Is Third World agricultural R&D slipping into a technological orphanage?†

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The developing world faces the tough task of producing adequate food to meet the demands of its burgeoning population, as yield levels of major crops have struck a plateau. Food and nutrition security being the major concerns, agricultural R&D in less-developed countries is at the crossroads. The earlier days, when the benefits from the technological breakthroughs attained by the Consultative Group for International Agricultural Research institutes and the public sector research of the developing countries, was spilling over to the developing countries may not come again. Hi-tech crops research is capital-intensive and only the private sector has been able to invest and harness. While the developing countries continued to bank upon public investment for their agricultural R&D during the 1990s, in the developed world, it is the private investment that dominates agricultural R&D. Private sector investment will be contingent upon stringent and facilitating IPR regime. The technology-buying disadvantages of the developing countries are thus too obvious to be emphasized. With shrinking base of the public sector and private sector investment and the research benefits not spilling over, the increasing inequality is bound to magnify inter-country technology gaps and push a big majority of the developing countries to the brink of a technological orphanage.

Keywords: Agricultural research, developing and developed countries, public and private investment, technological orphanage.

THE most challenging task for planners is to match the demand and supply of food. While the demand depends largely on the rate of growth of population, the supply depends on the application of improved production technologies on a given land, especially in big and land-scarce countries. With population expansion, demand for food has been ever increasing. While it took 102 years (between 1825 and 1927) for the world population to increase by one billion, the next billion took only 33 years (between 1927 and 1960), the subsequent billion has taken as little as 15 years (between 1960 and 1975) and the gap continues to further reduce[1]. The average annual rate of growth of world population has remained fairly high even in the recent decades, e.g. 1.98% during the sixties, 1.82% during the seventies, 1.70% during the eighties and 1.41% during the nineties[1], 1.14% during the last decade (2001–10) with a current population around 7.02 billion. The most significant demographic characteristic for the next century is that 'virtually all population growth will occur in the poorer parts of the world'[2].

The increasing population besides exerting pressure on food demand, has also been striving to boost production and bring about balance in the demand–supply chain. A consistently rising production largely realized through technology-driven productivity or yield breakthroughs, is the strategic answer on the supply side. Agricultural growth and expanding food supplies have been sustained in varying forms and content by agricultural R&D. Since the middle of the 20th century, a small group of rich countries (largely USA, followed by Japan, Germany and France) has been the cradle for agricultural R&D. Both rich and poor countries depend on the agricultural research conducted in the private and public laboratories of these countries. The public purpose and global outreach in agricultural research of these countries were manifested in their persistent efforts to innovate and deliver component technologies, almost philanthropically, to facilitate an increase in farm-level productivity and food security among the developing economies.

Those among the developing economies which strove to put their domestic agricultural R&D base into a state of preparedness for acclamatizing and absorbing the 'imported technology' on the one hand, and to put the needed market and institutional arrangements in place on the

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other, emerged as the primary drivers of the adoption of new technologies. On the positive side, the spread of Green Revolution Technology in certain regions of India, during the late sixties, is the strongest testimony of how R&D could transform a food-deficit and food-importing economy into a food self-sufficient economy. The actors were mainly in the public sector and the impact domains were rice, wheat, soybean, sugarcane, reclamation of saline soils, watersheds, vaccines and diagnostics, to cite a few. On the negative side, a very large part of the developing world, which is away from technological benefaction is now feared to become trapped into a technological orphanage, because of the 'changing rules' of technology generation and marketing. This poses a real threat of world food deficit, hunger and malnutrition.

The main objective of this study is to confirm the technological infirmities of the developing world agriculture, to caution the international development organizations, and facilitate the policy makers in the developing world in according agricultural R&D top priority for addressing the threatening prospects of severe food deficit, hunger and malnutrition. The technological weakness of the Third World, individual country-wise or regional group-wise, is seen in relation to the developed world realities. It encompasses R&D investment in all its manifestations: agricultural R&D in relation to overall R&D; agricultural R&D investment as a proportion of domestic GDP; agricultural R&D in public and private sectors, and agricultural R&D in relation to total rural population or population dependent on agriculture.

The data were sourced from the World Development Reports, UNDP Reports, World Development Indicators, FAO/IFPRI publications, individual country publications/reports, markedly on and from India, and individual research publications/papers/monographs which directly and/or indirectly address the issue of agricultural R&D, from all over the world. The data marshalled by the study, although riddled with definitional angularities and specificities, leave no doubt about the huge inadequacy, distortions and vulnerability of the developing world agricultural R&D.

