		L						L				
Colombia		P										L				
Philippines			P			L										
Paraguay	P															
Chile	P		P													
South Korea	a		a													
Honduras			A													
Belize	F	F	F													
Cuba			L			L			F							
Thailand		F				F						L				
Venezuela						L			L			F				
Zimbabwe		F										F				
Bolivia	F	F														
Costa Rica			L			F										
New Zealand				F												
Malaysia						L										
Pakistan		L				L										
Morocco								L								
Bangladesh						L										
Kenya			L													

Commercial Production	P
Regulatory Approval	A
Field Study	F
Lab/Greenhouse	L

Source: AGBIOS (2004); FAO (2004); ISB (2002); WISARD (2004); BINAS (2003).

Fig. 4. Global Biotech Activity: Vegetables—Highest Level of Biotech Development

Vegetables by Country	Potato	Tomato	Squash	Pepper	Pea/Bean	Lettuce	Cucumber	Cabbage	Carrot	Eggplant	Onion	Cauliflower	Broccoli	Spinach
West Europe (13/15)	F	F	F		F	F		F	F	F		F	F	F
United States	A	A	P		F	F	F				F			
Canada	A	A	A											
Australia	a	F			F	F								
Japan	a	a			F	L	F					F	F	
China	F	P		P				F	L					
Mexico	F	A	F	F										
Brazil	F	F			F	L			F					
Egypt	F	F	F		L		F							
Thailand		F		F	L									
Argentina	F	F												
East Europe (10/13)	F	L			F									
Cuba	F	L												
Zimbabwe	F													
Bolivia	F													
Peru	F													
South Africa	F													
Kenya	F													
Guatemala		F												
New Zealand											F			
South Korea				F										
Indonesia	L	L		L										
Malaysia				L	L					L				
India	L	L						L		F				
Chile	L	L												
Colombia	L	L												
Bangladesh					L									
Philippines		L												
Tunisia	L													

Legend	
Commercial Production	P
Regulatory Approval	A
Field Study	F
Lab/Greenhouse	L

Source: AGBIOS (2004); FAO (2004); ISB (2002); WISARD (2004); BINAS (2003).

Fig. 5. Global Biotech Activity: Fruits—Highest Level of Biotech Development

Fruits by Country	Papaya	Melon	Banana	Pineapple	Apple	Grape	Plum	Strawberry	Watermelon	Citrus	Cherry	Cantaloupe	Kiwi	Raspberry	Mango	Coconut
United States	P	A	F		F		F		F							
West Europe (8/15)		F			F	F	F	F	F	F	F	F	F	F		
Australia	F			F	F	F										
Canada	A					F										
Mexico	F	F	F	F												
Cuba	F		L	L						L						
Philippines	L		F												L	L
China	F	F														
Egypt		F	L									F				
Japan	L	F						L								
East Europe (3/13)						L	F									
South Africa								F								
Brazil	F															
Malaysia	L	L	L	L												
Chile		L			L	L	L									
Venezuela	L		L												L	
Colombia			L													
Costa Rica			L													
Bangladesh	L															
Thailand	L															

Commercial Production	P
Regulatory Approval	A
Field study	F
Lab/Greenhouse	L

Source: AGBIOS (2004); FAO (2004); ISB (2002); WISARD (2004); BINAS (2003).

Fig. 6. Global Biotech Activity: Other Crops—Highest Level of Biotech Development

Other Crops by Country	Tobacco	Chicory	Mustard	Peanut	Coffee	Lupins	Oilseed Poppy	Olive	Oil Palm	Cocoa	Garlic
United States	P	A		F	F						
West Europe (9/15)	a	A	F					F			
Australia			F			F	F				
China	F			F							
Brazil	F									L	
Canada			F								
East Europe (3/13)	F										
South Korea	F										
India	F										
Mexico	F										
Indonesia	L			L	L				L	L	
Chile	L										L
Bangladesh	L			L							
Malaysia	L								L		
Venezuela					L						
Philippines	L										
Argentina	L										
Cuba					L						
Japan	L										

Commercial Production	P
Regulatory Approval	A
Field Study	F
Lab/Greenhouse	L

Source: AGBIOS (2004); FAO (2004); ISB (2002); WISARD (2004); BINAS (2003).

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Comments

1.

Prof. Evenson has been working on the cutting edge of technology as long as I remember. I first saw him when he was working on Total factor productivity in agriculture. I said I saw him because he was pursuing his avocation with such single mindedness that it was almost impossible to get in to conversation with him. I later learnt that he was working on climatology. The point I am trying to make is that he has been working in areas where there is considerable skepticism. He takes on the role of persuading Pakistan to have a rework at the gene revolution. His reasons are compelling and one really wonders why Pakistan never went in to this regime much earlier on. The aspect that one has to worry about is that science starts with a lot of ifs and buts and over a period of time these ifs and buts are resolved. These doubts are resolved either definitively or through probabilities and this take care of the majority of those that are in such doubt. In our country these ifs and buts enter the social life and because of the cumulative experience of the past these fears have to be allayed. The problem then is not with the future but with the past and the experiences that go to make that historical past.

