From Policy Aims and Small-Farm Characteristics to Farm Science Needs

***Michael Lipton**, Research Professor of Economics, Poverty Research Unit, School of African and Asian Studies, University of Sussex, UK*

1. Introduction

This paper addresses four questions, often treated separately, but necessarily linked. Each question is complex, and space is limited. So please forgive simplifications and telegraphese.

1. Given the high and usually ***rising* share of farmland in small farms** in most poor countries, and the evidence on how output per hectare varies with farm size, when and where is development based on small farms conducive to mass poverty reduction, and with what implications for the **audience on which farm science should focus?**
2. Given what we know about how farms become and stay efficient, competitive, and poverty-reducing, what **type of technical progress** helps them do so—and is any type harmful?
3. How can **research** lead to more of the "helpful" technical progress and less of the "harmful" sort—or, to disaggregate the question, what kind of research might improve smallholder access, or returns, to key inputs (water, seeds, fertilizer, and pest management)? If policy analysts know that, it helps them to decide what incentives, and to whom, will get appropriate research done.
4. Do the answers to the last two questions depend on changing global **market requirements?** In particular, can technical progress "for small farms"—so far largely about production—respond to, or keep pace with, post-harvest changes (e.g., the rise of supermarkets) that challenge the foundation of small and family farms' competitiveness: relatively low unit transaction costs of labor?

2. The *Growing* Role of Small Farms in Low-Income Agriculture, the "Inverse Chicago Question," and the Nexus of Small Farming, Science, and Poverty Reduction

The "conventional wisdom" is that value added per hectare-year has a direct relationship (DR) to farm area in developed countries, but an inverse relationship (IR) in developing countries. This view is, however, mired in confused and confusing controversy. Why?

- Small farms overlap substantially with, but are not the same as, "family farms" (where a substantial majority of labor is from the family, cutting unit labor transaction costs); "part-time farms" (where a farm manager devotes a substantial part of her time to other activity); and "subsistence farms" (deficit farms mostly growing staples). Each of these three is often, with little or no evidence, called 'non-viable' (a term that is seldom defined), or otherwise assumed to be a Bad Thing. In particular, deficit staples farms are often absurdly contrasted with "commercial farms," yet they—although more than usually risk – averse—are under intense survival pressures to behave commercially.
- Farm size is normally measured in hectares per household; for most purposes, efficiency-units of land and/or per-person or per-family-worker holdings are more appropriate (Julka and Sharma 1989).[1]
- Much debate about the IR/DR seeks the evidence in larger farms' (a) higher/lower unit production cost, and (b) as a main cause of this, conventional diseconomies/economies of scale; and/or (c) lower/higher *crop- and season-specific yield*. Yet (a) agriculture shows no systematic variation with scale in unit production cost; (b) economies or

[1] In a village in the Indian Punjab, the per-person Gini of operational land (farm size) was halved when measured per person instead of per household (Julka and Sharma 1989).

diseconomies of scale are rare—and largely irrelevant, since large-area farms are not linear blowups of small-area farms but typically choose higher capital:labor ratios; and (c) the IR in developing countries, where found, is due largely to smaller farms' lower labor-linked transaction costs—and hence incentive to choose more labor intensity and thus a *higher-value product mix* and *greater land use intensity* (non-fallowing, double-cropping).[2]

- Farm size, as a determinant of net value added per hectare, interacts with land and water quality. So whether land productivity is affected by farm size—in any sense with policy implications for, say, land redistribution—depends on the extent to which land and water quality depends on farmer action (e.g., land/water improvement or maintenance) that itself depends on farm size. Whether or not it does so is hard to observe.
- There are serious technical problems empirically (a) in separating the effects on net value added per hectare of variability with scale of unit production cost, unit transaction cost (UTC), variable factor proportions, and access to and adoption of new techniques, and (b) with the production-function methodology for assessing any of the above (Mundlak 2001).[3]

Scholars have repeatedly reviewed the vast mass of micro-evidence, sometimes without romantic or ideological illusions about either clean, modern, large-scale progress or natural, peasant, small-scale tradition. Despite the above difficulties and big variations in research methods, an IR between farmland per household and net value added per hectare in developing countries and a DR in developed countries are among the best confirmed relationships in economics.[4] There are counter-examples within economics and in anthropological studies showing great variation of output per hectare *given* farm size[5]; both are commonly due to "hidden variables," for example, input or output subsidies or regulations selectively helpful to big farms, or rapid technical progress with initial adoption on medium-size farms. However, the IR-DR finding remains. Occasional ideological advocacy of small or big farms as such, sometimes based on selective rhetorical onslaughts on the work of others, can be good knockabout fun, but life is too short to refer to or refute such papers. Many reviews of careful micro-research show that:

a. There is little variation to scale in unit *production* cost in farming, though with a few cases of modest scale-economies in high-income, capital-intensive farming and of modest scale-diseconomies in low-income, labor-intensive farming.
b. In all countries, it is cheaper for small than for large farms, per unit of output, to seek, screen, and supervise family *and hired* labor; its skills are better known, and there are more supervising workers per laborer and per hectare. But it is cheaper for large than for small farms, per unit of output, to borrow and to supervise physical capital. Hence large and small farms show two differences in UTC: it is higher on small farms for capital, lower for labor.
c. However, in farming, capital UTC looms much larger than labor UTC in high-income countries. Farm labor is costly relative to farm capital, so farmers go for high capital:labor

[2] In developed countries a DR predominates, because capital, as a factor of farm production, becomes more important relative to labor; and it is *large* farms that have transaction-cost advantages in borrowing and in supervising physical capital. [For reviews of the literature, see Berry and Cline 1979; Booth and Sundrum 1985; Binswanger, Deininger, and Feder 1996; and Eastwood, Lipton, and Newell 2006 (forthcoming).]

[3] "Empirical assessment of scale economies in production is normally approached [by] fitting production functions to farm-level data so as to measure differences in total factor productivity between large and small farms as reviewed in Mundlak 2001. According to Binswanger et al. 1996 proper empirical assessment of efficient scale ideally requires a measure of 'profits net of the cost of family labour, per unit of capital invested' [however, if capital-related transaction costs are scale-dependent, perhaps the best measure, assuming a fixed supply of land, is Ricardian surplus per hectare, i.e., surplus calculated after accounting for all inputs except land]. Such a measure not only allows for transaction costs and scale economies, but also for the possibility that optimal factor proportions vary with scale (which would in general imply that narrowly-defined scale economies would vary according to the factor-proportions 'ray' along which they were being measured)" [Eastwood et al. 2006].

[4] If hectares are measured allowing for land quality, and if bigger farms *in the relevant sample* have exogenously better land, the IR weakens but does not vanish (Bhalla and Roy 1988). If we measure farmland per family member or worker instead of per household, the IR should on theoretical grounds strengthen, but there appears to be no research testing that.

[5] For excellent examples, see Dorward 1999 and Hill 1992.

ratios: crudely, they intensify (raise output per hectare) with capital rather than with labor. In low-income countries, farm capital is ample and inexpensive relative to farm labor—family or hired—so that farmers seek (and intensify via) low capital:labor ratios.

d. It follows from *b* and *c* that big farms' lower capital-related UTCs outweigh small farms' lower labor-related UTCs in high-income countries, so that total UTCs tend to be lower on larger farms. Conversely, in low-income countries, small farmers' low UTC in searching, screening, and supervising labor outweighs their high UTC in borrowing to obtain capital and in managing it—so that total UTC tends to be less on smaller farms.

e. It follows from *a* and *d* that we should expect a DR in agriculture in high-income countries and an IR in low-income countries. From *a,* in both cases there is little or no systematic variation of unit *production* cost with farm area. From *d,* unit *transaction* costs tend to be more on smaller farms in high-income countries, but on larger farms in low-income countries. Hence *total* unit cost—of producing and of transacting—tends to be lower on small farms in low-income countries but larger in high-income countries.

Can this go wrong? First, policy distortions may favor large farms over small in low-income countries or small farms over large in high-income countries. This would weaken or reverse the unit-cost incentives creating the IR and the DR respectively. However, except in unusually ruthless and effective dictatorships, farmers, customers, workers, and lenders learn, over time, how to gain (though not costlessly) by bypassing or ignoring such distortive policies. Also, price distortions for farm inputs and outputs *in developing countries* have substantially declined since 1970.

Second, changing markets, or institutions, may expose farms to new production or transaction costs, perhaps not directly linked to management or acquisition of labor or capital. Such new costs might modify or even reverse the DR in rich countries or the IR in poorer ones. However, intermediation—whether in response to market demand for it or by supply-side co-operation or government action—normally tends to cut such costs (see Section 5 on supermarkets).

In view of *e* above, we therefore expect that farm size (1) will be systematically larger in developed countries, and (2) will rise during development. The data strongly confirm the first expectation (especially with some crude allowance for land quality). As for the second, national micro-studies and aggregate censuses of agriculture strongly confirm that farm size has been increasing steadily in most developed countries, though only since about 1930 [Eastwood, Lipton, and Newell 2006]. For a large majority of farmland in Asia and Africa, however, as we shall show, typical farm size has been falling since 1960. We shortly review why and ask whether *falling* farm size in Africa and (fast-developing) Asia forces us to jettison or modify the argument that changing unit transaction costs with "development" *raises* optimal farm size. But facts first.

