# Crop science, poverty and the family farm in a globalising world
## Plenary Session, Brisbane International Crop Science conference, September 2004

Michael Lipton[1]

Abstract: Family farming, crop science and 'globalisation' together largely determine progress against poverty. Faster in 1960-90 than at any time in world history, such progress has slowed down. So have 'land reform' and science-based rises in small farmers' staples food productivity, while aid to agriculture has fallen by over two-thirds and farm prices have been further forced down (and farm science distorted) by EU and US farm policies. All these things hang together. Most of the world's poor are in, or employed mainly on, family farms. Big gains for *all* main groups of dollar-poor need, first, a special type of growth in farm productivity; partly by luck, the Green Revolution was of the right type. To resume and spread such processes, the tasks and organisation of pro-poor farm science need radical reform, especially for the crops and soil-water regimes of rainfed Africa, allowing for the new water crisis. Yet farm supports in Europe and the USA (apart from directly undermining developing countries' farm incentives) misdirect world farm science, shifting its goals away from the needs of the poor for employment-intensive, robust and water-economising farm yield growth. Privatisation of research has sharpened this misdirection; science requires new incentives, if the great hope of biotechnology is to cut world poverty. Today, paradoxically, the *relative*-poor among family farms in rich countries cause their governments to depress world farm prices. Partly by distorting science, that makes it harder to renew or spread the attack on *absolute* poverty. Remedies are urgent, to use a 'window of opportunity' in developing countries due to changing population structures, and to realise the poor's large, but too often subverted, gains from globalisation.

## 1. Prologue

Family farming, crop science and 'globalisation' together largely determine progress against poverty. Family farms are operated farm units in which most labour and enterprise come from the farm family, which in turn puts a significant part of its working time into the farm. Family farms have proved surprisingly resilient, often despite huge rises in size, even in the rich world – but small family farms dominate S and E Asia and sub-Saharan Africa, which in 2004 contain over 92 per cent of the world's 1.1 billion dollar-poor [World Bank 2004].[2] As in developed countries before 1900, so in developing countries since 1950: to kick-start the reduction of mass dollar poverty, accelerated growth of staples output on family farms is normally *necessary*. Whether it is *feasible* and *sufficient* depends on: (1) national political and economic incentives and institutions to create and apply appropriate crop science;[3] (2) enough land in the hands of the efficient farming poor; and (3) opening and widening markets. Many Latin American and Asian countries, notably China and India, have gone a long way on this path, but still have far to go. Much of Africa has hardly started. Progress is handicapped by rich-world policies towards agriculture, trade and science.

Increasingly complementing farmers' own experiments, formal crop science has played a huge role. However, despite continuing scientific advances, staples yield growth in developing countries has fallen

---

[1] Poverty Research Institute, Sussex University, Brighton, UK mlipton@onetel.com www.sussex.ac.uk/Units/PRU I am grateful to Tony Fischer and Jim Ryan for very helpful comments; I remain responsible for content and errors.
For unsourced statements or data, see [IFAD 2001] and [FAOSTAT and LABORSTA, both revised to Feb 2004].

[2] The dollar-poor, in any country and year, are those in households consuming, per person per day, less of a 'world average consumption bundle' than can be purchased with $1US (a purchasing-power-parity or PPP dollar) at 1993 prices. This assumes consumption distributed in proportion to 'need', within the household and across seasons – if not, dollar poverty is underestimated. Since a dollar buys more of a typical consumption bundle in developing countries than in developed countries, a person on the dollar poverty line consumes less than $1/day at official exchange rates, e.g. in India only about 20 cents. Acceptable nationwide household surveys, permitting dollar poverty estimated, exist for over 95 per cent of the population of the developing world. Poverty refers to a bundle of deprivations, of which dollar poverty is only one. See [Lipton and Ravallion 1995].

[3] As Jim Ryan emphasises,we should not forget the important role of livestock for the poor, especially the landless poor, nor the synergies between livestock and crop production. However, staple crops play an outstanding role in the production, consumption, and above all employment income of the poor.

sharply since the peaks of the 1980s. Investment – private, public, and aid-backed – in agriculture and its scientific and other infrastructures in developing countries has tumbled. This makes it harder for the remaining poverty heartlands[4] to benefit from the lessons of 1970-2000. Then, in much of East Asia, population slowdown, with falling dependency ratios,[5] massively slashed poverty via rapid rises in employment income and in the poor's command over food – but only because the extra workers were backed by science-based, job-creating and food-cheapening agricultural transformation. The remaining high-poverty areas of Asia and Africa are today enjoying a similar demographic 'window of opportunity'. Yet their extra workers are not being backed by comparable science-based agricultural transformation. The Green Revolution has faltered, before doing much for Africa's main crops, or for areas with little or no 'water control' – i.e. with neither irrigation nor farmer-managed methods to vary significantly the flow of rainwater to crops. International public spending on plant breeding has tumbled. Booming private investment in biotech has been directed principally at cutting costs for rich farmers in rich countries.

Accelerated globalisation (pp. 13-14) from the 1980s should have enhanced the market and trade prospects of the poor. Yet, outside China, dollar poverty declined much more slowly after 1990 than in 1970-90. Blame is shared by (i) discrimination against rural areas by poor countries' governments (though overt *price* extraction from *agriculture* is now much less than in the 1960s, inattention to infrastructure and basic institutions has become even more serious); (ii) the passive attitude of many African governments to new crop science and improved water control, (iii) the poisoning of developing-country farm incentives by developed-country farm support; (iv) the privatisation of science, without appropriate new incentives; (v) the interaction between these two, with incentives increasingly pointing farm science towards the subsidised products of the European and US non-poor. The last three factors are in large part due to political pressures from family farmers in Europe and the USA. Ironically, these farmers, often in *relative* poverty, are partly responsible for the declining success of family farmers in developing countries against *absolute* poverty. To address (i) - (v), a big reorientation of crop and water science is needed. There have been small improvements, but more radicalism is needed, e.g. in extending public-private partnerships beyond Third Way warm words, motivating companies to compete to attain public-purpose goals through revised profit incentives. Examples will be discussed later.

## 2. Argument

The argument is set out as eleven bald propositions. I provide a little evidence for them in sec. 3 below, but it is sketchy here, due to space constraints. Fuller evidence is in [IFAD 2001].

.

(1) **Whether small or large farms are more economic (as in developing and developed countries respectively), family farms have economic advantages, and tend to dominate**.

.

(2) **Dollar poverty will long remain mainly rural. Big gains for *all* main groups of dollar-poor need, first, a special type of growth in farm productivity; 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 organisation of pro-poor farm science need radical reform, especially for the crops and soil-water regimes of rainfed Africa**.

---

[4] The World Bank [2004: 11] estimates that in 2004 19% of the world's 1.1 billion dollar-poor were in China (concentrated in the west). UN [2003] estimates 30% in India (concentrated in eastern and central areas), a further 10% elsewhere in S Asia, and 29% in sub-Saharan Africa, over 60 per cent of them in six big countries, the first two desperately poor: DR Congo, Ethiopia, Nigeria, Tanzania and Uganda.

[5] The ratio of persons aged 0-14 or over 65 to persons aged 15-64.

