Population and Agricultural Development

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Abstract

Thinking about population as a driver of agricultural development provides insights into induced technical and institutional change, whether it be Esther Boserup's declining fallow period, modern crop varieties, or the *specialization pyramid* that arises in labor-intensive agriculture. The non-convexities of research and development, infrastructure investments, and specialization imply that modest population pressure does not necessarily exert downward pressure on wages. As agricultural growth stimulates industrialization, the non-convexities of specialization become ever more compact. The combination of these and the increased demand for human capital, if not inhibited by policy failures, tends to promote a virtuous circle of human progress.

JEL classification: J10, O12, O43, P23, Q01

Keywords: population, agricultural development, Boserup, non-convexities, specialization, institutional change

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That economics became known as the ‘dismal science’ can largely be attributed to the theory of population and agricultural growth as developed by Malthus and Ricardo, notwithstanding the term’s origin in another context. Starting from a point of relatively high wages, for example at the end of the Black Death in Europe, or after some exogenous technological improvement, population increases geometrically. The additional population is assimilated by agricultural growth at the extensive and intensive margins, both of which result in diminishing returns to labor. Extensive growth occurs through the expansion of cultivated land, which Ricardo (1817) presumed to be more distant from or of poorer quality than land already in use. Growth at the intensive margin likewise results in diminishing returns, due to the greater amount of labor and other inputs employed on the fixed quantity of previously cultivated land. As a consequence, Ricardo (1817) and Malthus (1798) theorized that wages would eventually decline towards a subsistence level, where population growth would cease due to ‘positive checks’ such as starvation and disease.

Modern economists still use this dismal theory to explain why growth in levels of living among the working classes was never sustained for long periods until the advent of the Industrial Revolution. Each technological improvement was subsequently ‘eaten up’ by population growth and the subsequent diminishing returns. The belief in this theory is so strong that Lucas (2002, ch. 3) wrote that he could look at a picture of a Korean peasant farm in an unknown century and confidently guess household income. Recent interest in ‘sustainable development’ has augmented resource pessimism. In this view, the conventional Malthusian vicious circle between population growth and poverty is exacerbated by resource depletion and environmental degradation. Expanding numbers of poor people in developing countries put more pressure on limited natural resources and fragile ecosystems, and the falling resource base makes the Malthusian circle even more vicious than with a fixed resource endowment.

Malthus famously argued that unchecked population growth is exponential while food production at best grows linearly, thus implying the inevitability – in the absence of sufficient *preventative* checks – of *positive* checks such as pestilence, plague, famine and war and of subsistence levels of income in the long run. Ironically, food supply has outstripped population growth ever since the publication of Malthus's *Essay on the Principal of Population*. Technological and institutional change has been more rapid than he envisioned and preventative checks more robust.

Boserup effects

Boserup (1965; 1981) takes a different tack by taking population growth as the exogenous variable and enquiring into the consequences thereof for agricultural technology and institutional change. I follow Boserup's lead in most of what follows, eventually returning to a more integrated view. Boserup focused on the effects of physiological population density on an additional intensive margin – the fallow period. As population (and other demand factors) grow, the predominant agricultural system gradually transitions from long to short fallow to annual cropping to multiple cropping. Table 1 describes these systems and illustrates the rough correspondence between the frequency of cropping and population density in less developed economies. Other authors have extended the correlation between population density and cropping frequency to European countries, both over time and country.

Table 1 Boserup's frequency of cropping by population density

System	Description of cropping system	Frequency of cropping	Person per km^2	Density
Hunting and gathering	Wild plants, roots, fruits and nuts are gathered	0%	0–2	Very sparse
Forest fallow (w/ pastoralism)	One or two crops followed by 15–25 years' fallow	0–10%	1–4	Very sparse
Bush fallow (w/ pastoralism)	Two or more crops followed by 8–10 years' fallow	10–40%	4–64	Sparse to Medium
Short fallow (w/ domestic animals)	One or two crops followed by one or two years' fallow	40–80%	16–64	Medium
Annual cropping (w/ intensive animal husbandry)	One crop each year with only a few months' fallow	80–100%	64–256	Dense
Multi-cropping	Two or more crops in the same			

	fields each year without any fallow	200–300%	≥ 256	Very dense

Source: Boserup (1981, pp. 9, 19 and 23).