The Food and Agriculture Organization's (FAO's) summary of standardized national agricultural censuses in the World Census of Agriculture (WCA) has weaknesses, omissions, and country gaps, including China. However, WCA is the only large, comparable data source for national trends in farm size. Table 1 shows—for all countries with more than 100,000 hectares of farmland and available data from more than one WCA round in the period 1986–2002—proportions of holdings *and* farmland in the smaller farm-size groups. In the period 1986–2002, accelerated globalization and commercialization were allegedly shifting competitive advantage, even capacity to survive, from small to large farms. This added to any UTC-type pressures from rising capital:labor ratios, alongside development, toward larger farms. Indeed, developed countries (Table 1B) show falling, sometimes sharply falling, shares of farmland in the smaller size groups, though in a few cases not in the very smallest. Surprisingly, however, in seven out of 10 developing countries in Table 1A, in the period 1986–2002 farmland shifted *toward* the lowest size category (< 1 hectare), and also the lowest two size categories (< 2 hectares).[6] These changes seem to refute the view that globalization, rising

[6] The two least-poor countries in Table 1A, Turkey and Uruguay—which could as well have been included in Table 1B—show modest falls in the proportion of farmland in the smallest farm-size categories in 1990–2001, as do non-WCA data for another upper-middle-income country, Brazil [Alberto Valdés, pers. comm. July 2005]. Among low-income and lower-middle-income countries, only Ethiopia shows a falling proportion of (private) land in holdings below 1 hectare (Table 1A). This reflects not a shift of private land to larger farms, but continuing redistribution of collective and state lands. This, from the 1989–1992 to the

capital:labor ratios, UTCs, or anything else has made small farms in developing countries dramatically less competitive or survivable. Table 1B does not, however, contradict this scenario for developed countries.

Table 2 uses median data (see below) to take a longer view, for more developing countries, over FAO Agricultural Censuses from 1969 to 1993. These data are not yet available for the 2000 round of censuses, so they exclude possible effects on farm size of recently accelerated farm commercialization and globalization; but Table 1A showed that this did not stop farm size falling in all low-income and lower-middle-income countries with available data. Care is needed in interpreting Table 2—wars, revolutions, and definitional noncomparabilities abound—but the message is unmistakable. “Median size for number” is the size of the median holding, with all *farms* ranked in order of area. If instead we rank all farmed *hectares*, starting with each of the hectares in the largest holding and ending with those in the smallest, “median size for area” is the size of the holding containing the “median hectare.” All 11 African and Asian developing countries in Table 2 show falls, usually steep, in the period 1969–1993 in both median farm size and the size of farm in which the “median hectare” is located, with the sole exception of Korea, which (like Latin American countries, where the trends are mixed) was already substantially industrialized by 1980, with capital:labor ratios and agricultural workforce shares since approaching Organisation for Economic Co-operation and Development (OECD) levels.

Tables 1 and 2 show that a large and—in sharp contrast to developed countries—generally growing proportion of cropland in most low-income countries is cultivated in small holdings; and that a large and growing proportion of farm operators is small. Other big low-income countries, without data for the comparisons in tables 1 and 2, also concentrate their cropland heavily in the smallest operated holdings (e.g., Bangladesh 69 percent below 2 hectares in 1996–1997) (FAO 2005; Singh 1990).[7] China, with already very small and equal farms after the land reforms of 1977–1985, shows falling farm size, now averaging about half a hectare, with few big farms and low per-person land inequality; China in 1997 had 58 percent of its 130 million hectares of cropland in holdings below 2 hectares (FAO 2005).[8] By contrast (Table 1), India in 1995–1996 had 36 percent of its 163 million hectares of cropland in 93 million such farms.

The trend to smaller farms is reversed in rich countries. It is starting to reverse in middle-income countries and in some advanced areas of India (and probably China), as development reduces rural labor (including family-farmer) supply and increases capital availability, so small farmers’ high capital-linked UTCs become more penalizing, relative to large farmers’ high labor-linked UTCs. Net reverse tenancy has, famously, emerged in India’s Punjab and Haryana. However, less famously, it is rare elsewhere in low-income and lower-middle-income countries. In brief, a large majority of farming communities of low-income and lower-middle-income Asia and Africa, where free to vote with their feet, have for decades, been voting for smaller farm size (Table 2) and continue to do so (Table 1A).

In the 1980s Michael Carter proposed to students of land reform the “Chicago question”: if there is an inverse relationship in developing countries, why is so much land in large farms?

2001–2002 agricultural censuses, raised private farm area 2.3-fold, while holdings rose only 1.8-fold. Thus many holdings in the smallest size group could be enlarged from formerly public lands. Despite this, the proportion of land in holdings below 5 hectares fell between the agricultural censuses; the falling proportion of land in holdings below 1 hectare was outweighed by the rising proportion in 1-to-5-hectare holdings. (In the period 1977–1989/92, median farm size fell by 46 percent, and size of the farm containing the median hectare by 43 percent [Table 2]).

[7] Singh (1990) documented the tendency to smaller farm size throughout South Asia.

[8] China’s only Agricultural Census (1997) does not show farm areas by size group. We have assumed that the average farm in each group is halfway between the group bounds (0–0.2 hectare at 0.1 hectare, etc.).

Table 1. Small and medium farms: Agricultural censuses from 1985

(Countries with > 100,000 hectares farmland *and* censuses in 1990 *and* 2000 rounds showing shares of area *and* holdings by size groups on the Food and Agriculture Organization's Web site)

Table 1, Part A: Africa, Asia, and Central and South America

Country	Year	Holdings (million)	Ha (million)	< 1 Ha		1–2 Ha		2–5 Ha		5–10 Ha		10–20 Ha	
				%hdgs	%ha	%hdgs	%ha	%hdgs	%ha	%hdgs	%ha	%hdgs	%ha
Colombia	88	1.45	36.03	14.1	0.3	21.5*	1.4*	13.0*	1.9*	16.0	4.4	12.6	7.0
	01	2.02	50.71	18.1	0.4	23.0*	1.7*	11.7*	1.8*	14.4	4.0	11.1	6.2
Egypt	90	2.91	3.30	60.6'	18.5'	29.3'	30.4'	6.8,	15.9,	2.1,	10.1,	0.9|	9.8|
	99/00	3.72	3.75	81.1'	33.5'	13.9'	24.0'	3.3,	13.2,	1.2,	9.9,	0.5|	8.8|
Ethiopia	89/92	6.09	4.87	72.1	36.9	20.2	25.2	7.4	25.4	0.3	2.2	..	..
	01/02	10.76	11.05	62.8	27.1	24.3	33.3	11.9	32.6	0.9	5.5	..	..
India	86	97.16	164.56	57.8	13.4	18.4	15.6	13.6"	22.3"	8.1"	28.6"	..	..
	91	106.64	165.51	59.4	15.0	18.8	17.4	16.8	30.9	4.4	19.3	..	..
	95/96	115.58	163.36	61.6	17.2	18.7	18.8	14.8	31.5	3.7	17.7	1.0	9.2
Nepal	92	2.74	2.60	69.8	30.5	19.4	27.6	9.4	28.0	1.2	8.1	..	..
	02	3.34	2.65	74.7	38.9	17.6	29.8	6.9	24.0	0.6	5.3	..	..
Pakistan	90	5.07	19.15	27.0	3.7	20.4	7.6	37.5	27.6	12.3	21.6	4.7	15.8
	00	6.62	20.41	36.1	5.8	21.5	9.7	28.1	27.9	8.8	19.1	3.9	16.3
Panama	90	0.21	2.94	46.7	0.5	11.4	0.9	13.5	2.7	7.6	3.5	7.1	6.7
	01	0.24	2.77	52.7	0.6	..	..	..	..	..	..	..	..
Thailand	88	4.88	17.46	14.4	2.5	12.3^	4.2^	59.7^	54.6^	..	..	..	..
	93	5.65	19.00	19.7	3.0	13.2<	4.6<	45.0<	36.1<	17.2<	32.0<	..	..
Turkey	91	3.97	23.45	15.9	1.4	19.0	4.3	32.1	16.5	18.0	19.0	9.7	21.0
	01	3.02	18.43	15.5	1.3	17.9	4.0	31.5	16.0	18.5	20.7	10.8	23.5
Uruguay>	90	0.05	15.80	>	>		8.1	-------------	0.1	12.1	0.3	13.2	0.6
	00	0.06	16.42	>	>		10.9	-------------	0.1	12.5	0.3	12.5	0.6

Notes: Holdings without farmland (Colombia 1988; Egypt, Nepal 2002; Panama 2001), area in them (Egypt), and government holdings (Pakistan) omitted. "m" = million

*: 1–3 ha and 3–5 ha, not 1–2 ha and 2–5 ha ': < 0.8 ha and 0.8–2.1 ha ,: 2.1–4.2 ha and 4.2–8.4 ha |: 8.4–21 ha

": 2–4 ha and 4–10 ha ^: 1–1.6 ha and 1.6–6.4 ha <: 1–1.6 ha, 1.6–4.8 ha and 4.8–9.6 ha >: excludes holdings below 1 ha

Table 1, Part B: Europe and North America

Country	Year	Hdgs (m)	Ha (m)	<1 ha		1-2 ha		2-5 ha		5-10 ha		10-20 ha	
				%hdgs	%ha	%hdgs	%ha	%hdgs	%ha	%hdgs	%ha	%hdgs	%ha
Austria	90	0.27	7.22	3.3	0.1	10.9	0.9	21.3	4.0	17.8	6.8	20.0	13.5
	99/00	0.20	6.80	13.5			2.2	22.0	5.3	19.4	9.7	22.7	17.8
Belgium	90	0.85	1.40	12.3	0.6	8.7	0.9	15.9	3.5	15.2	7.0	19.9	18.2
	99/00	0.06	1.43	15.4			0.8	13.9	2.2	13.7	4.4	16.8	10.8
Denmark	89	0.08	2.77	18.1							3.4	24.1	10.3
	02	0.05	2.67	19.2							2.2	19.3	5.3
France	88	1.01	28.60	7.8	0.1	11.1	0.4	11.6	1.3	11.3	2.8	16.6	8.5
	99/00	0.65	29.88	15.5			0.7	12.3	1.3	9.3	1.9	10.9	4.2
Italy	90	3.02	22.70	32.9	2.1	19.6	3.6	23.5	9.7	11.7	10.7	6.7	12.1
	00	2.59	19.61	38.1	2.4	19.2	3.6	20.6	8.5	10.1	9.3	6.1	11.2
Norway	89	0.10	0.99	4.3	0.3	9.4	1.3	23.5	7.8	25.1	17.9	25.5	35.8
	99	0.07	6.36	20.2					10.6	23.8	20.6	31.5	30.0
Portugal	89	0.59	4.01	30.1	2.3	28.2	5.8	23.8	10.9	9.4	9.6	4.6	9.4
	99	0.42	5.19	26.3	2.7	27.9	6.4	24.4	10.5	10.2	8.6	5.6	0.7
UK	93	0.24	17.14	5.6^			0.1^	8.9^	0.4^	12.0	1.3	15.2	3.1
	99-00	0.22	16.30	9.6			0.1	9.7	0.5	11.6	1.3	13.7	2.9
USA	87	2.09	390.31	8.8*					0.1*	19.8*			1.1*
	97	1.91	377.09	8.0*					0.1*	21.5*			1.2*
	02	2.13	379.71	8.4*					0.1*	26.5 *			1.6*

Notes: *USA: Holdings below 0.4 hectare excluded. The entries in the columns "< 1 Ha to 5 Ha" are in fact for 0.4 hectares to 4 hectares, and the entries in the columns "5 to 20 Ha" are in fact for 4 to 20.2 hectares.

