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The Family Farm in a Globalizing World

The Role of Crop Science in Alleviating Poverty

Michael Lipton

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Foreword

The topic of family farms has been gaining prominence in the academic, policy, and donor communities in recent years. Small farms dominate the agricultural landscape in the developing world, providing the largest source of employment and income to the rural poor, yet smallholders remain highly susceptible to poverty and hunger. With the advance of globalization and greater integration of agricultural markets, the need for increases in agricultural productivity for family farms is particularly pressing. Raising productivity and output of small farmers would not only increase their incomes and food security, but also stimulate the rest of the economy and contribute to broad-based food security and poverty alleviation.

In this paper, Michael Lipton builds an argument for greater focus on pro-smallholder crop science as a key solution to generate increases in productivity and income. Increasing the levels of investment into agricultural technology, improving water and land use and distribution, and creating positive incentives for developing-country farmers come to the forefront of the paper as critical steps that must be taken to ensure massive reduction in global poverty. Favorable demographic trends over the next few decades provide a window of opportunity for reforms and action that must not be squandered.

The future of smallholders is an important research theme at IFPRI. Several studies are currently underway that address the impact of changing agricultural markets on small farmers. In addition, IFPRI and its 2020 Vision Initiative is collaborating with the Overseas Development Institute and Imperial College London in organizing a research workshop on "The Future of Small Farms" in June 2005 in Wye, England, that will bring together leading experts to review the available evidence on the current and future status of smallholders in the world.

We hope that the release of this discussion paper on the eve of "The Future of Small Farms" workshop will stimulate and enrich the debate and provide valuable insights for articulating critical steps to strengthening family farms. The paper significantly contributes to developing this emerging theme at IFPRI, helping to identify research priorities and to better position IFPRI to undertake policy research on the future of small farms. It is an important step toward accumulating a body of knowledge on the topic and shaping an agenda for action.

Joachim von Braun
Director General

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Executive Summary

Family farms are operated units that derive most labor and enterprise from the farm family. They have proved resilient, even in the rich world, and small family farms dominate agriculture in East and South Asia and Sub-Saharan Africa. Yet these are areas of concentrated poverty: in 2004, they contained over 92 percent of the world's 1.1 billion "dollar-poor" (households consuming less than one U.S. dollar's worth of a world average consumption bundle, per person per day, at 1993 purchasing-power-parity values). Kick-starting the reduction of mass dollar poverty normally requires accelerated growth of staples output on family farms. Whether this is feasible and sufficient depends on national political and economic incentives and institutions to create and apply appropriate crop science, land and water access, and open markets in the context of appropriate state-led provision of public and merit goods. Many Asian and Latin American countries have gone a long way on this path, but they still have far to go. Much of Africa has hardly started. Progress is made possible by new science and by a crucial demographic shift—but is handicapped by rich-world policies towards agriculture, trade, and science.

The Argument

1. Family farms have advantages that enable them to dominate. Small farms have lower labor-related transaction costs and more family workers per hectare, each motivated to work and to find, screen, and supervise hired workers. Large farms have lower capital- and land-related transaction costs, allowing owners to more readily finance equipment, which they can use over many hectares. So small farms have advantages in early-developing countries, which have low capital per unskilled worker and scarce land per person, while large farms win out in developed countries, with more savings, capital, and (usually) good rural land per unit of unskilled rural labor.

Despite differing farm size and techniques, family management dominates farming at all levels of development. Consequently—unlike virtually any other major sector, even retailing—the economic advantages of family oversight prevail in farming across a wide range of development levels, typical farm sizes, capital/land/labor ratios, and types of product and ecology. Data strongly suggest that such farms retain competitive advantages despite market distortions, and despite some genuine and growing market handicaps as agricultural supply chains globalize and concentrate. The evolution of the family farm is thus linked to economic development.

Almost all family farms are now commercial, profit-seeking enterprises. The persistence and power of family farming not only chart a credible course for evolving farmers in Africa and Asia but also help explain the Northern farm protectionism that makes their lives so hard.

2. The Green Revolution provided a special type of growth in family farm productivity, partly by luck. A country normally needs to provide the poor with higher employment, higher unskilled wage-rates, and/or more command over low-cost food staples to initiate major cuts in mass dollar poverty. Productivity growth in small family farming alone usually has the potential to raise all three. Normally this later permits, and induces, further poverty reduction via cash-cropping, rural nonfarm work, and shifts to urban employment and income growth. But mass dollar poverty reduction almost always starts with large, widely shared increases in profitably produced farm output (especially food staples) and profitably sought and offered farm employment mainly on family farms. Especially as land gets scarcer, this requires a technology-based agricultural revolution. But even if that works, stringent conditions must be met for the main dollar-poverty groups—small farmers, rural laborers, and the urban poor—to benefit. There are virtually no examples of mass dollar poverty reduction since 1700 that did not start with sharp rises in employment and self-employment income due to higher productivity in small family farms.

However, while farm growth is *necessary* to initiate mass poverty reduction, it may not be *feasible* or *sufficient* to overcome binding land and water constraints. Feasibility depends on availability, quality, and distribution of farmland (and water); crop, land, and water science; and prospects for national and global trade and exchange, and their effects on farm sales and prices. Sufficiency depends on a corresponding rise in the poor's command over staple foods. Even large increases in staple food productivity would do little to cut mass dollar poverty if they were confined to large-scale farms, using tractors and combines but few workers, and selling at government-boosted prices that the underemployed and near-landless poor cannot afford.

The Green Revolution not only increased the supply of locally available staples but also the demand for farm labor, wage-rates, and thus the work-based income of the dollar-poor. The lesson for future crop science policy is clear. When choosing among research paths, a high employment share in extra science-induced farm income should normally be seen as a gain. For countries where the dollar-poor lose out if the demand for farm labor declines, aid-backed farm research should not support better combines, herbicides, mechanical transplanters—or varieties whose advantages depend on these—unless the results can be shown to be cost-effective ways to cut poverty.

3. Mass poverty can be slashed by farm-based progress given three predisposing, perhaps necessary, preconditions. Widescale pro-poor progress based on crop science for small family farms does not initially *need* good roads, credit, extension, and so on, helpful though they are, but the following are almost always essential: (a) total factor productivity (TFP) growth on farms via locally profitable and (usually) employment-intensive technology; (b) land and water that are neither very unequally distributed nor unsustainably used; and (c) farm production patterns that are not too vulnerable to disabling of incentives by domestic or overseas policies that sharply erode or distort farm prices; by unshiftable initial conditions, such as imposed gross land inequality; or by inbuilt adverse trends, such as poor farmers or workers not just producing but being locked into commodities where science-induced progress leads to more-than-offsetting price erosion.

4. Formal science is increasingly needed to satisfy the technology precondition. With the population acceleration of 1730–2000 and the increasing scarcity of unfarmed, high-quality land, 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.

5. Formal farm science needs radical reform to improve pro-poor results. The Green Revolution could not escape the law of diminishing returns. Despite success in parts of rainfed Asia and some of Africa, past evidence suggests severe limitations on conventional plant breeding, and research based on the Mendelian breakthrough has increasingly had to focus on maintaining yields rather than raising them. Radical scientific and institutional innovation is needed. Private companies need to see public-purpose research outcomes as made profitable, mainly by contracts to achieve specific outcomes to raise family-farm productivity or robustness in neglected areas and crops.

6. The land/water distribution necessary for family farming to cut mass dollar poverty is violated in southern and eastern Africa. Regions with mass poverty, such as southern and parts of eastern Africa, where family farming has been subverted (mostly by colonial land grab, but sometimes by inequality within traditional land systems or by the politicized economy of land redistribution) need to get their large, low-employment landholdings to shift towards not-too-unequal family farms, as consensually as is feasible.

7. Land/water sustainability is most threatened by crop expansion into marginal lands. Some aspects of intensification raise serious environmental concerns: loss of biodiversity, inappropriate or excessive pesticide use, water and plant nutrient depletion, salinity and waterlogging, and nitrate and nitrite buildup in drinking water imperfectly separated from excess nitrogen fertilization and ill-drained farm water. These environmental concerns, while not obviating the need for yield-increasing intensification through innovation in crop science, may narrow the acceptable means to that end.

8. Rich countries' farm support has increased, undermining incentives for developing-country agriculture. Most developing countries have greatly reduced the destruction of incentives to employment-intensive farming, but the baton has passed to the North, (a) through state subsidies and protection that stimulate Northern farmers to overproduce, thereby glutting world markets and reducing incentives to Southern farmers; and (b) through the effect of such protection in inducing Northern farmers to pay for more national science, producing yet more output than would be commercial at free prices. This output compounds the effect of directly subsidy-induced overproduction in undermining farm incentives for the South. In addition, global science is diverted away from the farm goals of the poor towards demands inflated by Western farm support for labor-saving production. To some extent, the prospects of better crop science to help the rural poor in globalizing economies depend on agricultural trade and policy reform in OECD nations.