(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**.

(7) **The land/water sustainability precondition is threatened by crop expansion into marginal land**.

(8) **Farm supports in Europe and the USA - and recently in emerging Asian countries (Japan, S Korea) - have cumulatively increased incentive destruction for developing-country agriculture, by drastically depressing farm prices.**

(9) **It is the relative-poor among family farms in rich countries that are preventing the remaining absolute (dollar)-poor - as family farmers, farmworkers, and usually as food consumers - in poor countries from renewing the attack on world poverty**.

(10) **Remedies are urgent, partly to use a 'window of opportunity' in developing countries: population slowdown's sharp, but temporary (30-40 year),[6] effect in cutting dependency ratios**.

(11) **The poor potentially gain from globalisation, but such gains are often reduced - and sometimes turned into losses – by faulty institutions connecting the poor with markets and information.**

## 3. The argument unpacked

(1) **While small farms tend to be more economic in developing, and large farms in developed, countries, in both cases family farms have advantages, and therefore - unless prevented - dominate.**

Small farms have lower 'labour-related transaction costs' – more well-motivated family workers per hectare, each able to find, screen, and supervise hired workers over a smaller area. Large farms have lower 'capital- and land-related transaction costs'; owners can more readily borrow, and can use equipment over many hectares. So small farms have advantages in early-developing countries, which can afford little savings and therefore capital per unskilled worker, and where prolonged population growth has made land-per person scarce.[7] Conversely large farms win out in developed countries, with more savings, capital, and (usually) good rural land per unit of unskilled rural labour. So farms are generally smaller in poor countries, and farm size tends to rise with economic development - though this is subject to historical and political distortions (e.g. colonial land grab) and their subsequent correction (e.g. land reforms) via coercive private or State action [Binswanger et al. 1995; Eastwood et al. 2005].

Despite big differences in farm size and technique, family management appears to dominate farming at all levels of development. We can infer this from data on (a) farm size [FAOSTAT], (b) distribution of farm labour force [LABORSTA] .

In **Europe** in 1990, national mean farm size was typically 20-30 ha (Greece 4.5, UK 70.2), with one-third of farms (occupying, typically, 5-10 per cent of farmland) smaller than 5ha. Most farms below 30 ha probably get most labour from the (owning or renting) managing family, and farms below 5ha are almost certainly family farms, in most cases part-time, except for a few thousand vegetable and tobacco farms.[8] Further - with combines, hireable farm services, and (increasingly) farm computers - many much larger farms can use mainly full- and part-time family labour. In France, FAOSTAT data show mean farm size in 1988 at 31ha, with 73 per cent of farms – on 92 per cent of farmland - above 5ha; all these numbers must have been higher by 1994, yet only 1 in 4 members of the farm workforce was an employee, the rest being 'employers' and/or own-account farmers. By 1998-2000, of 13 European countries with ILO work-

[6] After that, the ratio rises – and the window closes - as the numbers aged over 65 grow.
[7] 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 - except with costs, returns, and ecological sustainability all much less favourable than on existing farmland.
[8] In Italy and Portugal, over 75% of farms were below 5 ha; in Ireland and the UK, below 15 per cent.

force data, employees were a majority of the agricultural labour force only in Germany (51.5%) and Estonia (71.2%). Where, in 1998-2000, own-account farmers and contributing family workers are measured separately from employers, they still loom large in the European farm workforce.[9]

In **North America**, farms are typically much larger, averaging 187ha in the USA (1987) and 350ha in Canada (1991), with barely 6% of holdings (with 0.1% of farmland) below 5ha. Yet as long ago as 1964 I saw (in Montana) farms of over 1000 hectares where most of the work is done by family members. I'm sure most of you have seen the same in Australia, with average farm size (including pastoral as well as arable land) above 3500ha! In Canada in 1998-2000, only 3.1 per cent of the workforce was agricultural – and it comprised fewer employees (45%) than employers and own-account farmers (50.2%), with 4.5% contributing family workers. In the USA only 2.6% of workforce was agricultural, and 63% of these were employees; however, it is likely that most US farms get most of their labour from the family [Agriculture Fact Book 2001-2002 (2/03): http://www.ers.usda.gov/Briefing/FarmStructure/].

What of **developing countries**? Of their agricultural workers in 2000, 40% are in China, 21% in India and 14% in Africa South of the Sahara [FAOSTAT]. In **China**, where 67% of the workforce in 2000 (as against 78% in 1970) report agriculture as the main occupation, since the reforms of 1977-85 almost all farmland is distributed according to family size into household-responsibility farms. Despite very fast growth and mean farm size only 0.67ha, most Chinese workers still have the family farm as the main income source (i.e. are farmers, or their family members). **India** in 2000 had 60% of workers reporting agriculture as the main occupation (74% in 1970), but unlike China has many farm employees; in rural India in 1999-2000, households whose main income source was 'self-employment in agriculture' were 33 per cent of the workforce, almost the same as those reporting 'agricultural labour' as the main source (32%) [Sundaram and Tendulkar 2002: 43]. With average farm size in 1990 of 1.55 ha, and only 24% of holdings above 2ha - both figures must be even smaller today – and with most farm labourers getting significant income from own-account farming [Singh 1991], rural India remains family-farm country, as do Bangladesh and (even more) **sub-Saharan Africa**.[10] There, land in many areas is unequal and farm labour emerging and far from negligible; yet in Ethiopia – with 80 per cent of its 27 million 2000 workforce reporting agriculture as the main activity – 42 per cent of farm workforce were own-account farmers and 54 per cent were contributing family workers. **Latin America and Southern Africa** remain dominated by colonial patterns of extreme land inequality, so agriculture is dominated by larger farms and is far less labour-intensive than would be expected from still-high national labour/capital ratios; however, except in South Africa, more people report farming than farm labour as the main income source.

Hence, though few countries publish shares of employment, output or holdings in 'family farms' as such (or define them officially), data suffice to infer that the economic advantages of family overview prevail in farming - as they do in hardly any other major sector, even retailing - across a wide range of development levels, typical farm sizes, capital/land/labour ratios, and types of product and ecology. Family farming can be ousted by private or State force – colonial land grab, slavery, feudal serfdom, ethnic cleansing, compelled collectivisation – or by governments that shift incentives strongly against family farms, for example by making tenancy illegal or unattractive; but even against such interventions the economic advantages of family farming normally prevail in the long run, after much needless distress. Even in most highly-developed agricultures, many more farms, hectares and even production remain family-managed, and there are more farmers than farm labourers. Farming in the US and the EU shows economies of scale, and farm support payments - being proportionate to output or area - are heavily concentrated on a few

[9] Poland 87%, Austria 80%, Portugal 77%, Lithuania 71%, Latvia 57%, Spain 46%, Estonia 25%, Czech Rep. 12%.

[10] Those whose most important income source is rural labour, especially farm labour, are almost everywhere likelier to be below the poverty line – and, if they are, also deeper in poverty – than those whose main income source is farm operation. In South Asia and probably Latin America, rural labourers in poverty exceed farmers (in India in 1999-2000, similar numbers of rural households (about a third each) reported farming and farm labour as the main income source, yet about half the poor households reported farm labour, and about a quarter farming [Sundaram and Tendulkar 2002: 33]. This does not cut the role of small farms in fighting poverty; per hectare, labour use - even *hired* labour use - rises sharply as farm size falls, because of small farmers' lower transaction costs in managing labour.