^UK: The big rise, 1993–1999/2000, in the proportion of holdings below 2 hectares is partly illusory; 1993 data exclude farmers' only holding if below 6 hectares, with no regular full-time farmer or worker, fewer than 100 days of labor per year, *and* greenhouse area below 100 square meters.

Finland excluded because 1990 and 1999/2000 data appear non-comparable (60 percent fall in holdings, 53 percent in area).

Source: www.fao.org/es/ess/census/wcares/default.asp.

Table 2. Size (Hectares) of (A) Median Farm and (B) Farm with Median Hectare: Developing-Country Trends[1]

Country	Date	Med. Farm	Med. Ha	Country	Date	Med. Farm	Med. Ha
Africa				(**Dvpg. Asia**)			
Congo DR	1970	1.2	1.8	Turkey	1980	3.6	13.0
	1990	0.39	0.76		1991	3.0	13.0
Ethiopia	1977	1.0	2.3				
	1989/92	0.54	1.3	S/Cent. America			
Lesotho	1970	1.5	2.6	Brazil[3]	1970	0.4	520
	1990	1.1	2.4		1980	9.8	730
Malawi	1969	1.2	2.1		1985	8.6	670
	1993	0.52	1.8	Panama	1971	3.6	86
					1981	1.7	95
Dvpg. Asia					1991	1.2	110
India	1971	0.98	5.5	Paraguay	1981	8.2	---
	1977	0.85	4.8		1991	6.9	---
	1991	0.74	3.4	Peru	1972	1.8	---
Indonesia	1973	0.56	1.8		1994	2.5	---
	1993	0.54	1.8				
Korea, Rep.	1970	0.71	1.2				
	1980	0.75	.81				
	1990	0.81	1.4				
Nepal	1972	---	2.4				
	1982	0.49	2.8				
	1992	--	1.6				
Pakistan[2]	1980	2.9	7.8				
	1989	2.1	7.2				
Thailand	1978	2.7	5.8				
	1993	2.4	5.5				

Source: FAO agricultural censuses, rounds for the 1970s, 1980s, and 1990s, at www.fao.org/es/ess/census/gini/table2.asp.

Notes: Countries with less than 25,000 hectares of farmland are omitted. The column headed “Med. Farm” shows the “median size for number,” that is, hectare size of the median farm ranked by size. “Med. Ha” shows the “median size for area,” that is, hectare size of the farm containing the “median hectare” of farmland, with hectares ranked in order of the size of the farm where they are found.

Notes (from original FAO source):

1 Includes holdings without land [usually zero or very few]. Includes only countries with data for the 1990 census round and for the 1980 and/or 1970 census rounds.

2 Data exclude 149 Government holdings with 103 035 ha for 1989, and 192 Government holdings with 49 995 ha for 1980.

3 Due to lack of data for 1986–95, data from the 1985 Agricultural Census are presented.

One view (which I share) is that the challenge of the Chicago question can be met, credibly and testably, by pointing to capital-market information asymmetries that deny small farmers access to loans; interaction between land and other markets, giving large-farm owner-operators (but not to the same extent non-operating owners) power as employers, lenders, merchants, or politicians; and/or polities that provide better input or output prices, research access, farm water, or other advantages to big and powerful farm operators, partly because these are more likely to supply surpluses of savings, food, and labor to urban areas. Whether or not one accepts such reasoning, it is very much harder to answer intelligently the inverse Chicago question: if there is *not* an IR between farm size and unit (transaction plus production) costs in low-income and lower-middle-income countries—or if such a relationship is weakening, perhaps because supermarkets or grades and standards disfavor small farms—why is the proportion of farmland in the smaller size groups not only large but *rising?* Three plausible responses to the inverse Chicago question do not work.[9]

First, continuing growth in rural population, and hence over the generations in the number of rural households, may lead parents to split land among inheriting offspring. However, that is no reason why, if value added per hectare on smaller farms is lower than (or falling relative to) large farms, beneficiaries of partible inheritance should continue to farm ever-smaller farms. Smaller

9 We assume that total farmland cannot expand. Where it can, it is wholly incredible that high (and rising) proportions of land in small farms are consistent with their diminishing relative efficiency.

legacies of *owned* or *controlled* farmland do not imply rational choice of smaller *operated* farm size. Even if land sale and rental markets are weak, land can be left with relatives, or jointly farmed with neighbors, if bigger units are, or have become, more attractive as land uses.

Second, in the wake of the Green Revolution, rising farm productivity and a rising share of rural income from non-farm activity make it *possible* for a given farm household to subsist on less land. But this in no way makes it *sensible* for people to choose reduced farm size over time, if bigger farms are, or are becoming, more attractive land users. Moreover, on Boserupian lines, the growing number of small labor-intensive farms is likelier to *cause*, or accelerate, a labor-using and land-saving "induced" innovation pattern than to *be caused* by it. Anyway tables 1A and 2 show no sign that Asian and African falls in median farm size, and in the size of unit containing the median farm hectare, are sharper in countries with a faster "green revolution."

Third, Valdés (pers. comm., July 2005) rightly emphasizes the attachment of farmers to their homestead plots, and the wish of rural households, even as they move out of farming, to retain small farmable units so as to cut risk, via both food security and diversified portfolios. However, such preferences neither predict nor explain a *tendency toward* smaller farm area, if its advantages are sharply falling. Further, especially if those advantages were actually negative—if the IR had been replaced by a DR between output per hectare-year and farm area—one would expect tiny landowners, if they wish to keep small farm areas for risk-averting reasons, to rent out operating rights. They increasingly do that in developed countries, and in the Indian Punjab, but not in most low-income and lower-middle-income developing rural areas (tables 1A and 2).

Adaptations to rising rural population, farm productivity, and non-farm incomes are, of course, slowed down by market imperfections, especially in land and capital markets. But it is highly implausible that—*if* larger farms mean more farm output per hectare, and hence more income to be shared, and are thus in the interests both of those seeking to farm more land and of those seeking to farm less—market imperfections can be sufficiently widespread and persistent to explain falling farm size. Yet that is what we find across a very large majority of the 30-odd intercensal periods (mostly around 10 years) in low-income and lower-middle-income developing countries in tables 1A and 2. (Recall that there are many ways, other than formal market transactions and other than force majeure, for people to change farm size toward what they seek.)

Summarizing: Standard economic "explanations" (population growth, technical progress, risk aversion) do not, in fact, explain why most low-income and lower-middle-income countries, for 40 years, have had high and rising proportions of farmland in holdings below 5 hectares, often below 2–3 hectares. Nor can "political economy" explain it: if anything, the power of large local owner-farmers (who are potentially also employers, lenders, and traders) points the other way. The most credible explanations are that smaller scale *either* is becoming relatively more advantageous to farmers *or* has for some time been so, but that policy or other distortions concealing that fact are being reduced. The first option—given that development brings rising ratios of fixed capital to labor, pushing UTC advantages from the smallest toward gradually larger farms—is unlikely (Hossain 1988).[10] The second option, however, is plausible. Many developing countries featured either colonial land grab or the use of large farmers as tax and law intermediaries by the colonial power. After decolonization, land is often redistributed into smaller and less unequal holdings by land reform. Alternatively, decolonization enables market forces in labor-plentiful, land-scarce economies to bring about voluntary shifts of farmland to lower size groups.

The employment and food-entitlements reasons why small, equal farms are conducive to poverty reduction are familiar (IFAD 2001; Eastwood et al. 2006). The micro-evidence for the IR is consistent with trends in farm size in Asia and Africa. There is also evidence that great inequality of assets, especially land, is conducive in developing countries to slower growth of mean gross

[10] However, rising ratios of *working,* that is, non-fixed, capital to (complementary) labor may actually favor smaller farms. Mahabub Hossain (1988) showed that, after the initial middle-farm lead in adopting new Green Revolution technologies had been removed by more widespread adoption, it was, as before, smaller farmers who show higher levels of fertilizer use per unit area.

domestic product (GDP) (Eastwood and Lipton 2002). Add to these efficiency and equity considerations the evidence on sequence—the normal dependence of early rural non-farm growth on prior consumer demand by nearby smallholders, and the standard connections between agricultural growth and industrial capacity to employ and import (Johnston and Mellor 1961; Mellor 1976; Hazell and Ramasamy 1991)—and it is not surprising that almost every low-income country to achieve sustained mass poverty reduction began with widespread productivity growth on small farms.[11] Despite the damage from OECD farm and trade policy to that process, it is not obvious either that the small-farm sub-sector has become inefficient compared to large-farm alternatives or that there is any other affordable way to raise employment rapidly, and hence keep real wages rising (and poverty falling), in most African *and Asian* countries, where supply of persons of working age is set to grow at 1.5 to 2 percent yearly to 2035.

There is also a political-economy link from small-farm growth to sustained mass poverty reduction. Higher and more stable farm income during industrialization raises the opportunity-cost and bargaining power of the rural non-farm sector workers and townward labor migrants.[12] (This is especially so, if the small farm provides not only a decent reservation income, but also a secure house and food; this modifies the generally correct argument that tenancy helps the poor and restraints on it harm them.) Real income growth on small farms, like land reform (Moore Jr. 1966), empowers the industrializing poor in open societies for non-violent advance—politically and economically.