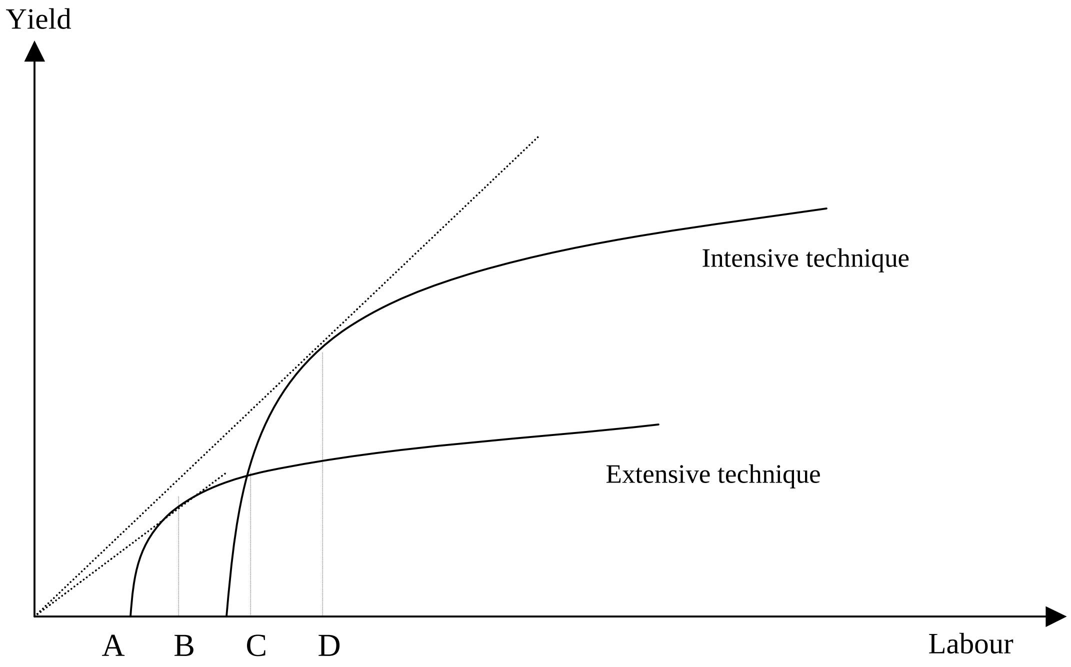
Boserup’s insight can be partly understood from the perspective of *induced technical change* (Ahmad, 1966). Absent industrial growth, population pressure makes land increasingly scarce relative to labor, thus inducing land-saving technical change. In the era of modern economic growth, the same tendency would influence whether capital was used to save labor or land. This was exemplified by labor-abundant Japan developing land-saving biological innovations and the United States developing labor-saving mechanical innovations (Hayami-Ruttan, 1985). As represented with standard neoclassical analysis, however, induced innovation simply increases the elasticity of factor substitution (especially between land and labor). In the *very* long run, that is, allowing for induced technical change, the elasticity of substitution, such as between land and labor, is higher than without technical change.

Similarly, decreasing the fallow period allows the marginal product to decline more slowly than otherwise. For example, suppose that 100 workers cultivate 100 hectares with a 50 per cent cropping frequency (short fallow) and that the population doubles. Even though the additional labor can be productively employed, for instance by better weeding and more thorough land preparation, the marginal product of labor will suffer a large decline if the cropping frequency remains unchanged (perhaps by a half or more). By switching to annual cropping, however, it may be possible to accommodate the additional labor with only a small decline in its marginal product, even in the steady state. The optimal solution involves some conservation of soil fertility over time, for example through the use of animal manure and crop rotation (Barrett, 1991).

Boserup contends that it is even possible that population pressure increases the productivity of agricultural labor. More intense farming systems require more fixed costs. For example, forest fallow systems require minimal land preparation. The slash and burn method leaves the land both fertile and weed-free. In the tropical African context that she describes, however, once the land has been burned and cropped, it is taken over by grasses and is no longer suitable for slash and burn agriculture until 20 or more years later, when the forest has returned. Consequently, land preparation requires time-intensive ploughing. Because of these fixed costs, the average product of labor rises over some range.

Other investments associated with intensification, such as irrigation and terracing, similarly increase labor productivity. This is illustrated in Figure 1. Once population has reached point C, the average product of the extensive and intensive techniques is equalized and it becomes worthwhile to switch to the intensive method. As labor increases beyond C, the average product rises until D, where diminishing returns just offset the gains from spreading the fixed costs, and average product begins to decline. In this sense, population eventually overcomes the transitory gains from switching techniques and causes productivity to fall.

Figure 1 Average product of labor under different farming techniques



Source: adapted from Krautkraemer (1994).

Innovation-through-intensification, as portrayed in Figure 1, does not require invention. It is as if new techniques are taken ‘off the shelf’ when they are warranted by increased land scarcity. Genuinely new technology, developed through invention or imported from other areas, may provide additional positive effects. The same population increase that warrants the fixed cost of intensification also warrants increased expenditures on experimentation and research. This research shifts the *innovation possibility frontier* (IPC) between land and labor inwards. In modern settings, R&D becomes an important source of productivity growth.