Agricultural technology – historical perspective

Since the beginning of civilization, man has been persistently striving to develop different skills, knowledge and tools for his use[3]. For instance, methods of irrigating and fertilizing crops were invented even before agriculture first appeared in the recorded history[4]. Centuries of cumulative inventive efforts, however, were not enough to bring about fundamentally new methods of production and augmenting food availability and the standard of living of people. Spectacular breakthrough in the history of agricultural technology came only during the 20th century, out stripping all those achieved earlier in terms of composition, depth and power of the changes. These included farm power sources, introduction of new crops and better farming techniques like dry farming, use of genetics to develop new strains of plants and animals, animal husbandry, use of electricity in agriculture, and chemical control of pest and disease in crops. Clearly, the 20th century concept of farm technology involved both science and engineering, and depended on their free interaction[3].

The initial important developments in agricultural research during the first half of the 20th century did take place in the industrial countries particularly USA. But, the situation started changing since 1950s. The former colonies in Africa and Asia, post-liberation from the colonizers, have initiated large scale reforms to improve their agriculture, adopting the Western methods modified to their situations. In short, a sort of spill-over of production technology economies took place from the advanced countries to the developing countries.

The emerging challenges for agricultural R&D

Numerous challenges to agricultural technology that would have a huge bearing on agricultural growth and its sustainability over time are emerging at the local, national and international levels that cannot be tackled through conventional research alone. The new agriculture has inevitably become a more involved cob-web of bio-tech and genetic complexities. Given the increasing trend towards public–private partnership in extension education, farmers' own education, knowledge and comprehension would be inescapable inputs. In brief, formidable R&D challenges, in and around agriculture, have already set in. These are likely to assume more daunting technical complexities, and going by the meagre R&D effort by a greater majority of developing countries, they may soon land themselves into a technology gap.

The world's agricultural economy underwent a remarkable transformation during the latter half of the 20th century led by the agricultural productivity growth generated primarily by agricultural R&D financed and conducted by a small group of rich countries. The most apt description of the ground reality is that 'agricultural R&D in the Third World countries is too little, and too late'.

The most incapacitating reason for the low-level and far-from-efficient R&D output in general, and the one for agriculture, in particular, is the low level of education, most markedly higher education. The north–south asymmetries in respect of public expenditure priorities attached to education and health, on the one hand, and the weak R&D outfits on the other, come out rather glaringly. Inadequate and poor quality of education, most notoriously higher and university-level education, in sciences and science-research, is their most glaring weakness.

At the global level, the developed world commands extreme dominance in terms of its share in world R&D

Table 1. Profile of global public R&D investment expenditure (GERD): 2002–2009

Country	Percentage share in world R&D expenditure and population						Researchers per million inhabitants (2007)	Percentage of GDP on R&D (2009)
	2002		2007		2009			
	R&D expenditure	Population	R&D expenditure	Population	R&D expenditure	Population		
Americas	40.5	5.16	37.5	5.07	35.8	5.03	2010	2.1
USA	35.1	4.65	32.3	4.56	30.6	4.53	4663	2.8
Japan	13.7	2.05	12.8	1.93	10.7	1.88	5573	3.4
Germany	7.2	1.33	6.4	1.25	6.6	1.20	3532	2.8
France	4.8	0.96	3.8	0.93	3.8	0.92	3496	2.2
UK	3.9	0.96	3.4	0.92	3.2	0.91	4181	1.9
Europe	30.0	7.63**	28.1	6.74**	28.5	5.96**	2639	1.9
Russia	1.8	2.32	2.3	2.15	2.8	2.09	3305	1.3
Asia	27.2	52.27*	31.8	51.96*	33.0	51.80*	746	1.6
China	5.0	20.66	8.9	19.94	12.1	19.64	1071	1.7
India	1.7	16.92	2.1	17.02	2.4	17.04	137	0.8[$]
Brazil	1.7	2.82	1.8	2.90	1.9	2.86	657	1.2
Mexico	0.5	1.63	0.5	1.59	0.5	1.58	353	0.4
Africa	0.9	11.2[#]	0.9	12.1[#]	0.9	12.4[#]	164	0.4
South Africa	0.3	0.73	0.4	0.72	0.4	0.73	393	0.9[@]
Egypt	0.1	1.07	0.1	1.14	0.1	1.22	617	0.2
Argentina	0.1	0.59	0.2	0.60	0.3	0.6	980	0.6

GERD is gross (public) expenditure on R&D. *Total of South Asia and East Asia (including the Pacific). **Total of Europe and Central Asia; [$]For 2007; [@]For 2008 and [#]For Sub-Saharan Africa.