*large* farms;[11] yet farming in most countries remains dominated by *family* farms [e.g. Baldwin and Wyplosz, ch.8]. Certainly family workers leave the land, in most cases faster than employers or labourers, but family farm management usually continues, with less labour-time (and more capital) per hectare. Economies of scale, while genuine, must be modest; otherwise, small farmer-owners would sell out faster. The tendency to larger farm areas in the USA has been consistent with continued dominance of family-farm over corporate management [http://www.usda.gov/factbook/chapter3.htm]. In England, from 1690 to 1831, though farmers were fewer than farm labourers, the ratio - a fair indicator of farm 'family-ness' - fell only very slowly, from 0.5 to 0.4 [Mingay 1968: 25].[12] In Asia, mean farm size has fallen during development, due to growing rural populations with partible inheritance, rising farm productivity, absence of scale economies, and land reforms. Asian mean farm size will eventually rise as development proceeds, but that need not cut the *share* of family farms in agricultural land, work, or even output.

The evolution of the family farm is thus clearly linked to economic development, with its concomitants of poverty reduction and ever-wider exchange. There are few subsistence farms left in the world; almost all small (and other) family farms are 'commercial', seeking profit, buying some inputs and selling some outputs, and often heavily involved with export crops such as tea, coffee, cotton and rubber. The proportions of inputs purchased rather than produced on the farm (e.g. inorganic fertilisers rather than manure), of outputs sold instead of consumed on the farm, and of farmers with secondary and tertiary education, all tend to rise with economic development. Meanwhile, normally *after* the initial rises in farm productivity, growth of the rural population[13] and workforce slows down; rising ratios of capital to labour erode, then reverse, the net advantage of small farms; and labour leaves the land. Those who choose to stay as farmers will be those who are more able, and willing, to manage larger farms. Even for highly developed agricultures, the USDA's Economic Research Service shows family farms persisting 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 US farms. Nevertheless, most of the remaining farms are family-run businesses with sales less than $250,000' [USDA 2003].

(2) **In countries with mass dollar poverty, 70% is rural; initially, big gains for main groups of dollar-poor (small farmers, rural labourers, urban poor) almost always require a special type of growth in family farm productivity; partly by luck, the Green Revolution provided the type needed.**

70% of world's dollar-poor are rural, and the projection for 2035 is 50% [Ravallion 2000]; rural shares in 'intensity of poverty' are substantially higher;[14] and in the poverty heartlands poverty is even more rurally concentrated. The dollar-poor get almost all their income from employment (hired or self-employed), 45-60 per cent of it in agriculture; and devote well over half their consumption to staple foods. To initiate major cuts in mass dollar poverty, a country almost always needs greater (i) employment (and unskilled wage-rates), (ii) command over less-expensive food staples. Productivity growth in small family farming alone usually has prospects to raise both, at low capital costs per workplace. Normally this *later* permits, and induces, further poverty reduction via cash-cropping, rural non-farm 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, at first, food staples - and in profitably sought and offered farm employment (including self-employment), mainly on family farms. Especially as land gets scarcer, that requires a technology-based agricultural revolution. Even if that works, there are

[11] The estimates of heavy concentration of farm support on 'large corporate' farms overstate their case: many of these are co-operative arrangements supporting many individual, often small family farms. Consulting the websites for the much-listed 'top twenty farm recipients' in the USA confirms this.

[12] In the UK as a whole, only in 1992 did 'farm employees' come to outnumber 'farm employers and own-account farmers' (by 50.9% to 49.1% of farm workforce) [LABORSTA: ILO EAO ind stat 1.xls]

[13] While it still grows fast, fragmentation of farms among offspring can mean that farm size falls. That is likelier as governments and/or markets reverse past colonial or collectivising land grabs via land redistribution. FAO Agricultural Censuses show falling mean farm size in much of Asia and Africa in 1960-90 [Eastwood et al. 2005].

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

quite stringent conditions (what I call the two tightropes) if all the main dollar-poverty groups - small farmers, rural labourers, the urban poor - are to benefit.

Before developing this argument, I set out an economist's paradigm of the evolution of farm size and ownership, and their interplay with poverty as well as with crop (and other farm) science and with globalisation (and other market enlargement). In very early development, there are few people per hectare of land, of fairly uniform quality, that can be made arable by applying labour (e.g. through land levelling or slash-and-burn). At that stage, land scarcity hardly affects farm size. Farmland is free or cheap, and is often not defined as property. Farm size depends in more egalitarian societies on what can be cleared and managed by a family or kinship unit, and in more authoritarian societies on how much labour, associated with land, can be managed or compelled by a feudal lord, slaver, chief or boss. The choice between family and top-down farm management is not closely related to land scarcity. In this initial era of farming, before sustained population growth and pressure – an era that lasted from the Neolithic Settlement until perhaps 500 BC 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.

The age of ample land presumably ended for most of Asia's agricultural population by 500BC-100AD, calling forth a series of 'blue revolutions' in water technology, spreading irrigation in the Yellow River and Yangtse Basins, Mesopotamia, Egypt and South India and Sri Lanka [Bray 1986]. Wittfogel [1957] implies that growing, organisable populations made authoritarian, non-family organisation of farming and water politically sustainable; Boserup [1965] hypothesises that wide-scale and organised agrotechnical change - whether Asia's 'blue revolution', the transition from slash-and-burn to organised land shaping and shortening fallows in Africa, or Asia's Green Revolution - is seldom exogenous (or due to spontaneous new science), but almost always induced by rising person/land ratios. Such rising ratios, and induced land and water scarcities, mean that almost everywhere – including in Africa[15] - yield enhancement has become more important than higher labour productivity in inducing farm-based poverty reduction. As in Asia's green revolution, so in Africa: to raise entitlements for all groups of rural poor, labour productivity has to rise, but land (and in some places and times water) productivity have to rise faster.

A minority of the dollar-poor is urban, but for them also, farm output growth cuts poverty. It raises staples supply, keeping prices down. Small family-farm growth, in particular, cuts townward migration of unskilled labour, thus helping to keep urban wage-rates rising and unemployment low. There is strong evidence, both from national cross-sections and from single-country time-series, that farm growth does more than non-farm growth to reduce poverty, even urban poverty – except perhaps in Latin America with its extreme land inequality and large areas in non-family farms [Thirtle and Piesse 2003; Eastwood and Lipton 2002: 36-8 and sources cited there]. As for the rural majority of the dollar-poor, most have income from family farming, or labour on others' family farms, as their main income source; and most who *in early development* escaped poverty 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 live mainly off their family farms: many farm labourers, plus the rural non-farm poor. The rural poor get significant and rising proportions of income from hired farm labour (the main income source for more of the rural poor than is the family farm [Sundaram and Tendulkar 2002: 43]). However, not only family but *hired* labour per hectare is usually higher on smaller and family