For example, the high-yielding, or modern, wheat and rice varieties (MVs) developed in the 1960s were in large part induced by population pressure on increasingly scarce land. In the extensive phase of agricultural development, cultivated hectarage is increasing. Eventually, cultivated area reaches a maximum and declines as towns and industrial areas encroach on agricultural land. At this point, land scarcity is exacerbated by both rising food demand and falling land supply, and intensification accelerates.

One of the effects of intensification is to increase the demand for land-saving technology. According to the ‘political Boserup effect’ (Evenson, 2004), increasing population densities induce countries to invest more in the genetic improvement of both crops and animals. By first characterizing existing technology by the unit requirements of land, labor, and capital, optimal investment by a country in new technology can be described by the amount of research and its factor-saving bias. In one version of this theory, a given research expenditure allows a country to pick any point on the IPC, the envelope of all unit isoquants in the land–labor plane, that said research expenditure affords. If it is assumed that the IPC shifts in a neutral fashion towards the ultimate IPC, wherein the marginal benefit of research is zero, then the factor-saving bias is in accordance with changes in relative factor prices. For example, if population growth results in a decrease in the wage rate and an increase in the land rental rate, both relative to the price of capital, then technical change will be land-saving and labor-using relative to capital (Binswanger and Ruttan, 1978, chs 2 and 4).

Inasmuch as the IPC shifts in a non-neutral fashion, however, these results will be modified. It is natural to assume, for example, that technical change is inherently capital-using, that the unit isoquant (net of capital costs) can be shifted inward more cheaply by increasing capital per unit of output than by increasing labor or land. Moreover, it may be that inventing technology that uses capital to save labor is cheaper than technology that saves on land. This may explain why the modern rice and wheat varieties have been found to be mildly labor-saving, in addition to being land-saving and capital-using (fertilizer responsive), even though their demand was created by falling wages relative to land rents. But even though labor per unit of output fell, output per hectare increased enough such that MVs had a positive effect on wages (for example, Evenson, 1982). Overall, MVs have had a beneficial effect on poverty reduction by decreasing food prices and increasing wages relative to what they would have otherwise been given population growth and labor demand in other sectors.

Boserup's other 'secondary effects' of population growth may also cause productivity to rise, even in the absence of agricultural research. Among these are property rights, work habits, division of labor, education, and the infrastructure for transport and communication. Changing property rights exemplifies how institutions can change in response to population pressure and other changes in factor scarcities. This insight led to the theory of *induced institutional change* as a complement of the theory of induced technical change. For example, as population pressure increased the demand for land-saving investments, private property sometimes emerged as a more efficient substitute for top-down land management by community leaders or feudal lords (see, for example, North and Thomas, 1973). Indeed, the first legal enforcement of the early English enclosures was effected by the Statute of Merton (1235), which noted the need to improve the land in order to generate greater rent. The subsequent waves of English enclosures beginning before the 17th and 19th centuries also appear to have followed increases in the rate of population growth, although the timing is not without dispute.

Population induced specialization in agriculture

While population growth potentially augments the benefits of private property, potential efficiency gains do not automatically induce institutional change. In particular, rent seeking may lead to a 'race' such that private property is created before it actually increases efficiency (Lueck, 1998). On the other hand, political costs may retard institutional change beyond the time that its benefits warrant. The advent of private property in Hawaii in 1848 was exceptional in two regards. First, the benefits of private property resulted from the increased profitability of sugar and pineapple production, even in the face of population decline. Second, the timing of private property accorded roughly with its efficiency benefits; the delaying effects of the political costs of change were offset by the expediency of governmental land sales.

A more profound institutional change that may be induced by population pressure and other sources of intensification is that of economic organization. The division of labor has fascinated economists since the time of Adam Smith, but was sidelined during the era of neoclassical economics. The theme of specialization has been resurrected, implicitly in endogenous growth theory and explicitly in the New Classical Economics (as in Yang, 2003). In Yang's model, population growth lowers the relative price of labor, thereby increasing the use and number of intermediate capital goods, which are produced with labor. This in turn increases production and the number of manufactured goods, and further bolsters the value of total output through learning-by-doing. In this model, agricultural growth is only indirectly stimulated, for example through the lower cost of manufactured fertilizer – a land-saving input.

Population growth can also facilitate specialization by lowering unit transaction costs. For example, the fixed costs of transport and communication infrastructure per capita may fall sufficiently to warrant additional infrastructure investment. Falling unit transaction costs, in turn, lower the friction that inhibits both horizontal and vertical specialization. In this case, learning-by-doing can directly bolster agricultural productivity.