What, then, is the role of agricultural science in alleviating poverty? Agricultural research in and for developing countries has huge and non-declining returns.[13] When, as in the 1980s, such returns comprise mainly extra real value of output, the poor gain anyway: economic growth cuts poverty, but does so much more when it is agricultural growth. Even then, benefit to the poor is likely to be higher still, if the extra output appears as greater value of income for small farms.[14] However, <u>small-farm concentration of research and its benefits—a desirable "optional extra" for poverty reduction when developing-country research gains were felt mainly as real extra GDP—becomes an essential, as a growing part of such gains comes to comprise bare maintenance of agricultural GDP</u> in the face of worsening physical production conditions and falling real farm prices.

As agricultural research has shifted from raising yields to defending them, so research benefits—while not falling (see footnote 13)—have shown up less in extra (agricultural) GDP and more in maintaining its existing level. Absent breakthroughs, raising yields on the scale of the maize hybrids (1940–1960) and the wheat and indica rice semidwarfs (1963–1985), breeders have increasingly concentrated on maintaining yields. This has been essential to counter both new pest biotypes evolved to attack a range of genetically similar cultivars over huge areas and water and soil nutrient depletion caused by intensive, repeated cultivation of such cultivars (and their temporarily profitable spread into marginal lands). This is consistent with the sharply falling trend growth of crop yield (and farm output) in developing countries.[15]

On top of this, there has been a downtrend (about 0.4 percent a year for the last 40 years) in real farm prices. This increasingly shifts the benefits of research from producers to consumers. That helps those of the poor who are net grain buyers: townspeople, farm laborers, and some deficit farmers. But how can one advance poor *producers* as a whole in these circumstances? One

---

[11] Korea is often wrongly cited as a country where manufacturing growth preceded agricultural acceleration; in fact the latter began in the 1930s. The city-states of Singapore and Hong Kong based their growth spurt on entrepôt gains from previously increased trading capacity due to farm growth in a "foreign," rural hinterland.
[12] Hence the imposition of poll and cattle taxes to press African peasants to work for colonial employers.
[13] Meta-analysis of several hundred studies of economic rates of return on agricultural research shows that, in and for developing countries, the rate is typically well over 25 percent and has shown no trend between the 1960s and the 1990s (Alston et al. 2000).
[14] Partly because the poor are then likelier to get income from land and enterprise, but mainly because labor demand per hectare is much higher in smaller farms (Eastwood et al. 2006; Booth and Sundrum 1985). This is true even of demand for hired farm labor; also, increased small-farm incentives (due to research-based TFP rises) normally switch deficit farmers' labor to their own farms, away from hired labor markets, thus improving wage and employment prospects for landless rural laborers.
[15] For staples, a big majority of developing-country crop area and value, from 3 percent in the period 1975–1985 to 1 percent in the period 1995–2005 [FAOSTAT].

approach is to reduce the effect of research-related growth in farm output on market supply, and hence on prices, by steering research gains to those with high income elasticity of demand for food staples. That means food-deficit farms (which will use research to grow extra staples likely to be eaten by producing households) and/or farmworkers (who benefit most, per unit of research, if it is adopted by labor-intensive small farms).

3. Conditions for Technical Progress to Cut Poverty: The Role of Small Farms

To understand how small farms fit into the nexus between science and poverty reduction, we should start with the greatest success of anything (let alone of science) in reducing poverty by any means (let alone just via farming): the Asian–Latin American Green Revolution of 1963–1985 (Kerr and Kohlavalli 1999; Hazell et al. 2001; Lipton with Longhurst 1989). Can the same trick be turned for the remaining poverty heartlands in coming decades? There are big differences—in significant part due to the Green Revolution itself—between “then and now” in poverty, agriculture, national and global economic policy, and the content and organization of science. Hence success may be more (or less) costly and difficult, and will require changes of tactics.

This section has three aims:

- First, it uses Green Revolution experience to illustrate neglected requirements for technical progress to help *all main groups* of poor: small farmers, farm laborers, and the non-farm (including urban) poor.
- Second, it shows that the Green Revolution—despite being (for all its scientific brilliance) informed by a mechanistic view, more wrong than right, of how crop science cut poverty and hunger—*happened* to meet the requirements for cutting them massively, partly by luck, partly because the scientific institutions were flexibly managed and not mainly profit orientated.
- Third, the section infers that such luck cannot be relied on now. For science to massively cut poverty through farming—which still almost always means working with small farmers—research planning, in today’s world of science, poverty, and agriculture, must address, much more explicitly than during the Green Revolution, the impact of potential outputs (new varieties, techniques of farming, water use, and natural resources management) on the problems of main poverty groups.

The aim of the Green Revolution was to increase the size of “the pile of rice,” and to some extent wheat, faster than impending population growth. The strategy was set out for India in a classic Ford Foundation document in 1959.[16] Following major irrigation spread in the 1950s, and corresponding rises in both gross cropped area and fertilizer use, it looked in 1959 as if modest further rises in foodgrain output could be achieved by extension of known improvements, but that no strategy existed for meeting the extra grain requirements of India’s impending population growth at 1959 levels, let alone for substantially reducing pervasive malnutrition or meeting extra requirements due to income growth and urbanization. The strategy proposed was science-based improvements in rice and wheat plant types. The financiers and planners of the Green Revolution advocated a similar approach for most of Asia, and indeed for much of the developing world.

The upstream science and initial breeding were located in the international public sector—spearheaded by the forerunners of the Consultative Group on International Agricultural Research (CGIAR) system, the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT)—and its wide-spectrum improved varieties were to be adapted for local use by public-sector national agricultural research systems (NARSs), mainly in Asia and Latin America.[17] The varieties were to go initially to securely watered areas, and were expected

[16] *Report on India's Food Crisis and Steps to Meet It,* by the Agricultural Production Team sponsored by the Ford Foundation, Ministry of Food and Agriculture and Ministry of Community Development and Co-operation, New Delhi, April 1959.

[17] That was the model; some NARSs, such as those of India, Mexico, Brazil, and above all China, were, or became, much more upstream than the model suggests.

to be used, at least initially, by middle-to-large farmers, responding to radically improved germplasm by buying more fertilizers, extra double-cropping, and more precise water control (more groundwater use especially) to deliver large surpluses for sale. Benefits for nutrition and poverty reduction were of course wanted but were seen as being achieved by winning a quasi-Malthusian race between people and foodgrains. It was argued that the breathing space would be used (contrary, of course, to Malthus's economics *and* ethics) to spread voluntary birth control.

How could this work? Almost everyone now agrees that most hunger and poverty (like most famine) (Sen 1981) is due to "failures of exchange entitlements," not to "food availability deficiency." How did the Green Revolution have the luck to succeed in raising income-based entitlements, when its goal (and its triumph) was to raise food availability? Answering that question will do much to clarify the conditions for farm research to be helpful, or more helpful, to all three main groups of dollar-poor: small farmers, farm laborers, and the non-farm poor. To raise income-based entitlements for all three groups, science-based agricultural change must—and the Green Revolution, without being planned that way, did—walk two tightropes, that is, satisfy two conditions.[18]

1. *The price/total-productivity tightrope:* <u>For new science to help poor farmers and poor food consumers (a lot), it must cut staples prices (a lot) but must raise total factor productivity (TFP) on small farms (a lot) faster</u>.[19] New science usually raises farm supply of outputs and demand for inputs. That makes outputs cheaper and inputs more expensive; hence the ratio of farm output prices to input prices falls.[20] Do small and poor farmers gain? If, and only if, this science-induced fall in their relative farm prices is slower than the science-induced rise in their conversion ratio of physical inputs into physical outputs (that is, TFP).[21] Yet, unless the extra food brings the price of staples down, the non-farm poor, especially in towns,[22] gain little or nothing from new crop science. Walking this tightrope successfully means addressing two demand issues: (a) Is there enough demand, for extra staples produced by agricultural research, to avert price declines that would unduly cut research gains to small farmers? (b) How can the poor afford this extra food? *It is easier to walk this tightrope if many of the research adopters are food-deficit small farmers*. These, a big majority of the rural poor in most of Africa and Asia, spend large parts of extra income on more (and better) staples. So they eat much of the extra food themselves.[23]

2. *The wage rate/labor-land-productivity tightrope:* In the early stages of development out of mass poverty, <u>for new science to help poor farm laborers (a lot), it must raise output per labor-hour (a lot) but output per hectare [and, where water is constraining, per liter] (a lot) more</u>. In a substantial and increasing majority of farming situations in developing countries, there is hardly any "spare" farmland worth cultivating.[24] With *A* (area of

[18] The rest of this section draws on Lipton 2005.
[19] Meeting the condition is one escape from the agricultural treadmill. The case is clear if farmers grow only food staples. New staple-crop science can cut staples prices somewhat more sharply than it raises staples TFP yet still help poor farmers, if they can then profitably shift some land into cash crops.
[20] Globalization means that farm prices are increasingly determined on a world scale, but transport costs (especially in Africa and for staples) and remaining state price interventions remain high enough that rises in most countries' domestic farm output changes—and research inducing such rises—still have a major impact on national prices.
[21] The condition is somewhat modified for staples produced by poor farmers who eat almost all they grow.
[22] Some rural non-farm poor can gain from higher demand for local non-farm products (especially construction, retailing, and transport) by farmers as their poverty recedes.
[23] How can a deficit farmer buy more inputs, even if research makes them profitable? Once research has raised her productivity when growing staples—and thus cut her staples deficit—she needs less money for staples purchases and can divert some of it to buying new inputs. Where does the money come from? Deficit farmers normally get much of their income from nonfarm activities or remittances. However, there is a credit problem in the early years of input-driven productivity growth.
[24] Africa is often seen as a continent of ample land and scarce labor. That was true 50 years ago, and a few places remain where smallholders leave decent arable land unfarmed because they lack enough labor to break, prepare, or weed it. But that has come to apply to ever fewer regions. Most areas, with long-continuing and ongoing rural population growth but few gains in land productivity, have arrived at or close to the "extensive margin." New land can be farmed only with sharply rising break-in costs and environmental fragility, yet sharply falling net annual returns. Employers always allege "labor shortage"; but in most of Africa the move from rural unemployment, low productivity, and low wages into genuinely tighter labor markets, as land-intensifying technical progress bids up the demand for labor, is the essence of both rural development and poverty reduction.