9. Small-scale family farmers in rich countries are a major effective pressure towards farm supports, which impede the absolute poor in poor countries. Political economy, not malice, is at work. Nevertheless, it is small and family farms in the North that perpetuate its farm support regimes and, in democracies, underpin rich farmers' lobbying for ever-greater farm support. The OECD and emerging-country family-farm lobbies will not respond to economic theory alone, however valid; but if the lobby is reasoned with and shown alternatives, victory is possible.

10. Remedies are urgent to take advantage of the population slowdown in developing countries, with its temporary but sharp effect in cutting the dependency ratio. Lower proportions of dependents create a window of opportunity for growth and poverty

reduction. The process began with large declines in infant mortality rates during 1945–60. Though these initially raised dependency ratios, the "saved" infants grew to working age, fertility fell, and dependency ratios also began to fall, as in Africa and South Asia today. Thus offers a window to help the poor out of poverty. However, if extra farm employment prospects are not provided by crop science and appropriate policy, the extra workers will face downward pressures on employment and wage-rates. The opportunity will then be lost as, after 2030–50, aging populations pull the dependency ratio up again.

11. Can crop science for family farms help the poor to gain from globalization? Given that most developing areas are labor-rich and capital-poor, most globalization should increase their specialization in high-employment farms and crops, which should make attacking mass poverty easier through extra employment, productivity, food output, and income growth from small family farms. Apart from growth effects, globalization should, within developing countries, make income distribution more pro-poor.

Conclusion

Mass poverty reduction initially depends on widespread growth of farm productivity and employment income, and hence on specific scientific progress, usable by small family farmers, mostly in so far recalcitrant areas. Such science needs to see *productive* employment creation in agriculture as a benefit, not a cost.

1. Prologue: Key Concepts and Their Relevance

Family farms are operated units in which most labor and enterprise come from the farm family, which puts much of its working time into the farm. Family farms, many now quite large, have proved resilient even in the rich world. In East and South Asia and Sub-Saharan Africa, small family farms dominate (see pages 4–5).[1]

Poverty is concentrated in those areas. In 2004, they contained over 92 percent of the world's 1.1 billion "dollar-poor."[2] As in developed countries before 1900, so in developing countries since 1950: kick-starting the reduction of mass dollar poverty normally requires accelerated growth of staples output on family farms. Whether this is feasible and sufficient depends on (a) national political and economic incentives and institutions to create and apply appropriate crop science,[3] (b) land and water access for the efficient farming poor (meaning those who can farm competitively and hence efficiently), and (c) opening and widening markets in the context of appropriate state-led provision of public and merit goods. Many Asian and Latin American countries, notably China and India, have gone a long way on this path, but they still have far to go. Much of Africa has hardly started. Progress has been handicapped by rich-world policies towards agriculture, trade, and science.

Crop science via farmers' experiments has driven smallholder productivity forward for millennia, but slowly. An increasingly predominant part has been played by formal crop science;[4] however, despite continuing advances, staples yield growth rates in developing countries peaked in the 1970s and have since fallen sharply (see page 15). Alongside the collapse of aid to agriculture (see footnote 24), international agricultural research funding stagnated from the 1980s to the early 2000s. In most of Africa and in some other developing countries (not including India and China), domestically financed investment in agriculture has been sluggish or falling, so total investment

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[1] *"Dominate" in this paper is shorthand for "account for a big majority of farm value-added, workforce, and area."*

[2] *Meaning those in households consuming less than one U.S. dollar's worth of a world average consumption bundle, per person per day, at 1993 purchasing-power-parity (PPP) values (World Bank 2004b). This assumes consumption distributed in proportion to need within the household and across seasons; to the extent that it is not, dollar poverty is underestimated. Since a dollar buys more of a typical consumption bundle in developing countries than in developed countries, a person can be above the dollar poverty line with much less than $1 per day at official exchange rates (for example, only about 20 cents in India). Acceptable nationwide household surveys, permitting dollar poverty to be estimated, exist for over 95 percent of the population of the developing world. Poverty is a bundle of deprivations; dollar poverty is just one of them (Chen and Ravallion 2004; Lipton and Ravallion 1995).*

[3] *Livestock has a major role for the poor, especially the landless poor, and should form part of the solution to poverty and agricultural productivity growth in the South. This has been emphasized by three commentators, one of whom writes: "Mixed crop–livestock farming can play a key role in spreading labor peaks, maintaining soil fertility, improving timeliness of plowing, and increasing crop productivity. Worldwide, the livestock feed industry serves as a key buffer, stabilizing inter-annual price swings" (personal communication with author). However, the very poor often cannot afford the risks or capital costs of largestock. Staples—with their higher per hectare value-added and employment, and given spreading land scarcities—play a leading, in some areas rising, role in the production, consumption, and above all employment income of the rural poor.*

[4] *This role is most effective, however, when guided by farmers' research and their production priorities (IFAD 2001, 140).*

in agriculture and its scientific and other infrastructures declined.

Demographics are potentially very helpful in spreading, to Africa and the poorer parts of Asia, the rapid falls in poverty achieved elsewhere. That potential can be realized if—but only if—there is renewed focus on improving smallholder yields. In East Asia during 1970–2000, the proportions of people of prime working or saving age (15–64 years old) rose significantly. Partly as a result, and aided by East Asia's science-based, job-creating, and food-cheapening farm transformation, dollar poverty incidence fell by over two-thirds. For similar reasons, the ratios of workers to dependents are rising even faster in today's poverty heartlands (see page 20).[5] Yet similar poverty impact requires similar farm transformation. In East Asia, the extra workers could escape poverty (for themselves and their relatively fewer dependents) by finding work with rising income and productivity. Initially, most of this extra work was on labor-intensive smallholdings, inducing expansion in rural nonfarm employment later. However, in most of Africa, and parts of Asia too, the extra workers are not enjoying comparable growth in labor demand. That is largely for want of East Asia's science-based farm transformation. The Green Revolution has faltered, before doing much for Africa's main crops or for areas with little or no "water control"—that is, with neither irrigation nor farmer-managed methods to vary the flow of rainwater to crops. International, and African, public spending on plant breeding has declined, and booming private investment in biotech has sought mainly to cut costs for rich farmers in rich countries. So Africa's "demographic gift"—its rising proportion of workers—does not yet face the farm-led boom in income and employment that East Asia's did.

Globalization, accelerating from the 1980s, "should have" enhanced the market and trade prospects of poor people. Yet each unit of economic growth, while still cutting dollar poverty after 1990, has done so less than during 1970–90. Blame is shared by (a) discrimination against rural areas by governments of poor countries;[6] (b) the passive attitude of many African governments to new crop science and improved water control; (c) the poisoning of developing-country farm incentives by developed-country farm support (see page 18); (d) the privatization of science, without appropriate new incentives; and (e) the interaction of (c) and (d), with incentives increasingly pointing farm science towards the subsidized products of the European and U.S. nonpoor. The last three factors are partly due to political pressures from family farmers in Europe and the United States (see page 19). Ironically, these farmers—often poor relative to norms in their own, wealthy, countries—are partly responsible for the declining success in reducing absolute poverty through progress by family farmers in developing countries. To address these five points, reorientation of crop and water science is needed.[7]

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[5] *The World Bank (2004a, 11) estimates that in 2004 19 percent of the world's 1.1 billion dollar-poor were in China (concentrated in the west). The United Nations (2003) estimates 30 percent in India (concentrated in eastern and central areas), a further 10 percent elsewhere in South Asia, and 29 percent in Sub-Saharan Africa—over 60 percent of them in five big countries, the first two of which are desperately poor: DR Congo, Ethiopia, Nigeria, Tanzania, and Uganda.*

[6] *Though overt price extraction from agriculture is now much less than in the 1960s, public-expenditure bias against rural infrastructure and institutions is probably worse (Eastwood and Lipton 2004).*

[7] *There have been improvements, but more radicalism is needed, for example, moving public–private partnerships beyond warm words—by motivating firms, via new profit incentives, to compete to attain public-purpose goals.*

2. The Argument Outlined

The argument is set out as eleven bald propositions. Evidence for them is provided in the next section.

1. Regardless of whether small or large farms are more economic—usually the case in developing and developed countries, respectively—family farms have economic advantages and therefore tend to dominate.
2. More than half the world's dollar-poor will reside in rural areas until about 2035, but big gains for all main groups of dollar-poor—smallholders, rural workers, and urban poor—are compatible only with a special type of farm productivity growth. Partly by luck, the Green Revolution was of the right type.
3. Mass poverty can be slashed by farm-based progress where three predisposing, perhaps necessary, preconditions are met: on technology, land/water use and distribution, and farm incentives.
4. Formal science is increasingly needed to satisfy the technology precondition.
5. However, the tasks and organization of pro-poor farm science need radical reform, especially for the crops and soil-water regimes of rainfed Africa.
6. The land/water distribution precondition for family farming to cut mass dollar poverty, met in much of Green Revolution Asia, has not yet been met in much of southern, and some of eastern, Africa.
7. The land/water sustainability precondition is threatened by crop expansion into marginal lands.
8. Farm supports in Europe and the United States—and recently in emerging Asian countries like Japan and South Korea—have cumulatively eroded the incentives for developing-country agriculture by drastically depressing farm prices and distorting world farm science.
9. In rich countries, small-scale (and often *relatively* poor) family farmers are a major effective pressure towards farm supports, which impede poverty reduction among the *absolute* poor in poor countries—as family farmers, farm workers, and usually as food consumers.[8]
10. Remedies are urgent, to take advantage of a "window of opportunity" to slash poverty in low-income countries: the effect of slower population growth in sharply, but temporarily, cutting dependency ratios.[9]
11. The poor potentially gain from globalization, but such gains are often reduced, and sometimes turned into losses, by faulty institutions that fail to connect the poor with appropriate markets and information.