A primary vehicle for increased specialization is hired labor. To see how population growth can induce hired labor, consider a hypothetical land-surplus economy wherein food is produced by family farms and where clearing costs are negligible. If we assume for the moment that output per hectare is a function of labor, farm size is efficiently determined where the marginal product of land is zero and the marginal product of labor is equal to the shadow price of household leisure. Once population growth brings lower quality, or sufficiently distant, land into production, intensification begins – lowering labor productivity. As the optimal land-to-labor ratio falls, the size of the average family farm declines. This process is efficiently halted, however, due to indivisibilities such as those associated with ploughs and draft animals. Eventually, farm size shrinks to a point where the economies of scale lost from further shrinkage are just offset by the transaction costs of hired labor. At this fundamental turning point, increases in labor per hectare induced by population growth are accommodated by hired labor instead of falling farm size. In this sense, the change in agricultural organization – known as the emergence of the rural proletariat – is not necessarily an indication of exploitation or inefficiency.

But hired labor is not a perfect substitute for family labor. Transaction costs are different, and, since hired labor is not necessarily tied to a particular farm, it can specialize in particular skills instead of adjusting to the attributes of that farm. In the common case where family labor has a higher shadow price of leisure, hired labor has a comparative advantage in arduous and well-defined tasks wherein transaction costs are manageable (for instance, because the results of the work are readily observable) and wherein speed and quality are enhanced by training and repetition. Family members have a comparative advantage in management-intensive tasks such as chemical applications that require knowledge of farm attributes and for which shirking is harder to control. The advent of hired labor stimulates horizontal specialization across tasks, as with men in the Philippines who specialize in transplanting rice and move from village to village to do so. The resultant learning-by-doing increases productivity – for example, in producing straighter rows of rice, which raise the productivity of workers through the use of rotary weeders. Vertical specialization also increases. For example, landowners may specialize in land improvements, such as irrigation, and employ tenants who specialize in management-intensive labor and who employ and monitor workers who specialize in arduous and more easily supervised tasks.

Further vertical and horizontal specialization is illustrated by the institution of piece-rate by teams. A team is hired to complete a task, such as transplanting, which is easily monitored by *ex post* inspection. In this sense, the task is equivalent to an intermediate good. The team may produce, for example, a stack of cane stalks that are of uniform length and ready for planting. Moreover, the team constitutes a separate firm. Its chief executive officer is the team manager, who contracts with the sugar grower and who bears the adverse reputational effects of any sub par performance. In this sense, the capacity for specialization in industry may be quantitatively greater than that of agriculture but not necessarily qualitatively different. Thus it is neither inevitable that population growth decreases or increases productivity in an agricultural economy.

The following stylized pattern of hired labor, based on Philippine rice farming in the 1960s to the 1980s, may serve to epitomize the evolution of specialization as labor intensification follows population growth. Once population density warrants clustered villages of farm families, the institution of exchange labor emerges for transplanting, harvesting, threshing, and often ploughing. Boserupian intensification increases the value of timeliness, and exchange labor allows these tasks to be completed in a day or less for one farm. The first widespread form of hired labor was for harvesting. Harvesters were paid a share of the harvest, typically one-sixth. This later evolved into the gama system, whereby a family or small group was assigned a portion of the farm to weed and later harvest, albeit for the same one-sixth share. This corresponded to a fall in wages relative to rents. In Java, Indonesia, where population pressure was even more intense, this same institution emerged – for the same one-sixth share – but the work requirement expanded even further, typically including transplanting.

When wage labor first appeared in Philippine rice farming, a given worker would typically perform a myriad of tasks over the cropping season. As intensification proceeded and the man-hours of hired labor increased, this undifferentiated wage-worker system was partially replaced by one involving specialized piece-rate workers who were paid according to their performance of a specific task. This evolved further into the piece-rate-by-team system described above. As per-hectare yields continued to increase, piece-rates were often converted back to wage contracts – due to the increased value of quality shirking – but task-by-task specialization was retained.

A common assertion in development economics is that large farms that rely primarily on hired labor are at a transaction-cost advantage relative to small, family farms. This view implicitly takes the distribution over farm size as exogenous, however. In the efficiency view sketched above, farm size is endogenous and responds to changes in population. Indeed, efficient farm size may actually increase as the increased incidence of hired labor warrants new contracting institutions that lower transaction costs. The transaction costs that remain are the necessary cost of retaining economies of scale and facilitating specialization. Whether productivity gains from specialization are enough to offset diminishing returns to more labor on a fixed amount of aggregate land cannot be determined a priori.