farmland) fixed, *L* (use of farm labor) can rise only if output per unit of area (*Q*/*A*) grows faster than output per unit of farm labor (*Q*/*L*): hence the above condition for total demand for farm labor to rise, pulling up employment or the wage rate. As and where the water constraint becomes binding upon profitable growth of farm output, this sentence also applies if we substitute H_2O for *A.*

The condition is more demanding if farm labor supply grows. Population of prime working age (15–64 years old) is set to rise at some 2 percent per year in most of South Asia and Sub-Saharan Africa for the next 10 to 20 years, and by more than 1 percent even in rural areas. For farming to help raise demand for labor faster than supply, with farmland scarce, scientific advances must raise output per hectare by at least, say, 1.5 percent per year faster than output per worker, to be all-round poverty reducing. So research output must be more, better, and *better planned*—but it is then well placed for high poverty-reduction gains per unit of research, because "high 15–64" families and nations have the best chance to work and save their way out of poverty. The ongoing "demographic transition" in Africa and South Asia provides a once-only chance to use the rising ratio of workers (and savers) in the next 20 to 30 years to "make (extreme absolute) poverty history" as large parts of East Asia did in the 1965–2000 period[25]—before aging populations drive dependency ratios up again and make poverty reduction much harder. But parlaying demographic gifts into poverty eradication requires generating more food and more labor demand where they are affordable and needed. In East Asia from 1965 to 1990 that required, as it will in much of South Asia and most of Sub-Saharan Africa from 2005 to 2040, greatly enhanced research that walks the two tightropes.

Tightrope 2 does not mean that agricultural research in poor areas can disregard output per worker. It too must rise significantly. First, its desperately low level is what makes poverty heartlands that way. Second, they are also kept poor by low labor productivity, which deters farmers and others from hiring more labor, thus retarding the poor's wages, employment, and bargaining power. Third, higher labor productivity is especially important in areas facing acute seasonal labor scarcity—most common in Africa, particularly when hoeing is needed; unless this is addressed, severe yield losses can occur due to late planting. Such conditions are partly due to lack of water control and robust crop varieties that can withstand moderately late or scarce rains.[26] Fourth, HIV/AIDS severely depresses local labor supply in parts of Africa. Research needs to raise labor productivity, especially in peaks, but it cannot help those afflicted by HIV/AIDS to cut the demand for poor people's labor! Agricultural research, with land and water limited, will seldom cut poverty much without raising their productivity faster than labor productivity. Otherwise, farm employment demand must fall. Only much further into the process of development and rural poverty reduction, when non-farm growth and emigration have pulled wage rates up, should researchers—like farmers—seek to raise labor productivity faster than land productivity. Meanwhile overt rural unemployment—rightly downgraded for empirical reasons in the 1960s as a policy concern—is a rising source of poverty in many developing countries, even some with rapid overall growth, due to a rising workforce alongside declining agricultural growth and labor-intensity: unemployment is patent (and much researched) in South Africa and several other African countries, on a sharp uptrend in India[27] and coming onto the policy agenda in China. With agriculture still the main income source of greater than 60 percent of the developing world's workforce (and more than 70 percent of its poor), rising rural unemployment, and India "pointing to the future" with labor the main income source for twice as many of its agricultural poor as own-account farming,[28] agricultural research can no longer claim to be targeting poverty unless it explicitly aims to raise land and water productivity substantially faster than labor productivity.

Temporary, local, and anti-developmental labor shortages are of course part of the disaster of HIV/AIDS; however, were these to induce long-term labor-displacing and hence wage-reducing investments or policies, the disaster would be compounded.

[25] "In 2000, there were 94 dependents for every 100 people aged 15–64 in Ethiopia; the projection for 2030 is 67. Over the same period, the dependency ratio is projected to fall from 99 to 67 in Nigeria, from 79 to 55 in Bangladesh, and from 71 to 58 in India. These are recent UN estimates, taking account of HIV/AIDS" (Lipton 2005). On East Asia, see Bloom and Williamson 1997.

[26] In such areas research might prioritize raising labor productivity at the peaks but land productivity in the slack season.

[27] The time-rate of unemployment rose from 6 percent in 1993–1994 to 7.3% in 1999–2000 despite fast economic growth, and, if this continues at 6.5 percent per year, it is scheduled to rise to 14.5 percent by 2021 (Dyson et al. 2001).

[28] S.Tendulkar, cited in (Lipton 2005).

The Green Revolution, after a faltering start and with different objectives, came to increase the entitlements of all main groups of the poor—deficit farmers, rural laborers, urban poor—by "walking the two tightropes," and it was, at worst, neutral among farm-size groups. This was not wholly luck. Early critics—and many farmers—stressed the need for more robust varieties, to reach both "difficult" regions and risk-averse poor farmers. Public-sector, public-purpose researchers addressed such criticisms (Lipton with Longhurst 1989), where private counterparts would have been pressed to focus on better-off, more secure customers.[29] However, brilliant as the science was, it was also lucky that the Green Revolution semi-dwarfs proved so amenable to crossing for better resistance to main pests and diseases—and that successive semi-dwarf varieties walked the two tightropes.

The new seeds let small, dollar-poor farmers turn their few resources into much more output of staple food. TFP far outpaced the fall in staples prices relative to the prices of inputs.[30] For dollar-poor farmworkers, larger harvests, more water control, and more fertilizer use all raised labor productivity somewhat—but land and water productivity much more. Therefore, demand for their labor rose significantly, while their staples requirements became cheaper.

The urban, and rural non-farm, dollar-poor gained from the restraining effect of the extra staples output, generated by the Green Revolution, on the price of food staples; and the latter group also gained from expanding local small-farm demand for consumables (Hazell and Ramasamy 1992). So all main groups of dollar poor saw their entitlements to food staples—typically absorbing more than half their incomes—substantially raised by the Green Revolution. These effects were partly luck and partly serendipitous adaptation of breeding goals ex post. Careful prioritization ex ante is needed if pending research—before and after the coming biotechnology breakthroughs in food staples—is to bring big benefits for all main poverty groups.

Nor can we expect research findings today, *without careful research planning*, to emulate another feature of the Green Revolution, especially in its later years (1975–1985), helpful to all three main categories of poor, including small farmers: its generally risk-reducing reduction in the year-to-year instability of food entitlements. More pest- and disease-resistant seeds, constantly adapted by researchers to resist new plant biotypes, reduced year-to-year variability of farm output and, as a result, of demand for farm laborers.[31] That also reduced price fluctuations for consumers (as well as producers), as did the larger levels of public and private stocks made possible by output increases. Seasonal variability also declined to some extent, because the new seeds were increasingly able to produce short-duration or multiple crops in some conditions.

What of the poor in regions (and nations) bypassed by modern agricultural science? Asia's Green Revolution, from about 1975 to 1980, increasingly spread into hitherto untouched regions, raising and stabilizing entitlements there also for the dollar poor as small farmers, farm laborers, and urban employees. Researchers generated results for water environments less ideal than the irrigated deltaic and canal flatlands that benefited in the 1964–1975 period. Today, in both China and India, the return to crop science is higher in *some* "backward" regions than in the lead areas of the Green Revolution, where dollar poverty has fallen much more sharply (Fan, Hazell, and Thorat 2000; Fan, Linxiu, and Zhang 2000). Further, a fast-rising proportion of the remaining poor is concentrated in these "backward" regions, where natural increase is considerably higher, net emigration lower, and

[29] The biotech revolution is more private-sector based than the Green Revolution (and its critics are more fundamentalist). Much institutional and incentive work is needed for biotech to "rerun" the Green Revolution's adaptability to poor farmers' needs.
[30] Major steps were taken in East Asia in the 1970s and South Asia in the 1980s to make competitive credit available to some small farmers and to reduce extraction via parastatal and trade-based price manipulation by governments. Speeding Africa's slower progress in this direction is a major part of the few recent successes in spreading science-based agricultural progress there.
[31] Hazell has shown that, in earlier years, the cereals-output destabilizing effects of India's Green Revolution via increased covariance (among output-weighted grain production sites) outweighed the stabilizing effects via decreased within-site variance. The balance was reversed, with stabilizing effect, after 1975 as semidwarfs spread to a much wider range of areas—and it was this, not the early Green Revolution to 1975, that brought the first big thrust of India-wide poverty reduction (Smith and Urey 2002).

governance often worse than elsewhere—and where the poor's dependence on agriculture is more.[32] However, while public-sector systems have often concentrated their efforts on such "pro-poor-region" goals as high yields in upland rice and in drought-tolerant maize, the incentives for increasingly privatized research to do so are weak. Moreover, in *other* "backward agricultural regions"—including many where the above two goals are crucial—rapid research progress probably depends on transgenics. The local genetic range of current crops has been selected for survival under stress. Both for the evolving plant and for the selecting farmer, over many centuries high yield has been a much lower priority than it is for populations facing today's land and water scarcities. Yet—without at all decrying the big contributions made by multinational seed companies to improving poor people's staples—that is not the priority (least of all for "backward" regions) of 90 percent of transgenics research today. Incentives can be changed; public transfers (and not only farmer royalties) should become a major competitive income source for private seed developers. However, until that happens, there are severe limits on sensible research planning to walk the two tightropes, cut risks, and steer farm research to reducing poverty among all three main groups of poor.

Progress in many "backward" regions requires better water control. Growth by this means, especially via double-cropping and higher-value crops, almost always meets both tightrope conditions, but it too is limited—by increasing water shortages, especially in semiarid areas. Where there is irrigation already, standard water reform—pricing, markets, user groups—is part of the solution, but the elasticity of the poor's farm output and income to "reform" will be small, absent new science—hydraulic, not just agricultural—to improve economic efficiency of water use. Otherwise—apart from threats to irrigated farmers from salinity and falling groundwater tables—many farmers, irrigated and rainfed alike, will be further imperiled by the "urbanization" of water and by rising evapotransporation rates due to global warming.