Pakistan started with biotechnology pretty early and in fact in the 1980s. That the institutional framework was in place but the persuading social infrastructure was not explains the poverty of intervention in this area. Even today the identification of various 'socio-political groups' is not in place. The role that these socio-political groups play in policy matters is critical to the success or failure of policy. This is particularly true when new areas are under exploration.

To go back to the green revolution the technology was thrust down the farmer's throat. HYV were moving simultaneously with chemical technology. I remember as a field personnel I was one of the persons responsible for pushing this technology through. Mexi-pak wheat was under fire as not being suitable for Chapattis the local bread. All kinds of conspiracy theories were passed around. The incentive price for the fertiliser was ridiculous, Rs 8 a bag for 50 Kg. We were not told that this was wasteful way of fertilising. The agriculture sector was not at the forefront-it were the administrative service and the much-hated CSP that managed to doing this. In the 60s we were on the brink and in the new millennium we will soon be if we are not there already.

The changes that are coming through are such that Pakistan will sooner or later have to take the necessary steps to ensure that we enter this new phase. Why should we doubt the scientific work elsewhere. Has not enough work been done on bio-safety and other regulatory requirements? If that is the case can Pakistan do better than other nations in science? Is it a question of removing doubts on the wok undertaken by other nations? Are we better at science than the other nations; then our own neighbour? The answer is simple and there is no need to feel slighted. We are not. We can go the same route that others have gone with or we can do what is what time saving countries do. Take on the generic on face value and go for some critical site-specific work that is required. Pakistan has already been the recipient of GM crops from USA [Soya] and the public accepted it. We are very innocent in some ways and very profoundly critical in others. You will find on super market shelves GM tomato puree and expensive. Those with voluminous disposable income are the purchasers of these products. Do they know what they are purchasing and what the constituents are dependent on truthful labeling? No they do not.

So why this reluctance and who leads this. reluctance and criticism? The institutional-framework that fuels these concerns is the NGOs. They realise that to make a mark they have to question the policies that might put them at the forefront of the other NGOs. The very fact that affirmative action does not put you in that position and only intransigence does is very much a reality all over the world. The functions normally performed in a positive manner by the government functionary are now the responsibility of the civil society. So how do you get them to change gear? Who are these NGOs? Who are the favoured ones? Who are struggling? What substantive work do they perform? Do the policy-makers consider it favourably or otherwise?

But again did the green revolution touch everyone? No the green revolution did not. The agrarian structure is such that the green revolution touched the feuds.

Notice that I have not used the word feudal but feuds. They are at the forefront of all the feuds in this countries agrarian structure. Despite a number of land reforms they stand singly and collectively for any kind of reform that would lift the poorer agricultural community to decent level of living. In the agrarian structure 93 percent are less than 12.5 acres of which 60 percent are less than 3 acres. These figures may be a little dated because these are couple of years ago and there is no moratorium on deaths and the Mohammedan law of inheritance. The remaining 7 percent have 63 percent of the landmass. So the income levels are poor and verging on the subsistence level. The one objection that NGO's have made is that the price of seed is high and it is replaceable every year. So where does he get the income to buy this seed and from where? The green revolution has touched about 40 percent of the farmers and the majority of them do not have the purchasing power. The NGO's point out to the price then and now? They point out on the basis of experience the trap that is being set for the poor farmers. They point to the government policy of corporate farming as a means to ensnare the farmer and to take him to the washers.

These are powerful slogans and there may not be any truth in what is being said.

In public policy it is obvious that perceptions are more important than facts. If the perception goes then that is it. It will take a lot of time and effort to correct. Kala Bagh dam is a case in point. The criticality of water aside it is he unfairness of the distribution system that is at the helm of such disaffection. A way out has to be found out. I could go on and list the number of ways that the policy-makers have distorted, over the ages, the actions that are mere slogans and the actions and deeds were quite contrary to the words. The culture goes on. So the problem may not be in the science but in the way that we have been manipulated. The farmers seek a very decent and appropriate response to their problem.

As to what is happening on the rest of the world developing countries have gone wild. The countries that are in this are China, India, Argentina, Brazil and it is now up to 80 million hectares. The growth is 20 percent per annum. India is astonishing in the sense that it was here that ecologists burnt and buried GMs but it has bounced back. India is going to crops that we in Pakistan could take action on. So what is the fetish about safety regulations? On farm evaluations have been done elsewhere and the results indicate that although there is some degree of uncertainty on the impact on farm biodiversity. We do not have the where with all to consider these niceties of say herbicide load. We use so little of herbicide anyway. We cannot even mimic some of the studies carried out elsewhere. So the morality of not accepting a finding is not may prerogative. What would be the affect on granivorous birds? And in Pakistan who cares about birds that feed on farm grains? There will be a problem if the pollinators suffer a set back but then we have never allowed these considerations to hamper our decision-making.