The view that share tenancy is inefficient is similarly incomplete. In the canonical view, share contracts are a pair-wise efficient institution for mitigating both the labor-shirking disadvantages of wage contracts and the risk-bearing disadvantages of rent contracts. Nonetheless, share tenancy is said to be socially inefficient because of the Marshallian labor shirking that remains under the common 50 per cent sharing. This view fails to explain how share tenancy fits into the evolution of agricultural organization in response to population pressure and other forces of intensification. Specialization is warranted by intensification and is facilitated by the evolution of contracts and other institutions. In particular, share tenancy facilitates vertical specialization between the landowner, the tenant, and the hired labor that the tenant supervises. It also facilitates the horizontal division of labor described above. On the other hand, share tenancy is primarily a type of family farm and may become less appropriate as agriculture becomes more capital-intensive. In any case, assessing the consequences of institutions without considering their causes, especially intensification, runs a risk of misplaced exogeneity.

A third example of questionable exogeneity concerns the view that the *modernization triad* – population pressure, technical change and commercialization – has inevitably immiserizing consequences. The case made against the new varieties of rice and wheat that emerged in the mid- to late 1960s is illustrative. Modern rice varieties are said to be most profitable on irrigated, highly productive land and for farmers facing relatively low shadow prices of credit and close connections with the money economy. These characteristics tend to favour wealthy landowners over small farm families. As the rich get richer, small farmers and tenants are allegedly disenfranchised, thus accelerating Ricardian forces of population and polarizing society into a class of landlords and the proletariat. Commercialization further augments proletariatization, breaking down safety-net customs such as gleaning rights for the poor, and setting the stage for violent conflict. The Boserupian and induced innovation perspectives provide a compelling counterweight to the neo-Marxian view. Technical change induced by population growth is primarily land-saving and offsets downward wage pressure, whereas Marxian technical change is strongly labor-saving and exacerbates the downward effect of population. Like induced technical change, induced institutional change in the form of ‘commercialization’ has a positive effect on wages. The efficient emergence of landless workers helps to avoid the immiserizing effects that would occur from a growing population being accommodated by shrinking farm sizes. This class division in turn creates both a supply and a demand for hired labor. As labor markets emerge, new institutions such as piece-rate contracts and work teams with team leaders emerge to lower contracting costs, thereby lowering the transaction cost wedge between effective wage paid, including costs of recruitment, training and supervision, and effective wage received, net of the costs of search, required tools, and the journey to work. As the unit-transaction-cost wedge shrinks, workers move up their supply curves and employers down their demand curves for labor, resulting in more hired labor and increased net wages. From this perspective, induced innovation at least partially offsets the downward pressure that population pressure puts on wages. These efficiency patterns are by no means inevitable, but serve to counter the view that the modernization triad is inevitably impoverishing. The efficiency view also provides a theoretical starting point for explaining agricultural growth or the lack thereof. Rent-seeking and policy distortions may induce arbitrary and inefficient patterns of ownership and farm size, thereby inhibiting the efficiency forces described. A challenge for economic historians and agricultural development theorists is to explain the political-economy forces that have facilitated induced innovation in some cases and inhibited it in others.

The positive Boserupian forces of induced innovation and specialization move in the opposite direction of the classical Malthusian effects. To summarize the above, even a small family farm can have four levels of vertical specialization – landowner, share-tenant farm manager, work team leader, and worker – as well as horizontal specialization across the array of farm tasks. The advent of each new form of specialization can be modelled along the lines of Figure 1. Because of the non-convexity associated with the fixed cost of each advance in organizational complexity, population-induced specialization gives rise to increased labor productivity, but only over a limited range of additional labor. In the absence of other effects and changes, we would expect to see the marginal and average products of labor initially rising after each increase in specialization; then, as labor per hectare increases further, to a decline until the next innovation is made. Adding learning-by-doing to the picture increases the chances of sustained productivity gains. Nonetheless, the theory cannot tell us whether the positive forces will outweigh the negative Malthusian forces in the long run.

An historical perspective

The history of agricultural growth is informative. As documented by Evans (1998), the long-run rate of agricultural growth closely matched that of population until 1825, when world population reached one billion people. The corresponding increase in food production was almost entirely sourced in an increase in cultivated area, that is, it was *extensive* in nature. In contrast, since world population reached five billion late in the 20th century, the increase in food production has been almost entirely driven by increased productivity. During the intervening period, when world population increased by four billion, growth in food production was increasingly intensive in nature (due to increased inputs) with increased productivity becoming more important as the period progressed. That is, as intensification led to diminishing returns, increased productivity became increasingly important.

This broad-brush generalization about the nature of agricultural growth is consistent with the induced innovation perspective. As population growth increases land scarcity, the Ricardian gradient, which depicts the proportion of agricultural growth due to intensification, is monotonically rising. Intensification increases the relative scarcity of land further, relative to labor and capital, thus stimulating induced productivity increases, both from technical and institutional progress. Ironically, food supply has grown ‘geometrically’ since 1938 (averaging 2.2 per cent per year) and population has grown nearly ‘arithmetically’ since 1959 (with one billion being added to world population roughly every 13.3 years). Technological and institutional change has seemingly inverted Malthusian theory.