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[8] *In the longer term, poor people gain, because dumping of Western food surpluses discourages domestic agrotechnical progress in developing countries, which normally helps the poor by durably cutting food prices (for example, Pinstrup-Andersen, de Londono, and Hoover 1976). Western dumping (which is unreliable and unpredictable) inhibits such progress even if it cuts prices temporarily and once for all. However, in heavily staples-importing countries with little prospect of moving into staples surplus, such once-for-all cuts may benefit the poor as staples consumers, via lower immediate food prices, but seldom enough to outweigh the brake on domestic agricultural advance and so on later domestic food price cuts.*

[9] *The dependency ratio (DR) is the number of persons aged under 15 or over 64, as a proportion of those aged 15–64 (the prime working and saving age group). After 30 to 50 years, the falling DR is reversed—closing the window—because the number of persons over 64 rises.*

3. The Argument Unpacked

1. Small farms tend to be more economic in developing countries, while large farms are more economic in developed countries; nevertheless, in both cases family farms have advantages that enable them, unless prevented, to dominate.

Small farms have lower labor-related transaction costs. They also have more family workers per hectare, each motivated to work and each able to find, screen, and supervise hired workers. Large farms have lower capital- and land-related transaction costs: owners can more readily finance equipment and can use it over many hectares. So small farms have advantages in early-developing countries, which have low savings and therefore capital per unskilled worker, and where prolonged population growth has made land per person scarce.[10] Conversely, large farms win out in developed countries, with more savings, capital, and (usually) good rural land per unit of unskilled rural labor. Therefore, farms are generally smaller in poor countries, and farm size normally rises with economic development—though this is subject to historical and political distortions via coercive private or state action, such as colonial land grab and subsequent counteractive land reforms (Binswanger, Deininger, and Feder 1995; Eastwood, Lipton, and Newell 2006, forthcoming).

Despite differing farm size and techniques, family management dominates farming at all levels of development. We can infer this from data on farm size (FAO 2004b) and distribution of farm labor force (ILO 2004). The rich-country facts in the next paragraph may seem a digression, but they are crucial for poor countries (see pages 19–20).

In Europe in 1990, national mean farm size was typically 20–30 hectares (4.5 in Greece, 70.2 in the United Kingdom), with one-third of farms below 5 hectares (typically occupying 5–10 percent of farmland). Most farms below 30 hectares and almost all below 5 hectares get most of their labor from the farm family.[11] This is also the case for many much larger farms, with the additional help of combines, computers, and other hirable capital-intensive farm services. In France, FAOSTAT data (FAO 2004b) show mean farm size in 1988 at 31 hectares, with 73 percent of farms, on 92 percent of farmland, above 5 hectares. Yet by 1994 only one in four members of the farm workforce was an employee; the rest were classified as employers or "own-account" farmers (meaning those whose primary occupation is farming their own or family land). By 1998–2000, of 13 European countries with data, employees formed most of the agricultural workforce only in Germany (51.5 percent) and Estonia (71.2 percent).[12] In **North America**, farms are typically much larger, averaging 187 hectares in the United

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[10] *This is even more so if land is measured in quality-adjusted "efficiency units." Even in Sub-Saharan Africa, few areas remain where much land can be cheaply brought into cultivation without the costs, returns, and effect on ecological sustainability all being much less favorable than on existing farmland.*

[11] *Farms below 5 hectares in developed countries are normally considered part-time. As of 2000, over 75 percent of farms were below 5 hectares in Italy and Portugal, but only 15 percent in Ireland and the United Kingdom.*

[12] *Where, in 1998–2000, own-account farmers and contributing family workers were counted separately from employers, they often loomed large in the farm workforce: 87 percent in Poland, 80 percent in Austria, 77 percent in Portugal, 71 percent in Lithuania, 57 percent in Latvia, 46 percent in Spain, 25 percent in Estonia, and 12 percent in the Czech Republic (ILO 2004).*

States (1987) and 350 hectares in Canada (1991), with barely 6 percent of holdings (0.1 percent of farmland) below 5 hectares.[13] By 2002, only 2.6 percent of the U.S. workforce was agricultural, 63 percent of them employees; probably most U.S. farms use mainly family labor (USDA 2003).

What of developing countries? As of 2000, 40 percent of their farm workforce was located in China, 21 percent in India, and 14 percent in Sub-Saharan Africa (FAO 2004b). In **China**, since 1978–85, almost all farmland is distributed into household-responsibility farms according to family size. Astonishingly, despite mean farm size of only 0.67 hectares, 67 percent of the workforce reported agriculture, largely family farming, as their main occupation in 2000 (down from 78 percent in 1970). In **India**, the 1999–2000 proportion was 60 percent (compared with 74 percent in 1970), but—in sharp contrast to China—rural Indian households that reported agricultural labor as their main income source were almost as numerous as those reporting self-employment in agriculture (33 and 32 percent of the rural workforce, respectively [Sundaram and Tendulkar 2002, 43]).[14] With average farm size in 1990 of 1.55 hectares, only 24 percent of holdings above 2 hectares, and most farm laborers getting significant income from own-account farming (Singh 1991), rural India remains family-farm country. The same can be said for Bangladesh and, even more so, for **Sub-Saharan Africa**, where land distribution is very unequal in southern and some eastern areas; hired farm labor is significant and increasing, yet small family farming still dominates. In Ethiopia, with 80 percent of its 27 million workers reporting agriculture as their main activity in 2000, 42 percent of farm workers were own-account farmers and 54 percent were contributing family workers. **Latin America** and southern Africa retain extreme "colonial" land inequality, with agriculture dominated by larger, far less labor-intensive farms than would be expected at still-high national labor/capital ratios. Nevertheless, in most countries, more people report farming than farm labor as their main income source (a notable exception is South Africa).

Consequently, though few countries publish shares of employment, output, or holdings in family farms as such (or define them officially), the above data[15] suggest that—unlike virtually any other major sector, even retailing—the economic advantages of family oversight prevail in farming across a wide range of development levels, typical farm sizes, capital/land/labor ratios, and types of product and ecology. Family and small-scale farming can be ousted by force (colonial land grab, slavery, feudal serfdom, ethnic cleansing, compelled collectivization) or by governments or other sources of market distortion that shift incentives strongly against small family farms (for example, by making tenancy illegal or unattractive). However, even against such sources of needless distress, small-scale and family farming has substantially raised its share of operated farmland in Africa and Asia. There, for countries having more than one Census of Agriculture from the 1960s, 1970s, 1980s, 1990s, and 2000s rounds, the average and median farm size and proportion of farmland operated in holdings below 2 hectares have, in almost every case, fallen (FAO 2004c; Eastwood, Lipton, and Newell 2006, forthcoming). This strongly suggests that such farms retain competitive advantages despite market distortions, and despite some genuine and growing market handicaps as agricultural supply chains globalize and concentrate (see page 22).

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[13] *Already in 1964, I saw (in Montana) farms of over 1,000 hectares with most of the work done by family members. This applies also in Australia, with average farm size (pastoral plus arable) over 3,500 hectares. In Canada in 1998–2000, 3.1 percent of the workforce was agricultural—with fewer employees (45 percent) than employers and own-account farmers (50.2 percent).*

[14] *Yet for poor rural households the respective proportions were about half and a quarter. Farm laborers, not only in India, are likelier to be poor—and more deeply poor—than those whose main income is from farming. This does not obviate small farms' role in cutting poverty; for one thing, as farm size falls, even hired labor per hectare rises.*

[15] *These confirm the domination of farming by small units in most countries (including many developed ones), and the persistently high ratio of employers, family workers, and self-employed to employees.*

Even in most developed agricultures, most farms, hectares, and even production remain family-managed, and farmers outnumber farm laborers. Farm support payments, being proportionate to output or area, are concentrated on a few large farms;[16] yet farming in most rich countries remains dominated by family farms (for example, Baldwin and Wyplosz 2003, Ch.8). Though family workers are usually leaving the land faster than employers or laborers, family farm management usually continues, with less labor (in terms of time) and more capital per hectare. Economies of scale, while genuine in OECD farming, cannot be very great; otherwise, small farmer-owners would sell out faster. Growing U.S. farm size has been consistent with the continued dominance of family-farm over corporate management (USDA 2003). In England, from 1690 to 1831, though farmers were fewer than farm laborers, the ratio—a fair indicator of "farm familyness"—fell only slowly, from 0.5 to 0.4 (Mingay 1968, 25).[17] In Africa and Asia, mean operated farm size has fallen with development, which can only partly be attributed to falling owned farmland per household (due to population growth with partible inheritance—division of farms among offspring—rising farm productivity, and land reforms). This suggests that small family farms can remain competitive and efficient well into early development (though the situation will change as development proceeds). Asian mean farm size will eventually rise, but not necessarily the share of nonfamily farms in land, work, or even output.