On present form, it is the poorest farmers who will bear the brunt of a worsening rural water shortage. Yet much *more* small farm irrigation, not less, is needed to address most rural poverty in Africa (and parts of "inner Asia"). On a generous estimate, 4 percent of cropland in Sub-Saharan Africa—most of it on not-very-small farms in four countries—is water-controlled, as against 40 percent in South and East Asia. That alone explains much of the difference between the regions in crop research progress and poverty reduction. Probably, rapid poverty reduction in much of Sub-Saharan Africa requires a lot more irrigation. Farmer-controlled micro-irrigation is a great idea, but *absent prior development of wells or macro-systems,* it spreads among farms very slowly (IFAD 2001). Much more major irrigation, however politico-greenly and hydraulically incorrect, is needed. Some can exploit currently underused water bodies, but much will come from sources competitive with urban uses. To be sustainable and economic, such developments will need new water science.

4. Some Priorities for Poor-Friendly Research Reform[33]

How can research generate more of the "helpful" technical progress—and less of the "harmful" sort (e.g., reducing demand for labor without making food cheaper)—for deficit farms (as well as for other groups with high poverty incidence, by walking the two tightropes), and for the growing proportions of poor people in "difficult" regions? Who should do it? For what sort of incentive? What kind of technology can or will be able to improve smallholder access to key resources and inputs, such as water, seeds, fertilizer, and pest management?

Formal science is increasingly needed to generate new technologies that will keep demand for labor growing faster than supply, and TFP growing faster than the ratios of input prices to output prices. During the millennia without sharp secular population growth, and with most farm output consumed locally, these tasks were much less demanding than they are today. Hence on-farm research sufficed in most areas, with farmer-to-farmer and area-to-area spread of experiment and innovation. This worked even after "revolutionary" changes in the concepts behind local farm

[32] For India, Dyson et al. (2004) show the heavy past and projected concentration of poverty into such regions. On China, particularly the slower rise of the rural non-farm share in such regions, see Lipton and Zhang 2005.
[33] This section draws on Section 4 of Lipton 2005.

technologies: the Neolithic, medieval, and early modern agricultural revolutions (Lipton with Longhurst 1989). Even in recent centuries, farmers' innovation usually sufficed to keep pace with population while it grew at up to 1 percent yearly (Hill 1977).

However, in the population acceleration of 1730–2000 (and as unfarmed quality land became scarce), poverty reduction increasingly required TFP-increasing technical progress to be faster, more yield-enhancing, and employment-intensive. To achieve this, farm-based innovation remained necessary, complementing (but increasingly elbowed out by) formal, off-farm science.

The content of science has also changed. Better natural resources management (NRM)[34] continues to be important, but less so relative to formal inputs—and increasingly *induced* (made more profitable for farmers) by such inputs, rather than *introduced* by supply-led NRM innovation, extension, or even research.[35] Since the 1730s in Europe, and most dramatically since the early 1960s in Asia, it has been increasingly formal, science-based water control, inorganic fertilizers, and plant breeding that allowed TFP improvements to outpace population growth and land/water depletion.

While good farm research always hears farmers' voices and builds on their experiments, it is not just client induced or demand driven. Whether it has something to deliver to poor farmers, farmworkers, and staples consumers depends also on prior development of basic science and incentives to applied science. As for science, Mendelian genetics supplied a basic model for applied Green Revolution breeding. As for incentives, though private profitability induced mainly labor-saving research (Binswanger and Ruttan 1978), public-purpose, not-for-profit finance made it pay—professionally and financially, not just ethically—for scientists to implement the Green Revolution model, and hence, albeit helped by luck (see above), to attack poverty. From the late 1960s, the emphasis moved increasingly to further applications of Mendelian genetics (with plant pathology, entomology, and so on) to immunize successive new varieties against successive new pest biotypes (though with less success against abiotic stresses) and to spread them into some less favorable environments.

As indicated, the Green Revolution has slowed sharply, as has yield growth, since the 1980s, without doing much for scores of millions of small family farms with little water control, especially in Sub-Saharan Africa. There, leading varieties and land races of the main staples (white maize, millet, sorghum, cassava, and yams) are probably low-yielding because evolutionary rewards (and farmer selection) over many generations have gone less to high-yielding varieties than to varieties—and indeed crops—able to tolerate low nutrient inputs, severe and variable moisture stress, and locally dominant pests (from quelea to striga) that have received less attention from plant breeders or other researchers than have insects, fungi, and viruses.[36] Neither conventional nor (heavily privatized) transgenic plant breeding is substantially directed toward such issues. How are the tasks and organization of farm science to be reformed to improve pro-poor results, with growing majorities of the poor in water-insecure areas largely bypassed by the Green Revolution—especially for the crops and soil-water regimes of rainfed Africa?

Can new crop science fill the gaps in less-favored areas? The Green Revolution could not escape the law of diminishing returns. The best areas were covered first, and the low-hanging fruit of scientific advance plucked first: what is left usually[37] yields less. Despite success in parts of rainfed Asia and some of Africa (mostly maize hybrids), past evidence suggests severe limitations on

[34] NRM is farmer-led agronomic control of nutrients, water, and biota (e.g., organic manuring, valley-bottom micro-irrigation, terracing, crop rotation and mixing, and removal of insect egg masses).
[35] Though the CGIAR has shifted substantial resources from plant breeding to NRM since the early 1980s, evidence of a high rate of return is much clearer for breeding than for NRM, other than integrated pest management (World Bank 2004a).
[36] For many African situations, it is claimed that good improved cultivars are available, yet farm-to-station yield gaps are huge (anecdotal evidence claims 90 percent for maize in Malawi). The Herdt-IRRI Asian gap studies, however, suggest that in Africa too, since farmers are no fools, economic yield gaps are much smaller and the new varieties much less suited to actual field conditions than claimed.
[37] Some areas, however, were agriculturally backward because they were neglected by applied science, not recalcitrant to it. In both China and India, some "backward" areas now offer more growth, and more poverty reduction, per extra dollar of crop research than do the conventional lead areas (Fan, Hazell, and Thorat 2000; Fan, Linxiu, and Zhang 2000).

conventional plant breeding. Not only has this slowed down sharply, but also most of its recent successes seem relevant mainly to water-controlled areas (for example, the "new plant type" of rice). Further, some features of Green Revolution farming slow down, or even reverse, yield growth: water table lowering via ever-deeper competing tube wells; micronutrient depletion; monocultures reducing biodiversity yet stimulating low-level buildup of new pest biotypes;[38] and restrictive responses to over-concentration of pesticide residues, and fertilizer-derived nitrates and nitrites, in water sources shared by humans and plants. Yet returns to staples breeding are high and have not fallen since the 1970s [Alston et al. 2000]. This is consistent with the slowing growth of staples yields, but the two together imply that research based on the Mendelian breakthrough has increasingly had to focus on maintaining yields rather than raising them.

More promisingly, the basic-science breakthrough by Crick, Watson, and others in 1954 is feeding into a key complement to conventional plant breeding: transgenics. In principle, this permits the identification, and insertion into African crops hitherto evolved or selected for characteristics competitive with yield, of yield-favoring DNA sequences from other plants (or other life-forms). Unlike the Green Revolution, however, research in applied biotechnology is largely owned, exploited, and motivated privately. Private firms must recover costs plus profit from farmers. That explains the concentration of transgenics on open-pollinated crops (and a few F1 hybrids of self-pollinators), large and visible farmers, crops and traits preferred by wealthier consumers, and in general the (so far) not very poor-friendly priorities of most plant biotech. Herbicide resistance, valuably labor saving in rich and labor-scarce developed rural areas, is likely to be poverty increasing where weeding is mostly done by laborers who, if displaced, cannot readily find other work at comparable wage rates. Bacillus thuringiensis (Bt)–based resistance (for example, to corn borer and bollworm), while surprisingly stable so far, remains vertical, and thus high risk for small farmers without ready emergency access to alternatives if the pest develops a new biotype. The main staples grown and eaten by the world's poor (including white maize)[39] have largely remained "Cinderellas" of transgenics research, though China, where this research is largely public sector, may create major exceptions.[40] Can new basic science, organized and applied as crop and field technology, serve poverty-reduction goals and complement conventional plant breeding and non-crop farm science to focus on yield enhancement and robustness promotion for main staples in rainfed areas? There are institutional and scientific issues.

Institutionally, the organization of crop science has become less adapted to eradicating poverty among family farmers. In the early Green Revolution, international agricultural research centers, and national centers in many Asian and Latin American developing countries, delivered a steady stream of high-yielding and pest-adapted varieties of rice, wheat, and maize, mainly for water-reliable areas, but raising incomes of poor farmers, laborers, and food consumers. But after 1980 public-purpose farm research funding fell (except in parts of Asia), was tied ever more tightly by donors to "restricted" areas and topics in ways that inhibited planning by researchers, and was diverted by donors away from crop improvement toward a series of less productive, and sometimes fashion-driven, aims. Moreover, an increasing proportion of frontier work is now in applied biotechnology. In sharp contrast to Green Revolution research, perhaps 90 percent of such work is now in a few big companies, which naturally protect their research, including plant varieties. Since 2000, there have been improvements. There have been moves to refocus the CGIAR, to increase its involvement in biotechnology (including transgenics), and to reverse the long fall in well-targeted resources for public plant breeding.[41] There has been talk (and some action) on public-private

[38] Breeders have largely kept ahead of new epidemics (though there have been nasty shocks—for example, with rice, the tungro epidemic in 1972, and new biotypes of brown planthopper). However, a few adapted pests, each causing small but significant crop losses, probably explain part of the fall in yields, with controlled water and nutrients, in IRRI research fields and in farmers' fields in the Indian Punjab.
[39] This is changing in some research centers, national (e.g., transgenic maize resistant to streak virus at the University of Capetown) and international (e.g., maize at the International Institute of Tropical Agriculture, rice at IRRI, sorghum and chickpea at the International Crops Research Institute for the Semi-Arid Tropics, and so on).
[40] We have been waiting for months for China's "imminent" release of Bt rice, plainly in the interest of its poor farmers and consumers, but suspect with some non-governmental organizations and potential European importers.
[41] This is, rightly, a not-so-hidden agenda for the Challenge Programmes.

partnerships; and generous, if marginal, poverty-related uses by big biotech companies of a few percent of their resources.