Table 2. Global forecast for R&D public investment expenditure

Region/country	2010		2011		2012	
	GERD (PPP billion US$)	GERD as % of GDP	GERD (PPP billion US$)	GERD as % of GDP	GERD (PPP billion US$)	GERD as % of GDP
Americas	437.7 (37.8%)	2.3	491.8 (36.9%)	2.3	505.6 (36.0%)	2.3
USA	415.1 (32.8%)	2.8	427.2 (32.5%)	2.8	436.0 (31.1%)	2.8
Asia	429.9 (34.3%)	1.8	473.5 (35.5%)	1.9	514.4 (36.7%)	1.9
Japan	148.3 (11.8%)	3.4	152.1 (11.4%)	3.5	157.6 (11.2%)	3.5
China	149.3 (12.0%)	1.5	174.9 (13.1%)	1.6	198.9 (14.2%)	1.6
India	32.5 (2.6%)	0.8	38.0 (2.8%)	0.8	41.3 (2.9%)	0.8
Europe	310.5 (24.8%)	1.9	326.7 (24.5%)	1.9	338.1 (24.1%)	2.0
Rest of the world	37.8 (3.0%)	1.0	41.4 (3.1%)	1.1	44.5 (3.2%)	1.1
Total	1251.9 (100.00%)	2.0	1333.4 (100.00%)	2.0	1402.6 (100.00%)	2.0

PPP, Purchasing power parity. Figures in parenthesis indicate the share of the region/country in world total.

expenditure (Table 1)[5–8]. For example, USA alone has one-third share of world R&D expenditure against its only 4.5% share of world population; for Europe, the two figures are 29% and 6%; for China, 12% and 20% and for India 2% and 17% respectively. The north–south asymmetry in respect of general R&D is too obvious, and that, by itself, is a clear indication of more such asymmetries in respect of agricultural R&D.

The global forecast for R&D public investment expenditure does not hold any cheers for the developing world; the dominance of the developed world, especially in terms of absolute levels of investment expenditure, continues unabated (Table 2)[9]. Even in terms of the proportion of GDP going to R&D, the developed countries are way ahead of the developing ones. For example, in 2012, USA spent 2.8% of its GDP on general R&D, while it was only 0.8% in India.

While the developing countries continued to depend upon public investment for their agricultural R&D during the 1990s, in the developed world, public investment started taking a back seat. In the developed countries, it is the private investment that now dominates agricultural R&D. The technology-buying disadvantages of the developing countries are thus too obvious to be emphasized.

Public investment in agricultural R&D has been highly concentrated in only a handful of countries, both in the developed as well as the developing world (Table 3)[10,11]. For example, in 2000, USA, Japan, France and Germany accounted for two-third of public research done by rich countries, about the same as two decades earlier.

Table 3. Global public agricultural research spending: 1981–2000

Country group	Research spending (million 2000 international dollars)			Annual growth rate (%)		
	1981	1991	2000	1981–1991	1991–2000	1981–2000
Developing countries	6904 (45.4)	9459 (47.3)	12,819 (55.7)	3.04	2.90	3.14
Sub-Saharan Africa	1196	1365	1461	1.25	0.82	0.99
China	1049	1733	3150	4.76	5.04	4.86
Asia and Pacific	3047	4847	7523	4.33	3.92	4.19
India	533		1858			
Latin America and The Caribbean	1897	2107	2454	1.13	2.06	2.01
Middle East and North Africa	764	1139	1382	4.12	1.87	3.35
Developed countries	8293 (54.6)	10,534 (52.7)	10,191 (44.3)	2.27	–0.58	1.10
USA	2533		3828			
Japan	1832		1658			
Total	15,197 (100.0)	19,992 (100.0)	23,010 (100.0)	2.63	1.20	2.11

The total of the figures for individual developing countries or country groups does not tally with the figures given for the whole group of developing countries; no explanation is forthcoming from the original authors. Perhaps, a minor overlap between the two groups of countries is involved, and the figures in parenthesis indicate the share of investment.