The evolution of the family farm is thus linked to economic development, with its concomitant poverty reduction and ever-wider exchange. There are few subsistence farms left in the world. Almost all family farms are commercial, profit-seeking enterprises that buy some inputs and sell some outputs; many grow export crops. The proportions of farm inputs purchased rather than produced (such as inorganic fertilizers rather than manure), of outputs sold instead of consumed by the farm household, and of farmers with secondary and tertiary education all tend to rise with economic development. Meanwhile, normally after the initial increases in farm productivity, growth of the rural population and workforce slows down.[18] Rising ratios of capital to labor erode and eventually reverse the net advantage of small farms, and labor leaves the land. The farmers who choose to continue are those more able, and willing, to manage larger farms. Even in the highly developed agricultures of the United States, family farms persist as farm size rises: "The number of farms has fallen dramatically since its peak in 1935. In the meantime, the number of large farms has grown, which means that large farms now form a larger share of the total U.S. farms. Nevertheless, most of the remaining farms are family-run businesses with sales less than $250,000" (USDA 2003, Ch. 3).

The persistence and power of family farming not only chart a credible course for evolving farmers in Africa and Asia but also help explain the Northern farm protectionism that makes their lives so hard (see pages 20–21).

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16 *However, the concentration of U.S. support on large corporate farms is less than the estimates suggest, since many such farms are in fact cooperative arrangements supporting many, often small, family farms. The web sites for the much-listed "top 20 farm recipients" in the United States confirm this.*

17 *In the United Kingdom as a whole, only in 1992 did farm employees come to outnumber farm employers and own-account farmers (by 50.9 to 49.1 percent of farm workforce; ILO 2004).*

18 *Despite slower rural population growth, partible inheritance, alongside land reform, has reduced farmland owned or controlled per household. In much of Asia, rising land productivity and growing rural nonfarm income have made these changes compatible with rising rural incomes. But why has less land per household led to large decreases in* operated *farm size in most of Africa and Asia since 1960 (Eastwood, Lipton, and Newell 2006, forthcoming)? Imperfect rental, sales, and other land-transfer markets and arrangements are unconvincing as a full answer. At the very least, the data are inconsistent with the view that small farms are, or are yet becoming, uncompetitive or inefficient in most of Africa or Asia.*

2. In countries with mass dollar poverty, 70 percent of it is rural. Significant gains for the main groups of dollar-poor (small farmers, rural laborers, and urban poor) almost always initially require a special type of growth in family farm productivity, which—partly by luck—the Green Revolution was able to provide.

Of the world's dollar-poor, 70 percent are rural, and the projection for 2035 is 50 percent (Ravallion 2002). Further, rural shares of poverty intensity are substantially higher;[19] and in Africa and Asia poverty is even more rurally concentrated.

The dollar-poor derive almost all their income from employment (hired or self-employed), 45–60 percent of it in agriculture, and devote well over half their consumption to staple foods.[20] To initiate major cuts in mass dollar poverty, a country normally needs higher employment, higher unskilled wage-rates, *and/or* more command over low-cost food staples. Productivity growth in small family farming alone usually has the potential to raise all three, at low capital costs per workplace. Normally this later permits, and induces, further poverty reduction via cash-cropping, rural nonfarm work, and shifts to urban employment and income growth. But mass dollar poverty reduction almost always *starts* with (a) large, widely shared increases in profitably produced (including self-consumed) farm output—especially food staples, and (b) profitably sought and offered farm employment (including self-employment), mainly on family farms.[21] Especially as land gets scarcer, that requires a technology-based agricultural revolution. But even if that works, stringent conditions must be met (the "two tightropes," discussed below) for *all* the main dollar-poverty groups—small farmers, rural laborers, the urban poor—to benefit from new farm technology.

Before developing this argument, it helps to set out an economist's paradigm of the evolution of farm size and ownership, and their interplay with poverty, farm science, and globalization (alongside domestic market enlargement). In pre-modern development, there were few people per hectare of land. Most land was of a fairly uniform quality and could be made arable by applying labor (for example, through land leveling or slash-and-burn). At that stage, land scarcity hardly affected farm size. Farmland was free or cheap and was often not defined as property. In more egalitarian societies, farm size depended on what could be cleared and managed by a family or kinship unit. In more authoritarian societies, farm size depended on how much land-associated labor could be managed or compelled by a feudal lord, slaver, chief, or boss. In this initial era of farming, before sustained population growth and pressure (an era that lasted from the Neolithic settlement until perhaps 500 B.C. in parts of Asia, but well into the last century in parts of Africa and Latin America), there was little call for yield-enhancing crop science. On-farm crop development by seed selection happened, as did much learning about nutrient and water management. The pace was probably not fast, however; for all but a tiny elite, rural poverty remained the natural and inescapable order of life.

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[19] *Intensity of dollar poverty in a region is incidence (proportion of people consuming below $1 per day) times depth (their mean proportionate shortfall below $1); poverty is deeper in rural areas (Eastwood and Lipton 2004).*

[20] *Staples (cereals, starchy roots, bananas, and plantains) constituted just under 70 percent of calorie intake in developing countries in 2000 (FAO 2004a). In low-income countries proportions are higher (78 percent in Mozambique, 72 percent in China, and 69 percent in India and Nigeria during 1996–98), and among the rural poor highest of all (IFAD 2001, 23). Household consumption surveys typically show that, in the consumption budget for persons below a dollar-per-day PPP poverty line, at least 65–70 percent is food, and 50 percent is staples alone—both slightly more in rural than in urban areas (Deaton 1997; Lipton 1983).*

[21] *Some poverty reduction is feasible through productivity gains even on small, food-deficit farms. However, in much of southern and eastern Africa, land distribution remains very unequal, mass poverty persists, and significant farm sales are confined to 10–15 percent of farms (Jayne et al. 2003). In such conditions, for rapid poverty reduction, land redistribution is often needed, as well as employment-intensive agrotechnical progress.*

The age of ample land presumably ended for most of Asia's agricultural population by 500 B.C.–A.D. 100, calling forth a series of "blue revolutions" in water technology, spreading irrigation in the Yellow River and Yangtze basins, Mesopotamia, Egypt, much of India, and Sri Lanka (Bray 1986). Wittfogel (1957) implies that growing, organizable populations made authoritarian, nonfamily organization of farming and water politically sustainable. Boserup (1965) hypothesizes that widespread, organized agrotechnical change—whether Asia's blue revolution, the transition from slash-and-burn to organized land shaping and shortening fallows in Africa, or Asia's Green Revolution—is seldom exogenous (for example, due to spontaneously discovered or imported new technology) but is usually induced by rising labor–land ratios. Such rising ratios, and induced land and water scarcities, mean that almost everywhere, including Africa, yield enhancement has become more important than higher labor productivity in inducing farm-based poverty reduction.[22] As in Asia's Green Revolution, so in Africa: to raise entitlements for all groups of rural poor, labor productivity has to rise, but land (and in some places and at some times water) productivity has to rise faster.

A minority of the dollar-poor reside in urban areas, but for them also, farm output growth cuts poverty. It raises the supply of staples, keeping prices down. Small family-farm growth, in particular, restrains urban migration of unskilled labor and thus helps keep urban wage-rates rising and unemployment low. Strong evidence exists, both from national cross-section and single-country time-series data, that farm growth does more than nonfarm growth to reduce poverty—even urban poverty—except perhaps in Latin America, which has extreme land inequality and large areas of nonfamily farms (Thirtle, Lin, and Piesse 2003; Eastwood and Lipton 2000). As for the rural majority of the dollar-poor, most receive their primary income from family farming or labor on other family farms, and most who escaped poverty in early development did so via science-based, employment-intensive, family-farm income growth. Further, science-based small farm growth is the main motor for increasing income sources for those rural dollar-poor who do not derive their livelihood from family farms (most farm laborers plus the rural nonfarm poor). The rural poor get significant and rising proportions of income from hired farm labor (see page 5 and footnote 14); however, not only family but also hired labor per hectare is usually higher on smaller and family farms (IFAD 2001). Rural nonfarm activity, especially construction, trade, and transport, also contributes substantially and increasingly to rural income, including that of the dollar-poor (Reardon et al. 1998), and most rural nonfarm income depends on demand by family farmers.[23]

Given that most of the world's poor depend on small family farms, the following seems logical: poverty plagues small family farms, so enrich them through crop science. But why reject an alternative: small-scale family farming means poverty, so get the poor out of farming? After all, once mass rural poverty starts to recede, most of the remaining poor

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[22] *Africa is often seen as a continent of ample land and scarce labor. This was true 50 years ago, and there are still areas where smallholders leave arable land unfarmed because they lack enough labor to break, prepare, and weed it all. But this 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 at sharply rising break-in costs and environmental fragility, yet sharply falling net annual returns. To turn rural unemployment, low productivity, and low wages into labor shortages because technical progress bids up the demand for labor is the essence of both rural development and poverty reduction. 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.*

[23] *In some rural situations, many rural poor rely on remittances from family members who have moved to towns. Usually this is the migration of hope, rising sharply only after farm growth and some capital-intensification. However, mass rural dependence on remittances signifies the migration of despair if it is because smallholdings are unrewarding for lack of adequate shares in land, water, or technical progress (for example, South Africa). Such migration depresses urban wage-rates and denudes rural areas of innovators; hence, while it may briefly relieve extreme need, it seldom cuts chronic poverty.*

(and nonpoor) come to require expanded nonfarm income for further gains. Yet the developing world—while spangled with successes of family-farm- and science-led mass poverty reduction, followed by rural and then urban industrialization—is littered with failures of premature industrialization. The associated capital cost per workplace, given that the poor initially depend on work for extra income, is just too high. Except in a handful of entrepôt city-states (for example, Singapore) and mineral economies unusually successful both in responding to their poor and in managing their economic surpluses (for example, Botswana), there are virtually no examples of mass dollar poverty reduction since 1700 that did not start with sharp rises in employment and self-employment income due to higher productivity in small family farms. This is not driven by mass rural emigration (leaving behind more farmland, and hence income-earning work, per person); that happens later (see footnote 23).