However, if private transgenics is to complement public purposes and to address the needs of the poor, a more radical approach is needed. Private companies need to see public-purpose research outcomes as made profitable, not mainly by private royalties from farmers or by public relations spin-off, but by contracts to achieve specific outcomes that will raise family farm productivity or robustness, especially for staples, in neglected areas and crops. One of many possible contracts might require development of maize hybrid or composite populations, viable and profitable over stated areas (with known pest populations) in Africa, meeting targets for (a) capacity to resist delayed rainfall (latency) at the time of anther formation, (b) yield, and (c) field spread to small farms. Such contracts should be competitively awarded; engage, and perhaps be designed by, public agricultural research institutions, jointly with end users; focus on applicability in low-income countries committed to genuinely additional research co-financing; but otherwise be mainly financed by aid. Present alternatives are unpromising.

As an economist I have no locus standi to assess natural-science (rather than institutional or economic) priorities. There is recent evidence that, even with existing inadequate incentives, biotech companies can generate transgenics-based crop science to address key unsolved problems of the farming poor (Nuffield Council on Bioethics 2004).[42] However, its applicability is squeezed between (a) the shortage of new water science, and (b) the farming poor's intensifying water crisis (see above). Transgenics-reinforced crop science may well improve resistance to moisture stress and, later, perhaps (polygene) water-to-output conversion efficiency (Nuffield Council on Bioethics 2004, esp. #3.42). Yet this must be complemented not just by water-market and institutional change but also by new basic water science and engineering: the first blue revolution for 2,000 years.

It would be a risky folly to assume that the lucky conversion of increased food availability into increased food entitlements for all the three main dollar-poor groups, achieved by the Green Revolution in parts of Asia and Latin America, will carry over into the biotech-based, water-economizing attack on poverty that is needed in those areas of Africa and the Asian interior lacking adequate water, or where reliable water control is uneconomic. Radical scientific and institutional innovation is needed. However, tearing down institutions, and locating and building new ones, is seldom a cost-effective path. It may also camouflage key issues, both of the content of science needed for rapid poverty reduction and of relations between public-purpose research institutions, their sometimes flighty and fashion-driven funders, and outstanding but "misincentived" private-sector researchers. Also, though one seldom attends a CGIAR meeting without observing the clear goodwill of the institutions toward poverty reduction, much clearer substantive anti-poverty guidelines are needed in research planning.

The "two tightropes" are a start (they would have released *aid* resources, misdirected toward, say, mechanical rice transplanters, combine-tolerant tropical wheat, or herbicide resistance, for better uses). But regional guidelines are also needed, as is integration with water-related research (not just the excellent work of the International Water Management Institute). Underlying all this is the need to reverse the recent downgrading of economic analysis in some CG institutions (and, even more important, to remedy its near absence from some key ones in NARSs) and to redirect such skills away from ex post complaining about research results toward direct involvement, alongside natural scientists, in research-planning choices. For example, economic and survey research into the diets, deficiencies, and requirements of the poor—and the costs and benefits of change—has achieved the redirection of work in nutrition breeding away from the Great Protein Diversion toward essential micronutrients. Obviously none of the groups involved—breeders, nutritionists, economists—can attack this problem, so central to the welfare and productivity of the poor, except by co-operating with the other two groups. Similarly only economists, crop scientists, and hydrologists, working together,

[42] They include widespread smallholder adoption of Bt cotton, Chinese and Indian public-sector biotechnology, Monsanto's release of data on the rice genome, and Syngenta's release of patents for provitamin-A enriched rice, rice, that can be produced only with transgenics and addresses a key nutrition problem affecting millions of poor people.

can attack the central and difficult issues of crop-water research planning for maximum gains to the increasing numbers of poor small farmers in water-insecure areas.

5. Globalization, Plant Science, Small Farms, and the Poor[43]

In the narrow economic sense, globalization involves (a) the secular trend, however incomplete and interrupted, to de-restrict international flows of goods and services,[44] money, labor, and investment, and hence science and technology; (b) the consequently rising share of international flows in total flows; and (c) the further result that trade and investment outcomes, including research patterns, are increasingly determined at world or individual levels, and decreasingly at national levels.[45]

What is the interaction between family farming, poverty, and crop science in the context of narrowly defined globalization? Freer trade induces specialization along lines of comparative advantage—that is, in products using a nation's more plentiful resources (others being more readily, and more cheaply, importable). Also, freer foreign investment flows will be attracted to a nation for production lines that use those plentiful resources. Most developing areas are labor-rich and capital-poor. So most globalization[46] should raise their specialization in high-employment farms and crops. That should make it easier to attack mass poverty through extra employment, productivity, food output, and income growth from small family farms. Growth effects apart, globalization should, within developing countries, make income distribution more pro-poor.[47]

Furthermore, freer trade and direct investment expose countries to more learning—about technology and markets—and to more participation in frontier science and technical progress.[48] In developed countries, freer international flows of trade and direct investment (while still raising GDP via specialization and learning) steer resources away from lines of production using a lot of unskilled labor and can thus harm distribution, unless poor losers are up-skilled, resettled, or otherwise compensated. This issue is crucial for farm reform in OECD countries. But such freer flows in labor-surplus developing countries can be expected, barring severe distortions or restrictions of access, to be clearly pro-poor.

So what went wrong? Few supporters of globalization claim that it has proved equalizing within developing countries. There has been widespread and growing inequality, and worsening transmission of growth into poverty reduction, in most developing countries during accelerated globalization (though not necessarily because of it) (Cornia et al. 2004). The poor as producers and laborers often seem to gain little, and sometimes to lose, perhaps especially in agriculture.

There appear to be three main reasons. First, some small farmers and farmworkers are overwhelmed by competitive imports and unable to change their product mix, either within farming or (being immobile and without basic education) toward manufacturing or services (Wood 1994).

---

[43] This section draws on Lipton 2005, Section 11.

[44] A highly significant consequence is the removal of obstructions to the "law of one price," and hence a leveling of prices, allowing for transport costs. This highlights the non-globalization of agriculture by OECD nations and the plea from developing countries that they too be allowed to compete!

[45] In addition to the economic implications of globalization, growing proportions of ownership, power, tastes, and cultures transcend national borders. This widens choices for some people but also, many fear, homogenizes local cultures and—ironically, given the supposed alliance between decontrol and globalization—increases the control of global outcomes by dominant world or regional powers, companies, or cultures.

[46] This includes investment by transnational corporations (TNCs). As Western complaints about call-center outsourcing show, TNC investment leaves rich countries for developing countries partly to exploit low labor-costs, but in so doing it bids up wages and employment, cutting poverty. This does not justify financial liberalization (Stiglitz 2003). "Hot money," absent strong regulated financial institutions, can destabilize growth, making the poor more vulnerable.

[47] There are caveats. Transferred technology may favor production that is intensive in its use of skills or capital rather than the labor of the poor. The small share of private international investment reaching the farm sector, and the negligible amount benefiting family farms, militates against major poverty impact. And the poorest may be insufficiently educated to make use of new opportunities (as is also a danger with freer trade [Wood 1994]).

[48] It is vital, however, that developing countries (public and private sectors) can and will select the more labor-intensive and hence appropriate science, techniques, and lessons from the usually rather capital-intensive mix used, and hence offered, by the capital-rich developed world, with which developing countries increasingly interact during globalization. This is central to the pro-poor use of crop science in a globalizing world.

Second, institutional changes linked to globalization—supermarkets, grades and standards, and so on—sometimes appear to help big farmers out-compete small ones. Third, in large countries (or those with costly internal transport), globalization has helped initially richer coastal areas, able to capture trade (and foreign investment), to out-compete the already poor interior regions. These factors can even mean that the poor and labor-intensive not only gain less than the non-poor from globalization, but may even lose more from increasing inequality than they gain from faster growth. Are such losses likely to be predominant or even inevitable?

There is no space here to review the massive and controversial evidence, but on balance it suggests that since 1980 developing countries that liberalized trade faster enjoyed faster growth, bringing faster poverty reduction—but not pro-poor shifts in income distribution. This is probably because, while preaching freer trade to an increasingly persuaded South, the North increasingly[49] supported its own agriculture. Therefore, gains to labor-intensive family farmers in the South from globalization were impeded by the steady undermining of farm prices via subsidies to Northern overproduction and by the responses of science to such incentives. Asian net food importers in the 1960–1985 period overcame this impediment because the Green Revolution raised TFP in farming fast enough to overcome the effect of falls in farm output prices due to OECD's market-distorting farm support. With changes in the global organization of science (see above), that might work for the remaining poverty heartlands in Africa and parts of Asia, but stronger pressures against OECD agricultural policy malfeasance would greatly improve the prospects.

Gains to the rural dollar poor from globalization appear to be seriously threatened by failures of intermediation between small/family farms and institutions of exchange that, while long familiar in developed countries, are near newcomers, spreading at unprecedented speed, in many developing ones: supermarkets, horticultural export companies, and public and private grades and standards (Reardon et al. 2001, 2003). As these spread, small family farms—even while retaining their advantages of low-cost labor management in production—may face high unit transaction costs (notably for quality control, for example, of pesticide levels, and delivery to outlets) between the farm and the increasingly concentrated outlets of the wholesaler or processor. Overcoming such barriers is feasible, as shown by recent examples (Reardon et al. 2003; IFAD 2001); by the success of very small Chinese farmers in accessing first horticultural exports, more recently rapidly growing domestic supermarkets (Hu et al. 2004); and by the earlier successful history of intermediation for rubber, sugar, and tea between processing, with scale economies in factory processes, collection and quality control, and smallholders, with advantages of low labor-linked transaction costs in production (Binswanger, Deininger, and Feder 1996).