Similarly, four big developing countries (China, India, Brazil and South Africa) accounted for almost 50% of the public agricultural research money of the developing world in 2000, up from 37% in 1981. The increasing unevenness is bound to magnify inter-country technology gaps and push a big majority of the developing countries to the brink of technological orphanage.

Public expenditure on agricultural R&D shows highly skewed distribution between the developed and the developing countries (Table 3). In fact, the latter, starting with a 45% share of global public expenditure in 1981, improved it to 47% in 1991 and 56% in 2000. Although this trend speaks well for the improving distribution of global public spending, in terms of the sheer size of rural population or agricultural workforce, the steadily improving share of the developing economies would not distract from the acutely inadequate quantum of investment. For example, public expenditure on R&D as a proportion of agricultural GDP has been hovering around 0.52% during 1981–2000, for the developing countries, while for the developed countries it registered a noticeable mark-up, from 1.4% in 1981 to 2.4% in 2000 (Table 4)[10]. In the former group, India showed a noticeable improvement from 0.18% in 1981 to 0.34% in 2000, while in the latter group, it increased sizably from 1.31% to 2.60% in USA and from 1.45% to 3.62% in Japan. It is clear that in the developing world as a whole, a rather negligible proportion of what is being produced in agriculture is ploughed back into R&D activities through public investment, and accordingly, with every passing decade, the developed world is leaving the developing world much behind in terms of this measure of investment.

Per capita public expenditure on agricultural R&D has not witnessed any sizable improvement in the developing world, either during the eighties or the nineties, while in the developed world, it increased from US$ 10.9 in 1981 to US$ 13 in 1991 and slumped back to US$ 11.9 in 2000 (Table 4). From the point of view of research intensity ratio too, the developing countries continue to be way behind their developed counterparts.

Research expenditure per economically active member of agricultural population shows the developed–developing country gaps far more tellingly. In 1981, public expenditure for every active member of agricultural population was US$ 45 in the developed countries against US$ 1 in the developing countries; in 1991, the ratio jumped to 64 : 1 and in 2000, it was 68 : 1. These figures show how public investment expenditure is woefully inadequate in the developing countries.

The relative weakness of the developing countries gets magnified when private expenditure on agricultural R&D is also brought in (Table 5)[10]: (i) Among the developing economies, agricultural R&D is largely a public sector concern. In the year 2000, no less than 92% of total R&D expenditure came through government spending. On the other hand, in the developed world, private corporate sector plays a substantial role; as much as 55% of total expenditure on agricultural R&D is contributed by the private sector. The worldwide agricultural R&D scenario thus clearly points towards strategic dichotomies between the developed world where, to a considerable extent, market determines the pace and pattern of agricultural R&D, and the developing world where the state assumes an overwhelming responsibility for generation and dissemination of research output. (ii) The worldwide total (public plus private) expenditure on agricultural R&D is unevenly distributed between the developed and developing countries. For example, the developing world has only a 38% share of total investment expenditure, while on the basis of its share of rural or agricultural population, or livelihood stakes, or the incidence of rural poverty, a much higher share should accrue to it. In relative terms, the developing world is thus acutely under-funded. (iii) An aspect of crucial significance in these days of

Table 4. Global public agricultural research intensity ratios: 1981–2000

Country/group	Expenditure as a percentage of agriculture GDP			Expenditure per capita (2000 international dollars)			Expenditure per economically active member of agricultural population (2000 international dollars)		
	1981	1991	2000	1981	1991	2000	1981	1991	2000
Developing countries	0.52	0.50	0.53	2.1	2.3	2.7	7.0	8.3	10.2
Sub-Saharan Africa	0.84	0.79	0.72	3.1	2.7	2.3	11.2	10.5	8.2
China	0.41	0.35	0.40	1.0	1.5	2.5	2.5	3.5	6.2
Asia and Pacific	0.36	0.38	0.41	1.3	1.7	2.4	3.8	5.2	7.6
Latin America and the Caribbean	0.88	0.96	1.16	5.5	6.6	5.9	45.1	50.5	60.7
Middle East and North Africa	0.61	0.54	0.66	3.2	3.6	3.7	19.2	27.3	30.2
Developed countries	1.41	2.38	2.36	10.9	13.0	11.9	316.5	528.3	691.6
Total	0.79	0.86	0.80	3.8	4.2	4.1	15.1	17.2	18.1