For reasons long understood (Johnston and Mellor 1961; Johnston and Kilby 1975; Mellor 1976), it is wishful thinking to expect industrialization in the mass poverty heartlands before—indeed without—productivity growth on family farms. Such hopes are still common among elites both in developing countries and in donor agencies, and this helps to explain the collapse of aid to agriculture.[24] Yet, as illustrated in Asia since 1960 (and indeed in Europe during 1740–1900), urban industry develops a substantial role in employment generation, and hence poverty reduction, only after successful agriculture-led development. Rural nonfarm growth does offer substantial early prospects for improved employment and income for the dollar-poor (Reardon et al. 1998), but this normally results from demand through growth linkages. Rising farm income drives demand for extra farm inputs and for processing of extra farm outputs; above all, extra farm income produces consumption linkages to local construction, trade, and transport. Such demand-led, employment-intensive poverty reduction normally comes from initial productivity and income growth on nearby small family farms; large farmers, on the other hand, tend to devote more of their extra income to less employment-intensive urban commodities, and to imports (Hazell and Ramasamy 1991).[25]

Conversely, supply-led mass poverty reduction by the nonfarm sector prior to employment-intensive technical progress on smallholder farms has usually proved to be a dead end, characterized by (a) once-for-all exploitation of mines or quarries; (b) state-driven capital-intensive, and ultimately unaffordable, industrialization; or (c) distress diversification into other rural nonfarm sectors (where it pushes down wage-rates), driven not by higher local farm-based demand but by underused workers in stagnant agriculture as the population grows. Nonfarm expansion, especially as a cure for rural poverty, is normally a consequence of—not an alternative to—family-farm, employment-intensive development and expansion. China exemplifies this in extreme form. In 1959–63, disastrous famines followed forced, but failed, industrialization based on surplus extraction from collective farms without rapid farm growth. This contrasts with China's dramatic successes in cutting poverty in recent decades. This happened via rapid farm growth in 1977–84, as egalitarian decollectivization

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[24] *For agriculture, including forestry and fisheries, the proportion of sectorally allocable aid disbursed fell from 20.2 percent in 1987–89 to 12.5 percent in 1996–98 (IFAD 2001, 41). The proportion of OECD bilateral aid disbursed to agriculture fell from 12.4 percent in 1982–83 to 3.7 percent in 2002–03 (OECD 2004). Total aid disbursed to agriculture in 1990 prices fell from US$9.2 billion in 1980–84 (17 percent of all aid) to $3.9 billion (6 percent) in 2000 (OECD 2001). And total aid committed to agriculture under FAO's "broad" definition fell from 16.3 to 9.1 percent of aid in 1988–99, and, under the "narrow" definition, from 9.1 to 4.5 percent (OECD 2003).*

[25] *Farms of thousands of hectares and with scores, sometimes hundreds, of hired workers exist in Latin America and southern Africa, where great land inequality turns many rural poor into an almost landless "proletariat." Elsewhere this is rare. In most of Asia and Africa, large-scale farmers typically farm 10–30 hectares. Though hiring a larger proportion of labor than do small farmers, they too are usually family farmers; the family provides 40–70 percent of the farm's labor. As stated, however, larger farmers' income is less likely to be spent on rural nonfarm output.*

accompanied less extractive farm prices, continued successful crop science, and better irrigation. Rural poverty fell again in the 1990s, as farm success was followed by rural industrialization through township and village enterprises, and by somewhat relaxed restraints on migration.

A careful, updated estimate of global trends in dollar poverty since the 1980s shows the crucial role of agricultural growth in early mass poverty reduction: "China's incidence of [dollar] poverty was roughly twice that for the rest of the developing world [in 1981]; by the mid-1990s, [it] had fallen well below average. There were 400 million fewer people living on under $1 per day in China in 2001 than 20 years earlier, though a staggering half of this decline was in [1981–84], probably due to . . . China's [agricultural] reforms starting in the late 1970s" (Chen and Ravallion 2004, 15). However, without massive prior investment in irrigation improvement, agricultural research, and rural infrastructure, decollectivization alone could not have produced China's huge, employment-enhancing and poverty-reducing rises in staples output. At some 6 percent per year in 1977–85, this staples growth rise was far faster than in subsequent periods, in which China enjoyed much slower poverty reduction.[26] Results for India, Indonesia, and elsewhere (as well as cross-national estimates) confirm that growth is far more pro-poor in "mass poverty" countries when it is mainly in agricultural rather than other output and income. The link is weaker, however, where farmland is highly unequal, so that large parts of farmland and agricultural growth are not in labor-intensive smallholdings (Eastwood and Lipton 2000).

A possible objection is that—even if accelerated and normally science-driven farm growth is *necessary* to initiate mass poverty reduction—it may not be *feasible* or *sufficient* to overcome binding land and water constraints. Feasibility depends on (a) availability, quality, and distribution of farmland (and water); (b) crop, land, and water science; and (c) prospects for national and global trade and exchange, and their effects on farm sales and prices.

Suppose all these, including the science, are feasible. Further, suppose we—like the architects of the Green Revolution—see the task of initial mass poverty reduction as winning a "growth race" between population and the pile of food staples, and in fact do win that race. Even that will not suffice for mass poverty reduction without a corresponding rise in the poor's command over staple foods (or food "entitlements" [Sen 1981]). Even large increases in staple food productivity would do little to cut mass dollar poverty if they were confined to large-scale farms, using tractors and combines but few workers, and selling at government-boosted prices that the underemployed and near-landless poor cannot afford. Not just the world as a whole but even India and some other developing countries have large grain stores but at the same time mass hunger, because income levels among poor people—whether from employment or self-employment—are too low to provide them with sufficient market entitlements to staples.

Brilliant as it was, the Green Revolution was also lucky in the sense that while it aimed at increasing the availability of staples ("the pile of rice") it also happened to achieve higher income-based entitlements to staples for the poor. The early rice and wheat semidwarfs mainly suited nonpoor farmers in initially well-watered and productive areas, but successor varieties proved increasingly amenable to small, poor, employment-intensive family farmers in large areas of Asia and Latin America, some unirrigated (Lipton with Longhurst 1989; Smith and Urey 2002). Hence, in many areas, the Green Revolution raised not only the supply of locally available staples but also, in the same process, the demand for farm labor, wage-rates, and thus the work-based income of the dollar-poor, both among small family farmers and (often even more [Hazell and Ramasamy 1991]) among farm laborers. The lesson for future crop

[26] *However, there was "a further drop of 120 million in the poverty count between 1993 and 1996 [probably due to] the substantial, but short-lived, increase in 1994 in the procurement price for foodgrains paid by the government" (Chen and Ravallion 2004, 17–18).*

science policy is clear. When choosing among research paths, a high employment share in extra science-induced farm income should normally be seen as a gain.[27] For countries where the dollar-poor lose out if the demand for farm labor declines, aid-backed farm research should not support better combines, herbicides, and mechanical transplanters—or varieties whose advantages depend on these—unless the results can be shown to be cost-effective ways to cut poverty.