[15]Africa is often seen as a continent of ample land and scarce labour. This was true fifty years ago, and there are still areas where smallholders leave arable land unfarmed because they lack enough labour 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 cost and environmental fragility, yet sharply falling net annual returns. To turn rural unemployment, low productivity and low wages into 'labour shortage' *because technical progress bids up the demand for labour* is the essence of both rural development and poverty reduction. Temporary, local and anti-developmental labour shortages are of course part of the disaster of HIV/AIDS; however, were these to induce long-term labour-displacing and hence wage-reducing investments or policies, the disaster would be compounded.

farms [IFAD 2001]. Rural income, including that of the dollar-poor, also comes substantially and increasingly from rural non-farm activity, especially construction, trade and transport [Reardon, in FAO 1998], and most rural non-farm income depends on demand by family farmers, especially when such income sources are growing and has prospects to carry the poor out of poverty.[16]

From the fact that most of the world's poor depend on small family farms, I reason: 'Poverty plagues small family farms: make them more enriching through crop science'. Why reject an alternative, viz.: 'Family farming means poverty: get the poor out of it'? After all, once mass rural poverty starts to retreat, most of the remaining poor (and non-poor) come to require expanded non-farm income for further gains. Yet the developing world – while spangled with successes of family-farm-led, science-based mass poverty reduction *followed by* rural, and later urban, industrialisation - is also littered with failures of premature industrialisation. Its capital cost per workplace - and the poor initially depend on work for extra income - is just too high. Except in a tiny number of entrepot city-states (e.g. Singapore) and mineral economies unusually successful in both 'poor pressure' and management of economic surpluses (e.g. Botswana), there are almost *no* examples since 1700 of mass dollar poverty reduction that do 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 fn. 16). It is wishful thinking to expect industrialisation to *precede* science-based productivity growth, on family farms, in the mass poverty heartlands. Europe in 1740-1900 and Asia since 1960 show that, when urban industrialisation offers major prospects for employment (and poverty reduction), it is fairly late in already successful, agriculture-led development processes. Rural non-farm production does offer early prospects of improved employment and income for some dollar-poor [Reardon, in FAO 1998], but this depends mainly on demand via 'growth linkages' from local agriculture – demand for extra farm inputs, for processing of extra farm outputs, and above all for extra trade, transport and buildings. Such extra demands are much likelier to create extra employment-intensive income for the poor if they come from nearby small family farms and their employees; large farmers[17] tend to devote more of their extra income to less employment-intensive urban commodities, and to imports [Hazell and Ramasamy 1991]. Mass initial poverty reduction 'led' by the non-farm sector, without technical progress in agriculture, is often a dead end: once-for-all (and not very employment-intensive) exploitation of mines or quarries; State-driven capital-intensive industrialisation; or, driven by underused workers in stagnant agriculture, 'distress diversification' into other rural non-farm sectors (where it pushes down wage-rates) as population grows. Non-farm expansion, especially as a cure for rural poverty, is normally a consequence of family-farm, employment-intensive development and expansion, not an alternative to it. China exemplifies this in extreme form. In 1959-63 disastrous famines followed forced, but failed, industrialisation *without* rapid farm growth, yet based on surplus extraction from collective farms. That contrasts with China's dramatic successes in cutting poverty both in 1977-84, as egalitarian family farming spread alongside reduced extraction from farmers and continued successful spread of crop science and irrigation, and again in the 1990s as farm success was *followed* by rural industrialisation through township and village enterprises and the relaxation of restraints on mass townward migration.

A possible objection is: 'Accelerated farm, growth - science-driven, to overcome increasingly binding land and water constraints – may well usually be *necessary* to initiate mass poverty reduction. But is it *feasible* or *sufficient* '? Feasibility depends on farmland (and farm water) availability, quality, and equality; on crop, land, and water science; and on the prospects for, and impact of, trade and exchange, national

[16]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. Otherwise, mass rural dependence on remittances because smallholdings are unrewarding for lack of adequate shares in land, water and/or technical progress (e.g. South Africa) is the migration of despair. It depresses wage-rates; denudes rural areas of innovators; and hence, while it may briefly relieve extreme need, seldom cuts chronic poverty.

[17]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' farmers typically farm 10-30 ha. Though hiring a larger proportion of labour than do small farmers, they too are usually family farmers; the family provides 40-70% of the farm's labour. But larger farmers' income from this (and from land) is less likely to be spent on rural non-farm output.

and global, on farm sales and prices. Suppose all these, including the science, are feasible, and 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. That will not be sufficient without a corresponding rise in the poor's command over staple foods ('entitlements' [Sen 1981]). Even big rises in farm productivity of food staples can do little to cut mass dollar poverty, if they are confined to big farms, with tractors and combines but few workers, selling at government-boosted prices which the underemployed and near-landless poor cannot afford. Not just the world, but India and some other countries, have lots of grain in store – even, often, during 'famine' - yet also mass hunger, because the poor's income, from employment and/or self-employment, is too low to provide enough market 'entitlements' to staples.

The 'Green Revolution', brilliant as it was, was also lucky: it aimed at higher staples availability ('the pile of rice'), and partly by luck also achieved higher income-based staples entitlements by the poor. The early rice and wheat semi-dwarfs suited mainly non-poor farmers in lead areas; but successor varieties proved increasingly amenable to small, poor, employment-intensive family farmers in big areas of Asia and Latin America, some unirrigated [Lipton with Longhurst 1989; Smith and Urey 2002]. Hence the Green Revolution in many areas raised not only the supply of locally available staples, but in the same process the demand for farm labour, 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 labourers. 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 in the large majority of situations be seen as a gain, not a cost. Aid-financed farm research, for developing countries where large numbers of the dollar-poor lose out if the demand for farm labour declines, should raise the productivity of land and water faster than labour-productivity. It should not, as a rule, support better combines, herbicides, mechanical transplanters, or varieties whose main advantage is greater compatibility with these.

For 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 (in the developing countries where its widespread use was feasible) was to benefit *all* main groups of dollar-poor, it had - without being planned that way - to walk two tightropes. The main groups of dollar-poor families depend for income mainly on (1) small farms, (2) hired farm labour, (3) non-farm, including urban, economic activity. To improve welfare for all three poor groups, advances in applied farm science must satisfy two conditions.

- 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 on small farms (a lot) faster.*[18] New science usually raises farm supply of outputs, and demand for inputs. That makes outputs cheaper and inputs dearer: the ratio of farm output prices to input prices falls.[19] 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 – in 'total factor productivity'.[20] Yet, unless the extra food brings staples prices down, the non-farm poor, especially in towns,[21] may not gain much from new crop science.
- The **wagerate-labour/land-productivity tightrope**: eventually, in late development, rural emigration and wage rises impel farmers to combat labour scarcity by combines and herbicides. By then, mass rural labour poverty is a thing of the past. Until then, *for new science to help poor farm labourers (a lot), it must raise output per labour-hour (a lot), but output per hectare (a lot) more*. Science that does not raise output per hour (apart from hardly being progress or development) does nothing to make it attractive for farmers to hire more workers. Yet, in most farm

[18]Meeting the condition is one escape from the notorious 'agricultural treadmill'. The case is clear if outputs are almost all staples. If not, new science that cuts staples prices somewhat *mor*e sharply than it raises total staples factor productivity for poor farmers, can nevertheless help them if it raises productivity for cash-crops important for them.