Table 5. Public and private agricultural R&D investment: 2000

Country/group	Expenditure (million international dollars)			Expenditure per capita (million international dollars)			Expenditure/economically active member of agricultural population (million international dollars)		
	Public	Private	Total	Public	Private	Total	Public	Private	Total
Developing countries	12,909 (91.6)	1,180 (8.4)	14,089	2.70	0.25	2.95	10.25	0.88	11.13
Developed countries	10,191 (44.8)	12,577 (55.2)	22,767 (100.0)	11.90	14.68	26.58	691.60	853.26	1544.86
Total	23,100 (62.7)	13,756 (37.3)	36,856 (100.0)	4.10	2.44	6.54	18.10	10.78	28.88

The figures in parenthesis are the respective shares of public and private investments.

globalization, privatization and marketization, is that private investment in agricultural R&D is overwhelmingly move in the developed world; the developing countries have a mere 9% share in the world's total private expenditure. This fact alone could result in dichotomy between the needs of millions of smallholders, and other marginalized sections in rural areas of the developing countries, and the business interests, profit motive and 'getting the prices right attitude' of a few global or sub-global level corporate players. (iv) Perhaps, it is pertinent to keep in mind that the small (9%) share of the global-level private expenditure of the developing countries is most unequally distributed among individual countries – only those having a minimum acceptable framework of intellectual property rights in place and a well-oiled rural connectivity network; India qualifies to be one such country.

The developing countries pale into sheer insignificance if we measure total (public plus private) R&D investment expenditure on per capita basis. In respect of private expenditure, the developing world stays behind the developed world; for every person, the developed countries are spending nearly 60 times that by the developing countries. Largely because of such private expenditure gaps, the per capita gaps at the level of total expenditure also look rather frightening; the ratio is 9 : 1.

The most telling differences between the two groups of countries are discernible in terms of expenditure per economically active member of agricultural population. On an average, for every economically active member of agricultural population, public expenditure on agricultural R&D by the developed countries is 67 times that by the developing countries. Private expenditure is shockingly 970 times as much higher, and total expenditure is no less than 140 times higher.

Conclusion

Clearly, the world agriculture today is suffering from a difficult and somewhat convoluted environment. It is becoming increasingly difficult for the developing world to produce adequate food to meet its expanding demand since yield levels are stagnating and under the 'business as usual' approach, food production is expected to worsen in the years ahead. By any objective measure, agricultural R&D for less-developed countries is at the crossroads. Under the prevailing market-driven international economic environment, the technology gap between the developed and the developing countries is increasing, both quantitatively as well as qualitatively. If the current R&D dichotomies continue, the agricultural research in developing countries may soon slip into a sort of technological orphanage for want of adequate investment patronage.

Many things need to be done, in varying form and content, to improve agricultural R&D in the Third World. Funding for agricultural R&D throughout the developing world needs to be substantially increased. The greatest urgency is to reverse the stagnant funding of agricultural R&D and broaden knowledge systems in Sub-Saharan Africa. Technological innovations must be combined

with institutional innovations to ensure that input and output markets, financial services, and farmer organizations are in place for broad-based productivity growth. Relative to the developed countries, the level/intensity of agricultural R&D in the developing countries, overwhelmingly supported by public funds, is too little. Many public research organizations in these countries face serious institutional constraints that inhibit their effectiveness and thus their ability to attract research funds.

Major reforms are urgently called for, both nationally and internationally. The rise of higher-value markets is creating new opportunities in the private sector to foster innovation along the value chain, involving cooperation among the public sector, private sector, farmers, and civil society organizations. What is needed now is to understand better what works well in what context and scale up emerging successes. Like in other areas, the age of partnerships has arrived in agricultural R&D, resource management and marketing. Agricultural R&D is the area in which international institutional efforts that relieved the hunger and stress among many developing economies during the earlier round of the Green Revolution, needs to be re-enlivened and re-invigorated. The global food scarcity and stress cannot be alleviated without appropriately sharing the technological efforts. Given the market economy, technology transfer (through spill-over) is no more a charity flow from rich to poor countries as it used to be earlier. Private investment in agricultural research, particularly high-tech oriented, is attuned to the free market environment supplemented by enabling provisions for strong intellectual property protection, something the developing countries are far from achieving. Till such a time this ideal is realized, public investment is the only way of keeping the conventional R&D apparatus of the developing world in combative mode against the scourges of malnourishment and hunger.

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