This does not imply that all technological change is demand-induced. Even the theory of induced innovation admits supply-side innovations. For example, knowledge capital produced in the defence industry may lead to better communications technology. Irrigation systems in ancient Mesopotamia and Egypt were presumably not induced by increasing land scarcity but because someone figured out how to produce more with less. Economic history in the United States suggests that demand was partly induced by labor scarcity, but, once certain types of farm equipment had been invented, they were adapted even in areas where land prices were increasing faster than labor prices. Kremer (1993) even suggests that until the late 18th century the Malthusian argument was so predominant that population could be viewed as a proxy for technological change.

On the other hand, the agricultural and industrial ‘revolutions’ are now viewed less as bursts in productivity spurred by invention and more as induced technical change. For example, the four-field system, whereby wheat, barley, turnips and clover were grown in separate fields and rotated the following year, was once viewed as an essential part of the English agricultural revolution during the 18th century. But the system was developed in land-scarce Flanders two centuries before and popularized in England only once it was warranted by sufficient population-induced land scarcity.

Even the mechanism of induced technical change is not entirely governed by factor prices, however. For example, the replacement of the fallow period in the medieval ‘three field’ rotation by beans or another leguminous crop appears to have been indirectly induced by the population decline in 14th-century western Europe. Higher wages and farm incomes, resulting from the lower population and decreased land scarcity, increased the demand for meat. Complemented with the Flemish demand for wool, this incentivized farmers to increase sheep production, and they responded by both converting some lands to pasture and growing legumes in place of fallow on much of the remaining lands.

The extent to which technical change in English agriculture was induced has been the subject of intense historical debate. Historians reporting that agricultural productivity increased rapidly, say in the late 18th and early 19th centuries, tend to see an agricultural revolution stimulated by exogenous technical change. Economic historians who estimate productivity increases to be quite gradual view changes in rotation and other innovations as induced. As suggested by the discussion of Figure 1, induced changes do not by themselves reverse the price and income trends that induced them in the first place and therefore tend not to be associated with dramatic increases in productivity.

Sustainable development

Resource depletion adds another negative dimension to the never ending debate between the development optimists and pessimists. Even before *sustainable development* became fashionable, neo-Malthusians argued that unbridled population growth in poor countries and economic growth in rich countries must inevitably cause severe pressure on the earth's limited resources, resulting in burgeoning poverty and international conflict. The only solution was said to be the *steady state economy* with constant population, capital stock, and output.

After the Brundtland Commission's 1987 report, resource depletion was broadened to include pollution and other environmental threats. Environmental degradation, including increasing water scarcity, soil erosion, deforestation, desertification, salinization, and global warming, as well as diminishing energy and marine resources, was viewed as exacerbating the Malthusian vicious circle. Accordingly, the Brundtland Commission called for a simultaneous assault on population growth, poverty, and environmental degradation, thus giving rise to the modern movement for *sustainable development*. Economists have had limited success in modelling sustainable development, however. One notable review and synthesis (Arrow et al., 2004) was unable to settle on positive principles of sustainability and settled on the negative *sustainability criterion* – an injunction not to deplete the value of natural capital more than the additional value of produced capital.

Even if we abstract from technical change, expanding models of economic growth to include environmental degradation does not produce a necessarily dismal outlook, however. If we represent concern for future generations by *intergenerational neutrality* and assume that population grows exponentially at a constant rate, optimal per capita consumption grows to its *golden rule* level, under plausible assumptions about substitutability, both between renewable and non-renewable resources and between natural and produced capital. Adding technical change provides even rosier possibilities (Weitzman, 1997). Whether these possibilities are realized depends largely on the effectiveness of private and public governance structures in facilitating specialization and exchange while guarding against unproductive rent seeking (Greif, 2006).

The co-evolution of specialization and governance

The economic history of Hawaii provides a relatively recent, pre-industrial example of how specialization and governance in agriculture co-evolve with changes in population. During the 'colonization' period from AD 300–600, population growth, including further migration of Polynesian peoples, was slow. Agricultural expansion was extensive. The population began to increase more rapidly towards the latter part of the 'development' period (600–1100), and agriculture began to intensify with the advent of irrigation. There was little if any division of labor among the commoners. During the expansion period (1100–1650) population accelerated and intensification greatly increased with a decreased fallow period, a major expansion in irrigation and with the development of fishponds. Horizontal specialization among workers became commonplace, with fishing more of a distinct occupation. Evolving from a system of somewhat separate extended families units, social and production relations became increasingly stratified, eventually with a distinct hierarchy from local chief upwards to governor (*ali'i*) of the watershed to district head (see Kirsch, 1985).