[19]Globalisation 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 major impact on national prices.

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

[21]Some rural non-farm poor can gain from higher demand for local non-farm products (especially construction, retailing and transport) by farmers as their poverty recedes

situations in developing countries, there is little or no 'spare' farmland worth cultivating (see fn. 15).[22] With A (area of cropland) fixed, L (use of farm labour) can rise only if output per unit of area (Q/A) grows faster than output per unit of farm labour (Q/L): hence the above condition for total demand for farm labour, and thus the wage-rate, to rise. The condition is tighter if supply of farm labour grows. The number of persons of prime working age (15-65) is set to rise at around 2% per year in most of South Asia and sub-Saharan Africa for the next 10-20 years, and by over 1% even in rural areas. To absorb that, if cropland is scarce, scientific advance must raise output per hectare at least, say, 1.5% per year *faster* than output per worker. Yet the latter also must rise significantly; if not, farmers will displace hired workers by herbicides, tractors and combines.

That the Green Revolution, after a faltering start, came to meet the needs of the poorest was not wholly luck. Early critics - and farmers 'left out' - stressed the need for more robust varieties, to reach both 'difficult' regions and risk-averse poor farmers. Public-sector, public-purpose researchers addressed the criticisms [Lipton with Longhurst 1989] - where private counterparts would have been pressed to focus on better-off, more secure customers.[23] However, brilliant as the science was, it was lucky that the Green Revolution semi-dwarfs proved so amenable to crossing for better resistance to many biotic and abiotic stresses. That successive semi-dwarf varieties walked the two tightropes was further luck. Small, dollar-poor farmers found that the new seeds allowed them to turn their few resources into much more output of staple food. Total factor productivity far outpaced the fall in staples prices relative to the prices of inputs.[24] Dollar-poor landless labourers found that larger harvests, more water control, and more fertiliser use all raised their productivity somewhat – but the productivity of scarce land much more. So the demand for their labour rose significantly - while their staples requirements became cheaper. The urban, and rural non-farm, dollar poor gained from the restraining effect of the extra staples output, generated by the Green revolution, on the price of food staples. So all three groups of dollar-poor, in green-revolution areas, 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 both small-farm output and hence the demand for farm labourers. 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 a small extent, because the new seeds were increasingly able to produce short-duration or multiple crops in some conditions. Finally, the Green Revolution in Asia increasingly spread into hitherto untouched regions - raising entitlements there also for the dollar-poor as small farmers, farm labourers and urban employees - as researchers generated results for water environments less ideal than the irrigated deltaic and canal flatlands that benefited in 1964-75. Today, in both India and China, 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 et al. 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**. For wide-scale pro-poor progress based on crop science for small family farms, initially well-functioning roads, markets, credit, extension, etc. are helpful but *not* essential. That is because more of these desiderata (as Asian experience shows) are effectively demanded by farmers in the political and economic marketplaces, once crop science raises yield and profitability sharply. Essential preconditions, however, are:

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

[23]The biotech revolution is much more private-sector, 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.

[24]East Asia in the 1970s, and South Asia in the 1980s, saw major steps 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.

- farm TFP growth via locally profitable, and now usually employment-intensive, **technology** - requiring, normally, better seeds, water control, and agronomy; often, irrigation, better pest control and more fertilisers; but seldom tractors or herbicides, unless (as in a few areas in West Africa) profitable area expansion is constrained by lack of ploughing or weeding labour: see below, (4-5).
- not-too-unequal, sustainably used **land and water**, much (potentially) family-farmed: (6-7).
- **farm production patterns** not too vulnerable to disabling of incentives to employment-intensive farming, e.g. by domestic or overseas policies that sharply erode or distort farm prices; unshiftable initial conditions, e.g. imposed gross land inequality; or inbuilt adverse trends, e.g. for poor farmers or workers not just producing, but *locked into*, commodities where science-induced progress induces more-than-offsetting price erosion (tea, coffee, cocoa, oilpalm): (8-9).

Can these preconditions can 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 'globalisation'. Second is demographics, specially the evolving ratio of workers to dependents (sec. 10). Third – and often surmountable if the other two are right – is local agro-ecology, and initial infrastructure (including markets), in each of the remaining poverty heartlands.

(4) **Formal science is increasingly needed to satisfy the technology precondition**. Local farm technology in Europe, Asia, and probably elsewhere, during millennia with no or very little long-term trend growth of population, improved by informal, farmer-to-farmer and area-to-area spread of experiment and innovation. This worked even during 'revolutionary' changes in technology such as the Neolithic, mediaeval, and early modern 'agricultural revolutions' [Lipton with Longhurst 1989]. More recently, farmers' innovations usually sufficed to keep pace with population while the latter grew at up to 1 per cent or so [e.g. in Northern 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. While always necessary, farm-based innovation increasingly required support from formal, off-farm science. From 1730 in Europe, and most dramatically since the early 1960s in Asia, it was increasingly formal, science-based work that allowed TFP improvements to outpace population growth and land-water depletion, and to cut poverty.

It is, however, wrong to see farm research as purely client-induced and demand-driven. Whether it has something to 'deliver' to poor farmers, farmworkers, and staples consumers depends also on (a) prior development of basic science, (b) incentives to applied science. On (a), Mendelian genetics supplied a basic model for applied Green Revolution breeding; on (b) - though purely private profitability induced mainly labour-saving research for rich capital-intensive farms [Binswanger and Ruttan eds. 1977] - public-purpose, not-for-profit finance encouraged scientists to apply the Green Revolution model to attack poverty.[25] The aim, to keep 'the pile of staples output' growing ahead of population, turned out in most Green Revolution countries to be consistent with increasing the food entitlements of all main groups of poor (sec. 2 above). Yield enhancement almost always implied more N-fertiliser. But farmers will not apply much, 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-fertiliser could profitably be applied (and with a higher harvest index). From the late 1960s the emphasis moved increasingly to further applications of Mendelian genetics to 'immunise' successive new varieties against successive new pest biotypes and (with somewhat less success) against moisture stress, and to spread them into (some) less favourable environments.

The Green Revolution has slowed sharply, as has yield growth, since the 1980s [Lipton 1999; IFAD 2001; FAOSTAT], without doing much for scores of millions of small family farms with little water con-

[25]Prof. Tony Fischer rightly comments that similar public research drove much progress in farming in 19th-century developing countries, e.g. Liebig's work on agrochemicals led to modern fertilisers. Also, long before Darwin or Mendel, public botanical gardens led to systematic plant selection and breeding; more recently US land-grant universities were a model for crucial work in India and elsewhere. Fischer 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 Thacherite ideas of the role of the private sector'.

trol, especially in sub-Saharan Africa. There, about 3 per cent of cropland is irrigated (as against about 40 per cent in S and E Asia). In the field, leading varieties and land races of main African staples – white maize, millet, sorghum, cassava, yams – are probably low-yielding because evolutionary reward (and farmer selection) over many generations has gone less to high yields than to tolerance: for low nutrient inputs, severe and variable moisture stress, and locally dominant pests (from quelea to striga) that have received far less attention, from plant breeders or other researchers, than have insects, fungi and viruses.[26]

(5) **The tasks and organisation 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-favoured 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[27] yields less. Despite success in parts of rainfed Asia (pp.8-9) and some of Africa (mostly maize hybrids), past evidence suggests severe limitations on conventional plant breeding *alone*. Its sharp slowdown apart, recent successes seem relevant mainly to water-controlled areas (e.g. 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* build-up of new pest biotypes;[28] and restrictive responses to over-concentration of herbicide residues, and of some fertiliser-derived nitrates and nitrites, in water sources shared by humans and plants.