Pakistan has to contend with the changes that have taken place in the farmland technology. Our farmers have to do a lot of catching up. They are still in the primordial stage, especially those in the marginal and peripheral areas. Credit and technology do not go together in Pakistan. It has to be a package. Take for instance the market system. At partition in 1947 Punjab had more than 650 markets now they are less than 300 while the produce has moved on by ten times. Is anyone caring? No. Policies have to change. We have moved on to the WTO but our own markets are in shambles.

The issue is not just GMs but the entire farm sector. In order to get on with it a fair and just policy has to come in. The fact is that this technology be used for rectifying the weaknesses of the sector and that may be a way out. Please do not hand me over the case-by-case basis for decision-making. The probability that the GMOs have come to stay is established. Pakistan has gone in to rice and cotton. The political system was such that the cotton part got eliminated and the rice part stayed on because the institutional framework was more stable. Raised eyebrows-yes that is true. It depends on the working relationships for we are not a system-oriented nation but a personality oriented one. The powers that be know more than the scientist or any informed person.

So the route is a different one if gene revolution is to be brought in to action. Prof. Evenson is right. Do not lose the race for then you will never be able to catch up.

As it is there is a lot of catching up to do. Gimmickry and trickery are out. These two do not find place in the comity of nation.

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2.

Prof. Dr Robert E. Evenson has presented a very comprehensive review of the impact of Green Revolution and the potential of Green Revolution in context of Pakistani agriculture. The Green Revolution has greatly impacted the agriculture of Pakistan and has enabled it to move from the food scarcity scenario to self-sufficiency environment. According to Prof. Evenson, Pakistan after harnessing the benefits of Green Revolution is lagging behind in exploiting the ongoing Gene or Biotechnology Revolution.

In this connection, a comparison of Green Revolution and on going Gene Revolution can be of interest. This comparison is presented in the following table:

Green vs. Biotech Revolution

Tasks	Green Revolution (1960)	Biotech Revolution (1985)
Technology	Hybridisation (Dwarf gene / Biodiversity)	Recombinant DNA Technology
Transfer of Technology	Free	Barriers
Inventor	Public (CGIAR / NARS)	Private (MNCs), Few PS
Regulations	None	PBR, WTO, TRIPS, CPB, SPS
Thrust	Public Good	Profit/Efficiency

One can see the biggest change with the on going Gene Revolution is the institution of more stringent regulatory procedures and Intellectual Property Right (IPR) regime. From the developing countries' point of view, this has created immense problems in getting access to technology in the same manner as happened in the Green Revolution. Therefore, developing countries have to develop their own capacity in the public sector in order to use the technology already developed.

In the agriculture biotechnology sector, Pakistan has made significant progress. The Government of Pakistan has invested more than Rs 900 million (about 15 million US dollars) in biotechnology during the last three or four years. The National Institute for Biotechnology and Genetic Engineering (NIBGE) at Faisalabad, has developed insect resistant cotton varieties through genetic engineering and is ready for commercial cultivation. Similarly, different transgenic lines of rice, sugarcane, tomatoes and chillies are also available.

After lot of effort and persuasion by the scientific community and personal interventions of Mr Shaukat Aziz, Prime Minister of Pakistan, Biosafety Rules and

Biosafety Guidelines have been notified by the Ministry of Environment and approval mechanism of GM crop varieties is now being developed. This has been the main bottleneck in commercially exploiting the benefits of Gene Revolution.

Prof. Evenson has mentioned about the precautionary principle as enunciated by European NGOs. However, while making our Biosafety Guidelines and Biosafety Rules, due consideration has been given to all such concerns for health and nutrition of our people. The Pakistani Biosafety Guidelines are in line with the model Biosafety Guidelines put forth by FAO and other International organisations. We continuously interact with the concerned NGOs and civil society in order to have dialogue and create awareness about the technology.

Prof. Evenson is right in saying that "an unusual degree of 'political' opposition to the GM crops and GM foods has emerged over the past decade" especially in Europe. However, scientific community in Europe is also as concerned as within North America about the role of NGOs. This is apparent by the fact that both the European governments and private sector are investing heavily in agricultural biotechnology and first rate scientific publications are coming out of Europe as well. In our opinion, this is the job of the scientific community to continuously interact with the civil society and keep them on board in making certain decisions.

We greatly appreciate efforts of Prof. Evenson as he has very strongly put forth the views in favour of using biotechnology Revolution for economic development of Pakistan.

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