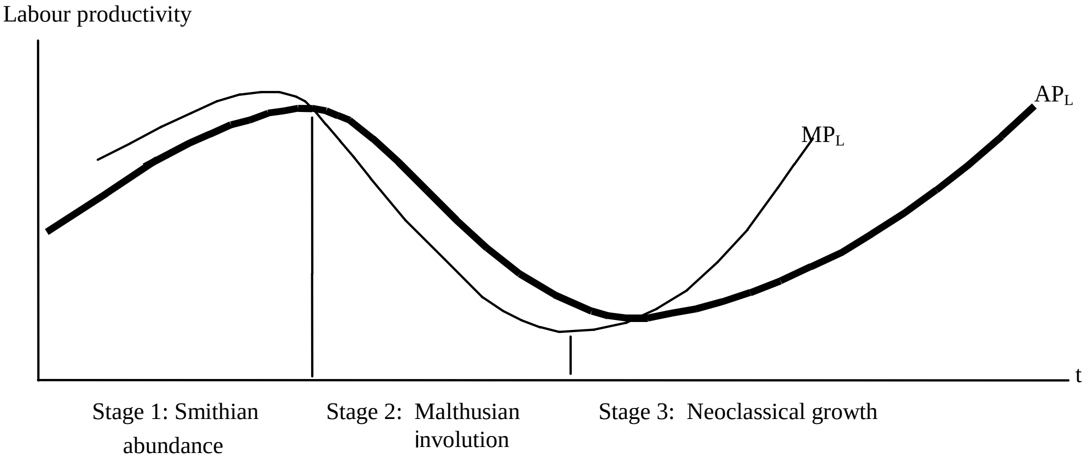
This stylized history is suggestive of a *governmental Kuznets curve*. During the extensive (pioneer) stage of development, family or extended family units are largely autonomous and decision-making is decentralized accordingly. During the intensive development stage, decision-making and governance are centralized at a higher, albeit intermediate level (for example, communal governance of the commons). As intensification and specialization continue, efficiency favours a further centralization of governance, at least for the minimal functions of defence and the justice system, but a decentralization of decision-making as facilitated by private property. This last stage occurred in Hawaii after Western contact in 1778. New trade opportunities raised the value of irrigation and other investments in plantation agriculture, initially for sugar and later pineapple. Private property provided the assurance that planters needed to commit to these investments and also facilitated specialization between districts that was warranted by international trading opportunities. Graphing this historical progression of increasing governmental centralization on the horizontal axis, and rising and then falling centralization of decision-making on the vertical axis, completes the governmental Kuznets curve. Viewing government intervention in these two dimensions provides a useful antidote to the misleading question of ‘how much government’ that sometimes arises in policy circles.

Smith to Malthus to Solow

A largely unexplored area of enquiry involves combining the theory of endogenous population growth with the theory of sustainable growth outlined above. Perhaps the simplest model of endogenous growth can be found in two-sector growth models of economic development wherein the birth rate is exogenous and the death rate declines to minimum as per capita income increases. The birth rate may also be made endogenous following the Chicago School’s *new household economics*. The increased opportunity cost of child care is one pervasive cause of the decline in fertility with economic development. Moreover, as the capital intensity of the economy increases, the returns to human capital are raised, thus creating incentives for families (individually or collectively) to invest in human capital, a partial substitute for increased fertility. Malthus’s emphasis on the supply of food determining population and Boserup’s focus on exogenous population growth increasing the demand for land and inducing supply-side changes in agricultural production are clearly complementary. Focusing on one or the other is a device for dealing with the shortcomings of human imagination and the fact that models with both forces are indeterminate without further, possibly arbitrary, restrictions added to the model. Indeed, due to the endogeneity of population, enquiring into the impact of population levels involves something of a category mistake. In light of this, the World Bank statement (1984; see also Kelley, 1988) that population growth in excess of two per cent per annum tends to have a negative impact on per capita income warrants reinterpretation. A more accurate statement would be that population growth in excess of two per cent tends to be associated with negative growth in per capita income after partially controlling for (imperfectly measured) positive effects. In particular, where high population growth occurs in the face of policy failures that cause an anti-labor bias, population growth tends to exacerbate the Brundtland vicious circle described above.

More generally, the effects of population growth on agricultural and economic development may be different depending on the population density and the stage of economic development, as illustrated in Figure 2. For the early American frontier and for parts of Africa today, physiological population density may be sufficiently sparse for Smithian economies of specialization and Boserupian economies in infrastructure to afford increasing labor productivity, as shown by the rising segment of the average product of labor curve. There is no labor market, at least in the sense of a competitive spot market, in such economies because paying labor its marginal product would more than exhaust total output. When the extensive land frontier nears economic exhaustion, population density becomes high, and the economy is still dominated by agriculture (as on the Indonesian island of Java in the 1960s and early 1970s), real wages fall, along with the average product of labor. Once the 'structural transformation' takes place, such that the growth rate of the agricultural labor force (if any) is but a small fraction of that of the industrial labor force, the marginal product of labor begins to rise, causing wage rates to rise and pulling up average labor productivity soon thereafter. Accumulation of produced capital and the relative increase of the industrial sector generate the transition to modern economic growth.