The Green Revolution's good luck was not limited to success in raising income-based entitlements, though its goal was to raise food availability. If the Green Revolution (where its widespread use was feasible) were to benefit all main groups of dollar-poor, it had—without being planned that way—to walk two tightropes. The three main groups of dollar-poor families depend for income mainly on small farms, hired farm labor, or nonfarm (including urban) economic activity. To improve welfare for all three of the major dollar-poor groups, advances in applied farm science must satisfy two conditions:

1. *The Price/Total-Productivity Tightrope*

   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.[28] 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.[29] 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).[30] Yet, unless the extra food brings the price of staples down, the nonfarm poor, especially in towns,[31] may not gain much 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? and (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 substantial majority of the rural poor in most of Africa and Asia, spend significant portions of their extra income on more (and better) staples, eating much of the extra food themselves.[32]

2. *The Wage Rate/Labor–Land/Productivity Tightrope*

   In the early stages of development out of mass poverty, for new science to help poor farm laborers (a lot), it must raise output per labor-hour (a lot) but output per hectare (a lot)

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[27] *Peak-season labor needs and HIV/AIDS do not justify farm science that cuts demand for labor (see page 12).*

[28] *Meeting the condition is one escape from the agricultural treadmill. The case is clear if farmers grow only food staples. If they can shift to cash crops, new staple-crop science can cut staples prices somewhat more sharply than it raises staples TFP, yet help poor farmers if they can then profitably shift some land into cash crops.*

[29] *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 a country's domestic farm output changes (and the research affecting them) still have a major impact on national prices.*

[30] *The condition is somewhat modified for staples produced by dollar-poor farmers who eat almost all they grow.*

[31] *Some rural nonfarm poor can gain from higher demand for local nonfarm products (especially construction, retailing, and transport) by farmers as their poverty recedes.*

[32] *How can a deficit or subsistence farmer buy more inputs, even if research makes them profitable? The answer, in part, is the counter-effect of the farmer needing less money for staples because research raises the productivity of growing rather than buying them. Deficit farmers normally get much of their income from nonfarm activities or remittances, which can be diverted from staples purchases to buying new inputs. However, there is a credit problem in the early years of input-driven productivity growth.*

more. In a substantial and increasing majority of farming situations in developing countries, there is hardly any "spare" farmland worth cultivating.[33] With A (area of cropland) 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.

The condition is tighter if supply of farm labor grows. The number of persons of prime working age (15–64 years old) is set to rise at around 2 percent per year in most of South Asia and Sub-Saharan Africa for the next 10–20 years, and by over 1 percent even in rural areas. For farming to help raise demand for labor faster than supply, with cropland scarce, scientific advances must raise output per hectare by at least, say, 1.5 percent per year faster than output per worker.

This is not to say 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; otherwise, 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.[34] 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 nonfarm growth and emigration have pulled wage-rates up, should researchers—like farmers—seek to raise labor productivity faster than land productivity.

That the Green Revolution, after a faltering start, came to meet the needs of the poorest was not wholly luck. Early critics—and farmers—stressed the need for more robust varieties, to reach both "difficult" regions and risk-averse poor farmers. Public-sector, public-purpose researchers addressed these criticisms (Lipton with Longhurst 1989), where private counterparts would have been pressed to focus on better-off, more secure customers.[35] However, brilliant as the science was, it was also lucky that the Green Revolution semidwarfs proved so amenable to crossing for better resistance to main pests and diseases and, further, that successive semidwarf varieties walked the two tightropes. Small, dollar-poor farmers found that the new seeds allowed them to 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.[36] Dollar-poor farm workers found that larger harvests, more water control, and more fertilizer use all

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[33] *See footnote 22. The argument also applies to water productivity, in the rising proportion of farm situations where the water constraint is biting or intensifying.*

[34] *In such areas research might aim to raise labor productivity at the peaks but land productivity in the slack season.*

[35] *The biotech revolution is much more private-sector based, and its critics are more fundamentalist. Much institutional and incentive work is needed if biotech is to "re-run" the Green Revolution's adaptability to poor farmers' needs.*

[36] *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 manipulation by governments of output and input prices. Speeding the much slower steps in this direction in Africa is a major part of the few recent successes in spreading science-based agricultural progress there.*

raised their productivity somewhat—but the productivity of scarce land much more. Therefore, the demand for their labor rose significantly, while their staples requirements became cheaper. The urban, and rural nonfarm, dollar-poor gained from the restraining effect of the extra staples output, generated by the Green Revolution, on the price of food staples. So all three groups of dollar-poor saw their entitlements to food staples—typically absorbing over half their incomes—substantially raised by the Green Revolution.

Moreover, especially in its later years (1975–85), the Green Revolution reduced 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. 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.

Finally, the Green Revolution in Asia, from about 1975–80, 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 1964–75. Today, in both China and India, the return to crop science is higher in many "backward" regions, where many dollar-poor remain, 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).

3. Mass poverty can be slashed by farm-based progress given three predisposing, perhaps necessary, preconditions: on technology, land/water use and distribution, and farm incentives.

We should be cautious about long lists of prerequisites for small-farm growth. Such lists induce undue pessimism and inhibit action. Widescale pro-poor progress based on crop science for small family farms does not initially need good roads, credit, extension, and so on, helpful though they are. Indeed, more of them (as Asian experience shows) are effectively demanded by farmers in the political and economic marketplaces, *after* crop science raises yield and profitability sharply.[37] However, the following preconditions are almost always essential:

1. Farm TFP growth via locally profitable, and (usually) employment-intensive, technology normally requiring better seeds, some water control, and agronomy; often, irrigation, better pest control, and more fertilizers; but seldom tractors or herbicides, unless farmland expansion is constrained by lack of plowing or weeding labor, as is the case in a few places in West Africa (see arguments 4–5).
2. Not-too-unequal land and water, sustainably used (see arguments 6–7).
3. Farm production patterns that are not too vulnerable to disabling of incentives by domestic or overseas policies that sharply erode or distort farm prices; unshiftable initial conditions, such as imposed gross land inequality; or inbuilt adverse trends, such as poor farmers or workers not just producing but being locked into commodities where science-induced progress induces more-than-offsetting price erosion—for example, tea, coffee, cocoa, and oilpalm (see arguments 8–9).

[37] *Especially if farmland is very unequal, the farmers who get new technology first, and press for better input and output markets, will concentrate on improvements other than those most important for poor farmers. For poor farmers to share fully in new market prospects following technical progress, public policy interventions are usually needed.*

Can these preconditions be met? Three sorts of things can help or hinder. Most important are policies and laws affecting institutions of, and support and incentives for, crop and water science, land reform and land use, and globalization. Second is demographics, specially the evolving ratio of workers to dependents (see argument 10, pages 20–21). Third—and often adaptable if the other two are right—is local agroecology and initial infrastructure (including markets) in each of the remaining poverty heartlands.

4. Formal science is increasingly needed to satisfy the technology precondition.

During the millennia, without sharp secular population growth, local farm technologies almost everywhere improved by informal, farmer-to-farmer and area-to-area spread of experiment and innovation. This worked even after "revolutionary" changes in the concepts behind local farm 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 (for example, in Kano, Nigeria [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 also changed. Better natural resource management (NRM)[38] 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.[39] From 1730 in Europe, and most dramatically since the early 1960s in Asia, it was 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, farm workers, 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, eds. 1977), public-purpose, not-for-profit finance encouraged scientists to realize the Green Revolution model, and hence to attack poverty.[40] Major yield enhancement almost always required more nitrogen fertilizer (N-fertilizer). However, farmers will not apply much of this if it is likely to make the plant fall over. Therefore, breeders produced short-strawed varieties of rice and wheat, to which much more N-fertilizer could profitably be applied (and with a higher harvest index). From the late 1960s, the emphasis moved increasingly to further applications of Mendelian genetics (with plant pathology, entomology, and so on) to immunize successive

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[38] *NRM is farmer-led agronomic control of nutrients, water, and biota (for example, organic manuring, valley-bottom micro-irrigation, terracing, crop rotation and mixing, and removal of insect egg masses).*

[39] *Though the Consultative Group on International Agricultural Research (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).*

[40] *A commentator points out that similar public research drove much progress in farming in 19th-century developing countries, for example, Liebig's work on agrochemicals led to modern fertilizers. Also, well before Darwin or Mendel, public botanical gardens led to systematic plant selection and breeding; more recently U.S. land-grant universities were a model for crucial work in India and elsewhere. The commentator traces current inattention to such history—and acceptance of the much lower ratio of research outlay to farm output in today's developing countries—to "excessive faith in [cross-border and cross-ecology research] spillovers, and Thatcherite ideas of the role of the private sector" (personal communication with author).*

new varieties against successive new pest biotypes (though with less success against abiotic stresses), and to spread them into some less favorable environments.

The Green Revolution has slowed sharply, as has yield growth, since the 1980s (Lipton 1999; IFAD 2001; FAO 2004b), without doing much for scores of millions of small family farms with little water control, especially in Sub-Saharan Africa. There, 3 to 4 percent of cropland is irrigated (as against about 40 percent in South and East Asia). In the field, leading varieties and landraces of the main African staples (white maize, millet, sorghum, cassava, and yams) are probably low-yielding because evolutionary reward (and farmer selection) over many generations has 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.[41]

5. The tasks and organization of farm science need radical reform to improve pro-poor results, 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[42] yields less. Despite success in parts of rainfed Asia and some of Africa (mostly maize hybrids), past evidence suggests severe limitations on 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 tubewells; micronutrient depletion; monocultures reducing biodiversity yet stimulating low-level buildup of new pest biotypes;[43] and restrictive responses to overconcentration 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 now 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

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41 *For many African situations, it is claimed that good improved cultivars are available, yet farm-to-station yield gaps huge (anecdotal evidence claims 90 percent for maize in Malawi). The famous Herdt–International Rice Research Institute (IRRI) Asian gap studies may, 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.*

42 *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).*

43 *Breeders have largely kept ahead of new epidemics (though there have been nasty shocks—for example, with rice, the tungro epidemic [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.*