More promisingly, the basic-science breakthrough by Crick, Watson and others in 1954 is now feeding into a key *complement* to conventional plant breeding: plant biotechnology. In principle, this for the first time permits the identification, and insertion, into African crops hitherto evolved or selected for characteristics competitive with yield, of yield-favouring DNA sequences from other plants (or other life-forms). Unlike the Green Revolution, however, research in applied biotechnology is largely owned, exploited, and hence motivated privately, and is leading to the privatisation of much relevant knowledge. That shows in its priorities: herbicide resistance, valuably labour-saving in rich and labour-scarce developed rural areas, is likely to be poverty-*increasing* where weeding is mostly done by labourers who, if displaced, cannot readily find other work at comparable wage-rates; Bt-based resistance (e.g. 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; and the main staples grown and eaten by the world's poor (including *white* maize)[29] have largely remained Cinderellas of transgenics research, though China, where this research is largely public-sector, may create major exceptions. Can new basic science, organised and applied as crop science and field technology, serve poverty-reduction goals, complement conventional plant breeding and non-crop farm science to focus on yield enhancement and robustness promotion for main staples in rainfed areas? There are institutional and scientific issues.

Institutionally, the organisation of crop science nationally and internationally needs to be adapted to eradicating poverty among many poor family farmers. In the early Green Revolution, international agricultural research centres, and national centres in many Asian and Latin American developing countries, delivered a steady stream of high-yielding and pest-adapted varieties of rice, wheat and (hybrid) maize,

[26]For many African situations, it is claimed that good improved cultivars are available, yet farm-to-station yield gaps huge (anecdote claims 90% for maize in Malawi). The famous Herdt-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 is claimed.

[27]Some areas, however, were agriculturally backward because they were neglected by applied science, not because recalcitrant to it. In both China and India, *some* 'backward' areas now offer more growth, and more poverty reduction, per extra dollar of (non-transgenic) crop research than do the conventional lead areas [Fan et al 2000a, 2000b].

[28]Breeders have stayed ahead of new *epidemics* (with nasty shocks, e.g., for rice, tungro in 1972, BPHIII and successors). However, probably a few adapted pests, each causing small but significant crop losses, explain part of the fall in yields, with controlled water and nutrients, in IRRI research fields, and in farmers' fields in the Indian Punjab.

[29]This is changing both in national programs (e.g. maize streak virus GMOs at the University of Capetown) and at IARCs (e.g. maize at IITA, rice at IRRI, sorghum, chickpea at ICRISAT etc.)

mainly for water-reliable areas, but raising incomes of poor farmers, labourers 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, and was directed away from crop improvement towards a series of less productive, and sometimes fashion-driven, aims [Lele et al. 2003]. As for applied biotechnology, perhaps 90% 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 reform the 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 spinoff, 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 start from a mission to develop 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 and (b) yield, which should normally rise faster than labour-productivity (see above, sec. 2). Such contracts should be competitively awarded; interactive with, perhaps designed by, public agricultural research institutions, jointly with end-users; focused on applicability in low-income countries committed to genuinely additional research co-financing; but otherwise mainly financed by aid. Present alternatives are unpromising. As Fischer comments: 'GM drought resistance will require a huge investment and I don't see the private sector doing it .. [and] the CGIAR Challenge Programmes on genomics [and water?] may be too dispersed [given their limited funding]'.

Scientifically, I cannot comment as an economist, but recognise recent evidence that, even with existing inadequate incentives, biotech companies can generate transgenics *crop* science to address key unsolved problems of the farming poor.[30] However, its applicability is squeezed between (i) the shortage of new *water* science, and (ii) 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 [e.g. Nuffield Council 2004, para 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 by **new basic water science and engineering: the first 'blue revolution' since 500 BC-AD**. I am delighted that a quarter of these meetings are devoted to handling scarce water.

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 to a lesser extent Latin America, will carry over into the (essential) biotech-based attack on poverty in water-insecure areas of Africa and the Asian interiors. Radical innovation, scientific and institutional, is needed; but tearing down well-performing 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**. That is due to the historically extreme inequality of farm land and water, and the 'politicised economy' of its redistribution to yeoman politicians.[31]

[30] See [Nuffield Council, 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 of many millions of poor.

[31] It is also violated in much of Latin America; there, however, dollar poverty is less prevalent (though more so than would be predicted from GDP per person), and non-agricultural escape more conceivable.

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 feasible). Land reform has large, underrated achievements in reducing mass poverty, if technical prospects, and incentives, for post-reform family farms are right [IFAD 2001: 73-90]. Land or tenure reform remains urgent in Latin America and Southern Africa, and in many transitional economies. Some - first and most dramatically China in 1977-84, but later Vietnam, Albania, Armenia and Romania - have addressed the central issues of egalitarian privatisation 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 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 that 'communicates' with excess nitrogen feritilisation and ill-drained farm water. But it is science that can, and does, address such matters – not generalised anathemas against all intensive farming from the well-fed and ignorant. These make little environmental sense in general. Yield growth, based on much higher inputs of fertiliser 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 USA - and recently in emerging Asian countries (Japan, S 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 in Africa, and much of Asia, between Independence and the mid-1980s. Policies to extract resources from farmers (to support industry and the State) turned prices, subsidies, and support (e.g., road, health and education provision) heavily against rural areas and farmers, and in favour of capital use (i.e. against employment) [Lipton 1977, Krueger et al 1996].[32] 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, 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 mean that 'Northern' farmers will pay for more *national* science, to produce 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), and towards the demands also inflated by Western farm support - of rich farmers, intermediary processors and supermarkets for labour-saving production via herbicide-tolerance, longer shelf-life, etc. Even in poor countries, large, low-employment farms get technology spinoffs from all this, but it undermines - both by scientific neglect, and by subsidised and science-inflated competition - employment-intensive small family farms.

To some extent, therefore, the prospects of better crop science to help the rural poor in globalising 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 countries, prices of domestic staples including transport costs usually remained competitive with dumped OECD exports, especially

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

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 deteriorating the terms of trade. Also, 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 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 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 SSA and 'interior' Asia finds 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 EU enlargements and by the US Farm Bill of 2002. US 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 – often due to labour-intensity, favouring family farms: crops such as tobacco, sugar and cotton, as well as some main staples. The countries joining EU in the current (and the next proposed) enlargement are more agricultural and less competitive than existing EU members, and, while temporarily excluded from much EU farm support, will in the medium term add to the pressures for its continuance, and to the sources of overproduction from which developing countries suffer. Yet domestic 'Northern' fiscal and consumer pressures increasingly combine to oppose the self-defeating farm supports. Aid agencies and crop scientists should lend what support they can, since 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 sugar and cotton subsidies is very welcome and may, with other pressures, have some effect.