Figure 2 Stages of economic development



These stages are not inevitable forces of history. Some economies may be able to bypass the Malthusian stage altogether. For example, economic policies in Taiwan during the 1950s and 1960s encouraged labor intensity in agriculture. This and the investments in physical infrastructure, a gradual transition to processing and high value-added agricultural production and an efficient system of marketing cooperatives kept the demand for labor and wages rising. Hong Kong and Singapore were able to skip the Malthusian stage by early industrialization that relied on trade instead of the Johnston–Mellor linkages whereby agricultural development increases incomes thus stimulating demand for industrial products, mobilizes savings for industrial investments, and provides a market for manufactured farm inputs (Johnston, 1970).Korea was similarly able to bypass an extended Malthusian stage by allowing investment coordination through *chaebols* (business groups)and focusing on manufactured exports. In contrast, the negative force of policy failures can extend Malthusian involution and even prevent the transition to modern economic growth. Finally, because of policy failures and exogenous shocks, history may record more than two turning points. For example, after going through a Malthusian period during the 'long 16th century', wages in England rose between approximately 1640 and 1740, but then fell again before entering a 'Solovian' period of increase starting slightly after the advent of the 19th century and accelerating after the American Civil War.

Nonetheless, we may meaningfully enquire into the mechanics of the two turning points shown, after abstracting from policy failures and exogenous shocks. While the first turning point has clear Ricardian underpinnings, the second has generated substantial controversy. How does an economy go from 'Malthus to Solow?' Forward linkages from agriculture are important in explaining the relative growth of industry, but they do not, in and of themselves, explain the rapid and sustained growth in labor productivity during modern economic growth.

Note first that there is an implicit Kuznets curve corresponding to Figure 2. During the Malthusian period, wages fall and Ricardian rents increase, worsening income distribution. Even as industrialization begins to pull up wages, income distribution may continue to worsen for some time as the total returns to capital increase faster than the wage bill. Eventually, as the returns to human capital induce the substitution of 'quality for quantity' in fertility decisions, widely distributed human capital accumulates and even produced capital becomes less concentrated. These forces cause a more equal income distribution in the model.

Were it only for Ricardian landlords accumulating an agricultural surplus and financing industrialization and the production of goods for a landed aristocracy, industrialization would have not have been as robust as that witnessed in modern economic growth. Indeed, increasing wages stifle the labor-intensive production that characterizes the early stages of industrialization, decrease the agricultural surplus, and detract from the rental incomes of capitalists and landlords that finance capital formation. What saves the day are the non-convexities inherent in industrialization.

While there are numerous possibilities for specialization and other non-convexities in agriculture, these are still few in comparison with those in industry. In industry, there is more horizontal specialization through proliferation in the number of products and more vertical specialization through multiple stages of intermediate production. In agriculture, the number of products is more limited, and vertical specialization without industry tends to be limited to separation of management and labor. With industry, agriculture can take advantage of land-saving intermediates such as fertilizer and tractors. Thus it is plausible that technological and institutional changes in agriculture have not been frequent enough to overcome the inexorable Malthusian force of increased food affording greater population growth.

In contrast, once industry becomes a major part of the economy, non-convexities may be sufficiently compact in the course of development to dominate the negative force of lower death rates. The resultant increase in per capita income in turn invokes a positive feedback mechanism whereby Engel effects increase the demand for manufactures, thus increasing capital formation and the returns to human capital, thereby contributing to the decline in the demand for child numbers described above. Greater product specialization and falling unit transport costs afford a further inducement to international trade, an additional positive feedback mechanism. This theory supports the revisionist interpretation that the agricultural and industrial ‘revolutions’ were misreadings of a gradual process of economic change (see Clark, 2007).

The role of industrial development in sustaining increased wages and per capita incomes does not imply that the appropriate development policy requires pushing industrial development while ‘squeezing’ or neglecting the agricultural sector. Indeed, for countries with a preponderance of the labor force in agriculture, economic development can be sustained only by ‘pushing’ on the agricultural sector with R&D, infrastructure, and non-confiscatory prices (Pingali, 2006). It does mean, however, that stimulating the agricultural sector alone – that is, relying on automatic linkages from the agricultural to the industrial sector – is not sufficient for sustained economic development. External economies of labor-market pooling, human capital, technological spillovers and other network externalities imply that there are aspects of investment coordination that are not internalized by spot markets. This leaves an important role for government in facilitating the requisite economic cooperation.

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