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. *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)[44] have largely remained "Cinderellas" of transgenics research, though China, where this research is largely public-sector, may create major exceptions. Can new basic science, organized and applied as crop and field technology, serve poverty-reduction goals and complement conventional plant breeding and noncrop 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 needs to be adapted to eradicating poverty among many poor 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 to shifting donor priorities in ways that inhibited planning by researchers, and was diverted by donors away from crop improvement towards a series of less productive, and sometimes fashion-driven, aims (World Bank 2004a). As for applied biotechnology, perhaps 90 percent of work is now in a few big companies, which naturally protect their research, including plant varieties. Since 2000, there have been improvements: moves to re-focus the Consultative Group for International Agricultural Research (CGIAR) and to reverse the long fall in well-targeted resources for public plant breeding; talk (and some action) on public–private partnerships; and generous, if marginal, poverty-related uses of a few percent of their resources by big biotech companies. However, if private transgenics is to complement public purposes and to address the needs of the poor, a much 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 PR 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 cofinancing; but otherwise be mainly financed by aid. Present alternatives are unpromising.[45]

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

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44 *This is changing both in national programs (for example, maize streak virus GMOs at the University of Capetown) and at international agricultural research centers (for example, maize at the International Institute of Tropical Agriculture [IITA], rice at IRRI, sorghum, chickpea at the International Crops Research Institute for the Semi-Arid Tropics [ICRISAT], and so on).*

45 *One reviewer writes: "GM drought resistance will require a huge investment and I don't see the private sector doing it . . . . The CGIAR Challenge Programs on genomics [and water] may be too dispersed [given limited funding]" (personal communication with author).*

companies can generate transgenics-based crop science to address key unsolved problems of the farming poor.[46] However, its applicability is squeezed between (a) the shortage of new water science, and (b) the farming poor's intensifying water crisis, as water is diverted to meet pressing domestic needs, and probably as global warming cuts rainfall reliability and increases evapotranspiration (IFAD 2001). Transgenics-reinforced crop science may well improve resistance to moisture stress (for example, Nuffield Council on Bioethics 2004, 3.42) and, later, perhaps (polygene) water-to-output conversion efficiency. Yet this must be complemented not just by water-market and institutional change (World Water Council 2000) 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 (essential) biotech-based, water-economizing attack on poverty 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.

6. The land/water distribution precondition for family farming to cut mass dollar poverty, met in much of Green Revolution Asia, is violated in much of southern, and some of eastern, Africa.

This violation is due to the historically extreme inequality of farmland and water, and in some countries to considerable inequality within traditional land systems (for recent survey work see Jayne et al. 2003) or to the politicized economy of land redistribution to yeoman politicians.[47]

Regions with mass poverty, but where family farming has been subverted by history, need to get their large, low-employment landholdings to shift towards not-too-unequal family farms (as consensually as is feasible). Land reform has large, under-rated achievements in reducing mass poverty, where incentives and technical prospects for post-reform family farms are right (IFAD 2001, 73–90). Land reform remains urgent in Latin America and southern Africa, and in many transitional economies. Some countries—first and most dramatically China in 1977–84, but later Albania, Armenia, Romania, and Viet Nam—have addressed the central issues of egalitarian privatization of state and collective lands, but most have not.

7. The land/water sustainability precondition is most threatened by crop expansion into marginal lands.

Some aspects of intensification raise serious environmental concerns: loss of biodiversity, without adequate safeguards (good, duplicated ex situ

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[46] *See Nuffield Council on Bioethics 2004. 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 of patents for provitamin-A-enriched rice, which requires transgenics and addresses a key nutrition problem affecting millions of poor people.*

[47] *The land/water distribution precondition is also violated in much of Latin America and West Asia/North Africa (WANA); there, however, dollar poverty is less prevalent (though more so than would be predicted from GDP per person), and nonagricultural escape is easier. Across main developing regions, the latest (post-1990) FAO Agricultural Censuses indicate that the unweighted country-average Ginis of distribution of operated farmland were 0.49 for Sub-Saharan Africa (from 11 available country censuses); 0.71 for WANA (from 8 censuses); 0.59 for South Asia (from 5 censuses); 0.53 for East and Southeast Asia (from 7 censuses, excluding China); 0.75 for the Caribbean (from 8 censuses); and 0.84 for mainland South and Central America (from 12 censuses) (Eastwood, Lipton, and Newell 2006, forthcoming).*

collections, and sometimes in situ conservation areas), inappropriate or excessive pesticide use, water and plant nutrient depletion due to poor recycling of water and (especially in monocultures) of plant nutrients, salinity and waterlogging, and nitrate and nitrite buildup in drinking water imperfectly separated from excess nitrogen fertilization and ill-drained farm water. However, it is science that can, and does, address such matters—not generalized anathemas by the well-fed against all intensive farming. These make little environmental sense in general. Yield growth, based on much higher inputs of fertilizer and managed water, remains the only hope to save Africa's soils, water, and biota from uncontrolled expansion of cropping into marginal lands. However, the above specific environmental concerns, while not obviating the environmental need for yield-increasing intensification through innovation in crop science, may narrow the acceptable means to that end.

8. Farm supports in Europe and the United States, and recently in emerging Asian countries like Japan and South Korea, have cumulatively increased, undermining incentives for developing-country agriculture by drastically depressing farm prices.

The precondition for farm-based initial mass poverty reduction of no systematic incentive destruction was undermined by domestic policies in Africa, Asia, and Latin America until the mid-1980s. Policies to extract resources from farmers (to support industry and the state) turned prices, subsidies, and support, such as road, health, and education provision, heavily against rural areas and farmers and in favor of capital use—that is, against employment (Lipton 1977; Krueger, Valdes, and Schiff 1996).[48] Most developing countries have greatly reduced such destruction of incentives to employment-intensive farming. However, the baton of such incentive destruction has passed to the North. First, familiarly and increasingly,[49] state subsidies and protection stimulate Northern farmers to overproduce, glutting world markets and reducing incentives to Southern farmers. Second, perhaps even more seriously, farm subsidies and protection in rich countries induce Northern farmers to pay for more national science, to produce yet more output that would not be commercial at free prices. This output compounds the effect of directly subsidy-induced overproduction in undermining farm incentives for the South. Third, global science is diverted away from the farm goals of the poor (notably employment-generating paths to higher yields of cheap staples that are more robust under moisture and biotic stresses) towards demands inflated by Western farm support—from rich farmers, intermediary processors, and supermarkets—for labor-saving production via herbicide-tolerance, longer shelf-life, and so on. Even in poor countries, large, low-employment farms get technology spin-offs from all this, but it undermines employment-intensive small family farms, both by scientific neglect and by subsidized and science-inflated competition.

To some extent, therefore, the prospects of better crop science to help the rural poor in globalizing economies depend on agricultural trade and policy reform in OECD nations. Some will think this is too gloomy a view. After all, the Green Revolution slashed poverty in Asia despite already massive OECD price distortions glutting world markets and sabotaging prices and incentives for many staples and for other temperate or temperate-competing crops—and despite domestic price regimes that, on balance, made agricultural production in Asia even less rewarding. This was because, in developing

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[48] *So how come there was a Green Revolution? It spread dramatically only where a good proportion of such extracted resources was plowed back into science-based farm investment, mostly as irrigation and research. Leading scientists, such as Norman Borlaug, and thoughtful ministers, such as India's C. Subramaniam, did much to bring this about.*

[49] *See Eastwood, Lipton, and Newell (2006, forthcoming): "In 1995, OECD agricultural subsidies to producers totaled US$182 billion, or 40 percent of production. OECD farm producer prices were 66 percent above border prices (de Moor 1996). Subsidies reached $248 billion [per year] in 1999–2001 (Ricupero 2003)."*

countries, prices of domestic staples, including transport costs, usually remained competitive with dumped OECD exports, especially under Green Revolution conditions. Rises in output per unit of input—and, in later stages of the Green Revolution, in robustness to pests—achievable on family farms as a result of the new varieties, were enough to outweigh the falling prices of farm outputs relative to inputs.[50] In addition, while in general extractive from agriculture, most Asian governments kept and used the power to use stocking and other policies to stop farm price falls in the face of import surges. None of these safeguards, against subversion of pro-poor effects from farm science by OECD dumping, is powerful in the poorest countries today. Some (those in food deficit) can mitigate the disincentives by focusing on crops that are consumable on or near farms in remote or ill-connected areas that rely on bad and costly transport for protection, but at huge efficiency cost.

Most of Sub-Saharan Africa and many parts of Asia find it increasingly hard to compete against dumped staples imports, especially as international (though in Africa not national) transport costs per unit of output have fallen since the 1970s. The range of Northern farmers stimulated into dumping via farm support has been extended by European Union (EU) enlargements and by the U.S. Farm Bill of 2002. U.S., and recently EU, reforms are gradually switching farm support from a production to an area basis, but this switch applies much less to crops where developing countries are most competitive: crops such as cotton, sugar, and tobacco, as well as some main staples. The countries joining the EU in its 2004 enlargement (and those at the top of the waiting list) are more agricultural and less competitive than existing EU members. While temporarily excluded from much EU farm support, in the medium term the newcomers will add to the pressures for its continuance, and to the sources of overproduction from which developing countries suffer. Yet domestic OECD fiscal and consumer pressures increasingly combine to oppose the self-defeating farm supports. Aid agencies and crop scientists should lend what support they can; their outputs, too, are devalued and distorted by Northern farm supports. Oxfam's greatly increased emphasis on the harm done to the world's poor by cotton and sugar subsidies is welcome and may, with other pressures, have some effect.