These examples confirm three facts:

1. In family farming, as in other sectors, the responsiveness of growth to incentives—whether created by scientific progress or by globalization—depends on producers' prospects of responding to new information, and therefore on affordable but substantial provision of, and reasonably equal access to, education (Jamison and Lau 1982; Birdsall et al. 1995).
2. Appropriate farm science increases or "potentiates" gains from globalization: labor-intensive small farms are better placed to raise production in response to freer trade and investment if they are reached by appropriate science-led innovations and find them profitable. Such potentiation requires communication of information, so that new science raises the returns to universities and extension organizations.
3. The poor gain more from all this if they have not-too-unequal access to land, which may require land reform.

In much but not all of Asia, these conditions were met to a significant extent prior to the large acceleration of open trade and foreign direct investment, and to a lesser extent foreign financial flows, that constituted economic globalization. The parts of Asia left behind in the surge of mass poverty

[49] In 1995, OECD agricultural subsidies to producers were US$182 billion: 40 percent of production. OECD farm producer prices were 66 percent above border prices. Subsidies reached $248 billion (per year) in 1999–2001 (Ricupero 2003).

reduction overlap all too well with the countries, and even the regions within countries, that were for some reason denied a Green Revolution, not-too-unequal family farming, or adequate near-universal (that is, rurally extended and gender-blind) primary schooling, or all three. In Sub-Saharan Africa, with a few exceptions, the general failure to use farm science to achieve substantial and sustainable acceleration of family farm growth *before* the thrust to globalization has made it harder for globalization to help much in reducing poverty. The responsiveness of aggregate farm output, and hence employment, to better farm prices or export access, for example, is small if the productivity of labor and land are low and sluggish.

Finally, an almost unexplored issue for farm science is raised by the combination of globalization and the rising real cost of farm water. In formally irrigated areas, farmers will increasingly divert scarce (and desubsidized) farm water from irrigated rice and wheat to cash crops producing much more value per drop (especially compared with rice). Prospects of global markets for such crops will accelerate this. Conversely, where transport costs loom large or there is a preference for foodgrain self-sufficiency, there will be corresponding moves *toward* staples in unirrigated areas. This sets a new agenda for both crop and water science, especially if concentration on small farmers and poverty reduction is a goal.

I am uneasily aware that this paper in effect suggests a “planning” model for agricultural research that is in tune with neither the history of competition-driven research success before 1960 nor the current reliance on markets. However, the implications of poverty-reduction priorities are, as has been shown, complex (regions), not particularly intuitive (tightropes), essentially interdisciplinary (nutrition, water), and very little aligned with a reward structure that encourages competition for the final demand of wealthy consumers or for the intermediate demand of large farmers. Research, unlike farming, does have scale economies. If it is to meet the needs of the poor, support for large-scale public provision is required. However, the concentration of “frontier” knowledge and techniques in the private sector means that this will have to be bought in and motivated by incentive, if the effort to advance the poor is to succeed.

References

Alston, J., C. Chan-Kang, M. Marra, P. Pardey, and T. Wyatt. 2000. *A Meta-Analysis of the Rates of Return to Agricultural R&D: Ex Pede Herculem*? IFPRI Research Report #113. Washington, D.C.: International Food Policy Research Institute.

Berry, A. and W.S. Cline. 1979. *Agrarian Structure and Productivity in Developing Countries*. Baltimore: Johns Hopkins.

Bhalla, S. and P. Roy. 1988. Mis-specification in farm productivity analysis: the role of land quality. In *Oxford Economic Papers*, 40: 53-73.

Binswanger, H., K. Deininger, and G. Feder. 1996. Power, distortions, revolt and reform in agricultural land relations. In *Handbook of Development Economics: vol. 3B,* eds. J. Behrman and T.N. Srinivasan. Amsterdam: North Holland.

Binswanger, H. and V. Ruttan. 1978. *Induced innovation: technology, institutions, and development*. Baltimore: Johns Hopkins.

Birdsall, N., D. Ross, and R. Sabot. 1995. Inequality and growth reconsidered: lessons from East Asia. In *World Bank Economic Review*, 9: 477-508.

Bloom, D. and J. Williamson. 1997. Demographic transitions, human resource development, and economic miracles in emerging Asia. Harvard Institute of International Development Working Paper. Cambridge, Mass., USA: HIID, Harvard University

Booth, A. and R. Sundrum. 1985. Labour Absorption in Agriculture. Delhi: Oxford University Press.

Cornia, G.A., T. Addison, and S. Kiiski. 2004. Income distribution changes and their impact in the post-Second World War period. In *Inequality, Growth, and Poverty in an Era of Liberalisation and Globalisation*. New York: Oxford University Press.

de Moor. 1966. *Perverse incentives, subsidies, and sustainable development: key issues and reform strategies*. San José: Earth Council.

Dorward. 1999. Farm Size and Productivity in Malawian Smallholder Agriculture. In *Journal of Development Studies,* 35: 141-161.

Dyson, T., R. Cassen, and L. Visaria (eds.). 2004. *Twenty-first Century India: population, economy, human development, and the environment*. Oxford: Oxford University Press.

Eastwood, R., M. Lipton, and A. Newell. 2006. Farm size. In *Handbook of Agricultural Economics: vol.3B*. Amsterdam: North Holland. Forthcoming.

Eastwood, R. and M. Lipton. 2002. Pro-poor growth and pro-growth poverty reduction: meaning, evidence and policy implications. In *Asian Development Review* 18 (2), 2002: 22-58.

FAO (Food and Agriculture Organization). 2005. World Census of Agriculture. Rome: FAO. http://www.fao.org/es/ess/census/wcares/default.asp.

Fan, S., P. Hazell, and S. Thorat. 2000. Targeting public investments by agroecological zone to achieve growth and poverty alleviation goals in rural India. In *Food Policy* 25 (2000): 411–428.

Fan, S., Z. Linxiu, and X. Zhang. 2000. *Growth and poverty in rural China: The role of public investments*. Washington, D.C.: International Food Policy Research Institute

Hazell, P. and C. Ramasamy. 1991. *The Green Revolution Reconsidered*. Baltimore: Johns Hopkins.

Hazell, P., P. Jagger, and A. Knox. 2001. *Technology, natural resource management, and the poor*. Thematic paper for International Fund for Agricultural Development *Rural Poverty Report*. Rome: IFAD.

Hill, P. 1982. *Dry Grain Farming Families: Hausaland (Nigeria) and Karnataka (India) compared.* Cambridge: Cambridge University Press.

Hill, P. 1977. *Population, Prosperity, and Poverty: Rural Kano, 1900 and 1970*. Cambridge: Cambridge University Press.

Hossain, Mahabub. 1988. *Nature and Impact of the Green Revolution in Bangladesh*, Washington, D.C.: International Food Policy Research Institute.

Hu, D., T. Reardon, S. Rozelle, P. Timmer, and H. Wang. 2004. The Emergence of Supermarkets with Chinese Characteristics: Challenges and Opportunities for China's Agricultural Development. In *Development Policy Review*, 22: 557-86.

Jamison, D. and L. Lau. 1982. *Farmer Education and Farm Efficiency*. Baltimore: Johns Hopkins

Johnston, B. and J. Mellor. 1961. The Role of Agriculture in Economic Development. In *American Economic Review,* 51: 566-593.

Julka, A.C. and P.K. Sharma. 1989. Measurement of land inequality in India: a revision of the Lorenz-Gini ratio. *Indian Journal of Agricultural Economics*, 44: 423-429.

Kerr, J. and S. Kohlavalli. 1999. *Impact of agricultural growth on poverty alleviation.* Environment and Production Division Discussion Paper #56. Washington, D.C.: International Food Policy Research Institute.

Lipton, M. and R. Longhurst. 1989. *New Seeds and Poor People.* London: Routledge.

Lipton, M. 2005. *The Family Farm in a Globalizing World: The Role of Crop Science in Alleviating Poverty*. 2020 Discussion Paper No. 40. Washington, D.C.: IFPRI.

Lipton, M. and Qi Zhang. 2005. *Reducing inequality and poverty during liberalisation in China: rural and agricultural experiences and policy options*. Forthcoming.

Mellor, J. 1976. *The New Economics of Growth*. Ithaca: Cornell

Moore Jr., Barrington. 1966. *Social Origins of Dictatorship and Democracy: lord and peasant in the making of the modern world*. Boston: Beacon.

Mundlak, Y. 2001. Production and supply. In *Handbook of Agricultural Economics*, Vol 1A. eds. B.L. Gardner and G.C. Rausser.

Nuffield Council on Bioethics. 2004. The Use of Genetically Modified Crops in Developing Countries. London.

Reardon, T., P. Timmer, C. Barrett, and J. Berdegue. 2003. The rise of supermarkets in Africa, Asia, and Latin America. In *American Journal of Agricultural Economics* 85: 3–20.

Ricupero, R. 2003. Report of address to the UN Economic and Social Council, June 30. www.twnside.org.sg/title/twe309a.htm.

Sen, A.K. 1981. *Poverty and Famines*. Oxford: Clarendon.

Singh, I.J. 1990. *The Great Ascent: the rural poor in South Asia*. Baltimore: Johns Hopkins.

Smith, L. and I. Urey. 2002. *Agricultural growth and poverty reduction: A review of lessons from the post-independence and Green Revolution experience in India*. Working paper Department of Agricultural Sciences. Wye: Imperial College. www.imperial.ac.uk/agriculturalsciences/research/sections/aebm/projects/poor_ag_downloads/indiaback.pdf.

Stiglitz, J. 2003. *Globalisation and its discontents.* New York: Norton.

Valdés, Alberto. 2005. personal communication with author. July.

Wood, A. 1994. *North-South Trade, Employment, and Inequality: changing fortunes in a skill-driven world.* Oxford: Clarendon.

World Bank. 2004a. The CGIAR at 31: An independent meta-evaluation of the Consultative Group for International Agricultural Research. Washington, D.C.: World Bank Operations Evaluation Division.