(9) **The relative-poor among family farms in rich countries help to prevent the remaining absolute (dollar)-poor - as family farmers, farmworkers, and usually as food consumers**[33] **- in poor countries from renewing the attack on world 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 US/EU farm support are captured by a few wealthy farms (see, however, fn. 14).

However, it is small and family farms in the North that perpetuate the farm support regimes. The few rich farmers need support from many others to acquire political clout (e.g., in France, to block roads with tractors when farm support is threatened). It is relative-poor family farms that, in democracies, underpin rich farmers' lobbying for ever-greater farm support - with its effect of diverting and distorting the pattern of incentive-responsive, increasingly private farm science. And 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 been faster in most of the EU than under most of the less-protectionist farm regimes of the Cairns group [FAOSTAT; LABORSTA].

(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 (30-40 year)**[34] **but sharp effect in cutting the dependency ratio** (defined in fn. 4). In East Asia, the effect of new farm technologies in reducing poverty incidence in 1965-2000 was much ampli-

[33] In the longer term, these gains as domestic agrotechnical progress in developing countries cut food prices [e.g. Pinstrup-Andersen et al 1976]; dumping of Western food surpluses – anyway unreliable – inhibits such progress, even if it cuts prices once-for all. However, in heavily staples-importing countries with little prospect of moving into staples surplus, such once-for-all cuts may well benefit the poor, as staples consumers, via lower immediate food prices, enough to outweigh the brake on domestic agricultural advance and thus later reduction of home food prices.

[34] After that, the ratio rises – and the window closes - as the numbers aged over 65 grow.

fied by the falling dependency ratio. 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 triggering this process[35] 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 99 dependants for every 100 people of prime working age Ethiopia; the projection for 2030 is 72. For Nigeria the dependency ratio falls from 99 to 67; for Bangladesh from 79 to 55; and for India from 71 to 58. These are recent estimates, taking account of HIV/AIDS[36], and demonstrate is a 'window of opportunity' for growth,[37] and for poverty reduction. If the conditions upon 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 – about 2000-2040 is an ideal time for family-farm-led poverty reduction. 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,[38] as aging populations put the dependency ratio into reverse (i.e. it starts to rise again). Where that happens, some of the blame will lie with developing countries, but the rich world will bear a heavy burden of guilt for destroying farm prices and distorting farm science.

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 labour-land productivity tightrope. The Green Revolution, luckily, did, but incentives to (privatised) plant science have changed, and few if any research institutions see employment as a goal, not merely a cost, of farm innovations or of the underlying applied research. We cannot count on the Green Revolution's luck. 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 exceptions.

(11) **The poor potentially gain from globalisation, but such gains are often small, and sometimes there are losses; can crop science for family farms help?** In the narrower economic sense, globalisation involves (i) the secular trend, however incomplete and interrupted, to derestrict international flows of goods, services, [39] money, labour and investment, and hence of science and technology; (ii) the consequently rising share of international flows in total flows; (iii) the further result that trade and investment outcomes, including research patterns, are increasingly determined at world or individual level, and decreasingly at national level. Corresponding to the economics has been globalisation in the wider sense: growing proportions of ownership, power, tastes and cultures that transcend national borders, widening choice and opportunity for some people, but also, many fear, homogenising global cultures and, paradoxically given the derestriction emphasis of globalisation, increasing the control of global outcomes by dominant world or regional powers, companies, or cultures. I look only at the interaction between family farming, poverty and crop science in the context of narrowly 'economic' globalisation.

Freer trade induces specialisation along lines of comparative advantage, i.e. in products using a nation's more plentiful resources (others being more readily, and more cheaply, importable). Freer foreign investment flows will be attracted to a nation for production lines that use those plentiful resources. Most de-

[35]Strictly, the process starts with big infant mortality falls during 1945-60 as malaria is controlled and nutrition improved. This first raises dependency ratios, but as the 'saved' infants age into the workforce, the process slows down and then reverses. Later, fertility decline strengthens the reversal (fall in dependency ratios).
[36]HIV/AIDS hits mainly (i) persons aged 15-30, (ii) infants. The effects on the dependency ratio are offsetting.
[37] In 1962-90 it added 1.7%/year to growth of income per person in E and SE Asia [Bloom and Williamson 1997].
[38]The dates of the turning point vary by country, as did the earlier changes (fn. 35) that set the whole process going.
[39]A highly relevant consequence is the removal of obstructions to the 'law of one price', and hence a levelling of prices, allowing for transport costs. This highlights the *non*-globalisation of agriculture by OECD nations, and the plea from developing countries that they too be allowed to compete!

veloping areas are labour-rich and capital-poor (see also fn. 15). So most globalisation[40] should increase their specialisation in high-employment farms and crops, making it easier to attack mass poverty through extra employment, productivity, food output, and income growth from small family farms. Not only growth, but within developing countries the distribution of income, should get more pro-poor.[41] 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.[42] In developed countries freer international flows of trade and direct investment (while still raising GDP via specialisation and learning), steers resources *away* from lines of production using a lot of unskilled labour, and can thus harm distribution, unless poor losers are up-skilled, resettled or otherwise compensated; this issue is crucial for farm reform in OECD. But such freer flows in labour-surplus developing countries can be expected, barring severe distortions or restrictions of access, to be clearly pro-poor.

On balance, the evidence since 1980 shows that developing countries that liberalised trade faster enjoyed faster growth, and that this brought faster poverty reduction. However, while preaching freer trade to an increasingly persuaded South, the North protected its own agriculture, arguably increasingly so. Therefore, gains to labour-intensive family farmers in the South from globalisation are 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 total factor productivity in farming fast enough to overcome the effect of price changes. With changes in the global organisation of science (see above that might work for the remaining poverty heartlands in Africa and 'interior' Asia, but much stronger pressures against EU and US agricultural policy malfeasance would greatly improve the prospects.

That apart, gains to the rural dollar-poor from globalisation appear to be threatened by failures of intermediation between small/family farms and some newish institutions of exchange: supermarkets, horticulture exporters, grades and standards, and new modes of communicating technical progress. Small family farms retain their advantages of low-cost labour management in production, but may have high unit costs (notably for quality control and delivery) between the farm and the wholesaler or processor. Overcoming such barriers is feasible, as shown both by recent examples [IFAD 2001: ch. 5] and by the history of processing, with timing and quality control, for smallholders in sugar, rubber and tea [Binswanger et al 1995]. However, these examples confirm three facts. First, in family farming as in other sectors, responsiveness of growth to incentives – whether created by scientific progress or by globalisation – depends substantially on affordable but substantial provision of, and reasonable equality of access to, education [Jamison and Lau 1982; Birdsall et al 1995]. Second, appropriate farm science increases or 'potentiates' gains from globalisation: labour-intensive small farms are better placed to raise production in response to freer trade and investment, if they are reached by, and find profitable, appropriate science-led innovations – and such potentiation requires communication of information, so that new science raises the returns to universities and extension organisations, . Third, the poor gain more from all this if they have not-too-unequal access to land; that may require land reform.