9. In rich countries, small-scale family farmers (often relatively poor there) are a major effective pressure towards farm supports, which impede the absolute poor in poor countries—as family farmers, farm workers, and usually food consumers—from reducing their poverty.

Political economy, not malice, is at work. Mancur Olson has argued that in lobbying, "small is effective"; small groups can more readily collect fees and subscriptions, as no member can confidently (or, as a rule, secretly) free-ride on the contributions of others. Indeed, major parts of U.S. and EU farm support are captured by a few wealthy farms (see, however, footnote 16). However, it is small and family farms in the North that perpetuate its farm support regimes. The few rich farmers need support from many others to acquire political clout (for example, in France, to block roads with tractors when farm support is threatened). It is relatively poor family farms that, in democracies, underpin rich farmers' lobbying for ever-greater farm support. It is "saving" the family farm, with its supposed contribution (for example) to the French landscape, culture, and "la France profonde," that motivates many urban people to accept the costs of farm support. Nevertheless, the concentration of farm size and the decline in family and self-employed farm personnel as a proportion of the farm workforce—and probably the decline of, at least, small-scale family management—has

[50] *This was due to rising supply of farm products (caused both by the Green Revolution itself and by increasing farm support in the OECD, directly via incentives to OECD farmers and indirectly as new farm research for them was stimulated) and, therefore, to rising demand for farm inputs to grow them.*

been faster in most of the EU than under most of the less-protectionist farm regimes of the Cairns group[51](FAO 2004b; ILO 2004).

To reason with the advocates of farm support—and hence to reverse the resulting anti-poor depression of farm prices and distortion of farm science—it is essential to understand the persistence, evolution, and growing power of family farming during the evolution from very poor, through emerging, to developed polities and economies. Though rising capital/labor ratios in economic development mean that very small farms come to operate less and less of the farmland, this does not mean that family farms die away (see the data on Europe and North America on pages 4–5). Indeed, their persistence, growing political clout, and relative low incomes, rather than possible "Olsonian" organizing advantages of a few giant farmers and their lobbies, explain the persistence and scale of farm support and protectionism in OECD countries, despite the huge damage not only to the absolute poor in developing countries but also to consumers, taxpayers, and efficient growth in developed economies. Further, as poor developing countries (normally based on smallholder growth and mass poverty reduction) emerge from underdevelopment and become Koreas or Mexicos, their family farmers also use their growing power to get the "OECD drug" of farm support. This harms both the impoverished farmer/farm worker populations of remaining mass poverty countries, and their governments' bargaining power, at the World Trade Organization (WTO) Doha round and subsequently. This "family farm logic" is at the root of farm protectionism as an enemy of poverty reduction. The OECD and emerging-country family-farm lobbies will not respond to economic theory alone, however valid. If the above logic is tackled, and the lobby is reasoned with and shown alternatives, victory is possible.

10. Remedies are urgent, because poverty reduction will become much harder after the closure of the window of opportunity created for developing countries by the population slowdown, with its temporary (30- to 40- year) but sharp effect in cutting the dependency ratio.

In East Asia, the effect of new farm technologies in reducing poverty incidence in 1965–2000 was much amplified by the falling dependency ratio (see footnote 9). Lower proportions of dependents were supported by fast-rising numbers of workers, for many of whom the new farm technology provided rising employment income. The fertility reductions that amplified this process[52] came somewhat later to South Asia and Africa but are now sharply cutting dependency ratios for poor countries in these regions too. 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 estimates,

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51 *The Cairns Group, set up in August 1986, now includes 17 developed and middle-income countries, together accounting for 23 percent of world farm exports. It is committed to achieve "a fair and market-oriented agricultural trading system [and] to ensure that the next WTO agriculture negotiations . . . put trade in agricultural goods on the same basis as trade in other goods. All trade distorting subsidies must be eliminated and market access must be substantially improved so that agricultural trade can proceed on the basis of market forces" (Cairns Group 1998).*

52 *The process began with big declines in infant mortality rates during 1945–60 because malaria was controlled and nutrition improved. This first raised dependency ratios, but as the population of "saved" infants grew into working age, the rise steadily slowed. By the 1970s in most of Asia and by the 1980s in Africa, fertility was falling, and so were dependency ratios.*

53 *Data are from ECOSOC (2004). HIV/AIDS mainly hits infants and persons aged 15 to 30 years. The effects on the dependency ratio are offsetting.*

54 *In 1962–90, the declining dependency rate added 1.7 percent per year to growth of income per person in East and Southeast Asia (Bloom and Williamson 1997).*

taking account of HIV/AIDS.[53] They reveal a window of opportunity for growth[54] and poverty reduction. If the conditions on land and water use, farm technology, and incentives are roughly met—providing, as earlier in East Asia, substantial extra income-earning chances for the rural poor—the ideal time for family-farm-led poverty reduction is about 2000–40. If those chances are not provided by crop science and appropriate policy, the extra workers will face downward pressure on rural wage-rates or employment, and the opportunity will be lost after 2030–50,[55] as aging populations put the dependency ratio into reverse (that is, it starts to rise again).

Why was the opportunity seized in East Asia? Irrigation and new crop science meant that the extra workers found work on family farms, with rising rewards per hour worked. Many could thus pull their (relatively dwindling) number of dependent relatives out of poverty. With a less employment-oriented, or slower, path of agrotechnical progress, the rising supply of workers would have faced more sluggish farm demand and would have earned far less income. The techniques introduced by new crop science, too, will need to be employment-intensive—to walk the labor–land productivity tightrope. Employment-related goals need to be incorporated systematically in crop research planning, even in most of Sub-Saharan Africa, though with due allowance for local and seasonal variation in labor supply.

11. The poor potentially gain from globalization, but such gains are often small, and sometimes there are losses. Can crop science for family farms help?

In the narrow economic sense, globalization involves (a) the secular trend, however incomplete and interrupted, to de-restrict international flows of goods, services,[56] 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.[57]

What is the interaction between family farming, poverty, and crop science in the context of narrowly defined economic 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[58] should increase 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. Apart from growth effects,

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53 Data are from ECOSOC (2004). HIV/AIDS mainly hits infants and persons aged 15 to 30 years. The effects on the dependency ratio are offsetting.

54 In 1962–90, the declining dependency rate added 1.7 percent per year to growth of income per person in East and Southeast Asia (Bloom and Williamson 1997).

55 The date of the turning point varies by country, as did the earlier changes that set the whole process going (see footnote 52).

56 A highly relevant 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 nonglobalization of agriculture by OECD nations and the plea from developing countries that they too be allowed to compete!

57 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.

58 This includes investment by transnational corporations (TNCs). As Western complaints about call-center outsourcing indicate, 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 logic does not justify financial liberalization (Stiglitz 2003). "Hot money," without strong financial institutions and regulation, can destabilize growth, making the poor more vulnerable.

globalization should, within developing countries, make income distribution more pro-poor.[59] 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.[60] 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.

There is no space here to review the massive and controversial evidence, but on balance it is consistent with the view that since 1980 developing countries that liberalized trade faster enjoyed faster growth, bringing faster poverty reduction—but not (as predicted above) pro-poor shifts in income distribution. While preaching freer trade to an increasingly persuaded South, the North increasingly supported its own agriculture (see footnote 49). 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. This impediment was overcome by Asian net food importers in 1960–85, because the Green Revolution raised TFP in farming fast enough to overcome the effect of falls in farm output prices due to the 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.

Also, 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 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 both by recent examples (Reardon et al. 2003; IFAD 2001, Ch. 5) and by the history of processing, with timing and quality control, for smallholders in rubber, sugar, and tea (Binswanger et al. 1995). However, 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, Ross, and Sabot 1995).

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[59] *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])*

[60] *It is vital, however, that developing countries (public as well as private sectors) are able and willing to 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.*

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 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, 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.

4. Concluding Thoughts

Dollar poverty probably fell faster in 1960–90 than in the previous five centuries, and crop science can claim much of the credit. Yet both staples yields and (except in China) poverty reduction have languished since 1990, responding more slowly to economic growth than previously. Aid donors and recipients now agree that aid should be targeted to help developing countries halve dollar poverty incidence in 1990–2015. We are falling well behind that target. Since the late 1980s, aid to agriculture, on which most of the dollar-poor depend, has fallen in real terms by over two-thirds, while public-purpose crop science, at international levels and in most of the developing world outside China and India, has been cut back. Mass poverty reduction initially depends on widespread growth of farm productivity and employment income, and hence on specific scientific progress, usable by small family farmers, mostly in so far recalcitrant areas. Such science needs to see productive employment creation—not make-work, of course—in agriculture as a benefit, not a cost. There is a profound global common interest in farm science to remove the causes of mass poverty, which, in the midst of increasingly visible prosperity, is a sea in which terrorists swim, while weak states fail and drown.

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