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

---

[40] This includes investment by TNCs. As current complaints about call-centre outsourcing indicate, TNC investment leaves rich countries for developing countries partly to 'exploit' low labour costs - but in so doing bids up wages and employment, cutting poverty. This logic does *not* justify financial liberalisation [Stiglitz 2003]. 'Hot money', without strong financial institutions and regulation, can destabilise growth, making the poor more vulnerable.

[41] There are caveats. Transferred technology may favour the skilled or capital-intensive. The small share of private international investment reaching the farm sector, and the negligible amount benefiting family farms, militate 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].

[42] It is vital, however, that developing countries (public as well as private sectors) are able and willing to select - from the usually rather capital-intensive mix used, and hence offered, by the capital-rich developed world, with which they enter into increasingly close relations during globalisation – the more labour-intensive and hence appropriate science, techniques, and lessons. That is central to the pro-poor use of crop science in a globalising world.

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 (i.e. rurally extended and gender-blind) primary schooling, or all three. In sub-Saharan Africa, the general failure, with a few exceptions, to use farm science to achieve substantial and sustainable acceleration of family farm growth before the thrust to globalisation has made it harder for globalisation 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 labour 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 is targeted to help developing countries halve dollar poverty incidence in 1990-2015; yet we are fare behind that speed of poverty reduction; 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 level and in most of the developing world outside China, 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 makework, 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.

## References

Baldwin R and Wyplosz C (2003). 'The Economics of European Integration' (McGraw Hill).

Binswanger H, Deininger K and Feder G (1995). Power, Distortions, Revolt and Reform in Agricultural Land Relations. In Behrman J and Srinivasan TN (eds) 'Handbook of Development Economics', vol. IIIB (North Holland Amsterdam)

Binswanger H and Ruttan V (eds 1977). 'Induced Innovation: technology, institutions and development' (Johns Hopkins Baltimore).

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

Bloom D and Williamson J (1997). Demographic transitions, human resource development, and economic miracles in emerging Asia. (HIID Working Paper, Harvard, Cambridge, Mass.).

Boserup E (1965). 'Conditions of Agricultural Progress' (Asia Bombay)

Bray F (1986). 'The Rice Economies: Technology and Development in Asian Societies' (Blackwell Oxford).

Eastwood R and Lipton M (2000). Pro-poor growth and pro-growth poverty reduction: meaning, evidence and policy implications. Asian Development Review 18, 22-58.

Eastwood R and Lipton M (2004). 'Rural-urban dimensions of inequality change'. In 'Inequality, Growth and Poverty in an Era of Liberalization and Globalization', ed. Cornia GA (UNU-WIDER Studies in Development Economics, Oxford University Press, Oxford).

Eastwood R, Lipton M and Newell A (2005). Farm size. In Evenson R and Pingali P, 'Handbook of Agricultural Economics: Vol III (forthcoming North Holland Amsterdam).

ECOSOC (2004). *World Population Prospects: 2002 Revision* (http://esa.un.org/unpp, Population Division, ECOSOC, UN Secretariat, New York).

Fan S, Linxiu Z and Zhang X (2000a). Growth and poverty in rural China: the role of public investments (International Food Policy Research Institute Washington DC).

Fan S, Hazell P and Thorat S (2000b). Targeting Public Investments by Agroecological Zone to Achieve Growth and Poverty Alleviation Goals in Rural India. Food Policy 25, 411-428.

FAOSTAT http://apps.fao.org/faostat/collections?version=ext&hasbulk=0&subset=agriculture, last updated March 2004. FAOSTAT (Rome)

Hazell P and Ramasamy C (1991). 'The Green Revolution Reconsidered: the Impact of High-yielding Rice Varieties in South India' (Johns Hopkins Press, Baltimore).

Hill P (1977). 'Population, Prosperity and Poverty: Rural Kano, 1900-1970' (Cambridge University Press, Cambridge).

International Fund for Agricultural Development (IFAD) (2001). 'Rural Poverty Report 2001: the Challenge of Ending Rural Poverty' (Oxford University Press New York).

Jamison D and Lau L (1982). 'Farmer Education and Farm Efficiency' (Johns Hopkins, Baltimore).

Krueger A A Valdes and M Schiff (1996). 'The Mulcting of Agriculture in Developing Countries' (World Bank Washington DC)

LABORSTA http://laborsta.ilo.org/ , last updated Feb 2004. ILO (Geneva).

Lele U et al (2003) The CGIAR at 31: an independent meta-evaluation of the Consultative Group for International Agricultural Research' (World Bank Operations Evaluation Division Washington DC)

Lipton M (1977) 'Why Poor People Stay Poor: urban bias in world development' (Temple Smith London)

Lipton M (1999). Reviving global poverty reduction: what role for genetically modified plants? Sir John Crawford Memorial Lecture (CGIAR Washington DC).

Lipton M with Longhurst R (1989). 'New Seeds and Poor People' (Unwin Hyman London).

Lipton M and Ravallion M (1995). Poverty and policy. In 'Handbook of Development Economics: vol. IIIB', ed. Behrman J and Srinivasan TN (North Holland Amsterdam).

Mingay G (1968). The agricultural revolution in English history: a reconsideration' in Minchinton W (ed), 'Essays in Agrarian History' (David and Charles Newton Abbott)

Nuffield Council on Bioethics (2004). Working Group: D Burke, M Gale, M Lipton., S Thomas and A Weale: 'The Use of Genetically Modified Crops in Developing Countries'.

Pinstrup-Andersen P, de Londono N and Hoover E (1976). The impact of increasing food supply on human nutrition. American Journal of Agricultural Economics 58, 131-142.

Ravallion M (2000). On the urbanisation of world poverty (mimeo World Bank Washington DC).

Reardon T (1998), in 'The State of Food and Agriculture' (Food and Agriculture Organisation Rome)

Singh I J (1991). 'The Great Ascent' (Johns Hopkins, Baltimore).

Smith L and Urey I (2002). Agricultural growth and poverty reduction: lessons from the post-independence and green revolution experience in India (mimeo, Dept of Ag Sciences, Imperial Coll Wye).

Stiglitz J (2003). 'Globalisation and its discontents'. (Penguin, London).

Sundaram K and Tendulkar SD (2002). The Working Poor in India: Employment-Policy Linkages and Employment Policy Options (International Labour Office Recovery and Reconstruction Dept Geneva).

Thirtle C, Lin L and Piesse J (2003). 'The impact of research-led agricultural productivity growth in Africa, Asia and Latin America', World Development (31), 1959-75.

United Nations (2003). 'Human Development Report 2003' (Oxford University Press New York).

USDA 2003. Agriculture Fact Book 2001-2002 (2/03). http://www.ers.usda.gov/Briefing/FarmStructure/

Wittfogel K (1957) 'Oriental Despotism: a Comparative Study of Total Power' (Yale Univ New Haven).

Wood A (1994) 'North-South Trade, Employment, and Inequality. Changing Fortunes in a Skill-Driven World' (Oxford University Press, Oxford).

World Bank Group (2004). 'Partnerships in Development: Progress in the Fight against Poverty' (World Bank, Washington DC).

World Water Council (2001). 'A Water-secure World: Vision for Water, Life and the Environment (World Water Vision Commission Report).