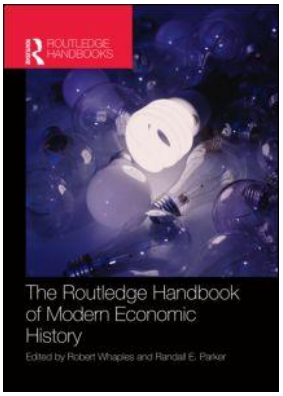

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Giovanni Federico
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THE ECONOMIC HISTORY OF AGRICULTURE

Giovanni Federico[1]

Introduction: two centuries of successes

In the last two centuries, world agriculture has succeeded in feeding a growing population (from about 1 billion in 1800 to more than 6 billion two centuries later) and in producing enough raw materials for industry, while using proportionally less land, capital, and labor. This chapter sketches out and tries to explain this outstanding performance.

Mapping the growth of world gross agricultural output for the first 70 years of the period is difficult, because estimates refer almost exclusively to a few countries in Europe and North America. Output increased in all these countries but Portugal, and in the majority of cases it increased faster than population. We cannot rule out that these gains were offset by a decline in output per capita elsewhere in the world, but this hypothesis is not terribly plausible. The growing population was mostly employed in agriculture and new farmers could find new land to till in almost all countries. After 1870, it is possible to estimate an index of "world" output from national production series for 25 countries, accounting for about 50 to 55 per cent of world population (see Figure 14.1). Production per capita increased by about a quarter from 1870 to the First World War and stagnated from 1913 to 1938. If, as it is reasonable to hypothesize, output per capita in the remaining countries remained constant, world production almost doubled over the whole period, increasing by 10 per cent in per capita terms. Figure 14.1 links this index to the official series by the Food and Agricultural Organization (FAO) of the United Nations), which covers all countries (except the Soviet Union to 1948). The acceleration in the second half of the twentieth century is dramatic: in 50 years, total output trebled and per capita production increased by a third. Current production would be sufficient for comfortably feeding the world population. One billion people are still undernourished, however, because of shortcomings in its distribution.

Production can be augmented by using more inputs – capital, labor, and land – and/or by using them more efficiently. The next section outlines the growth in inputs, and shows it to have accounted for only a part of the increase in output. The rest reflects an increase in efficiency, so the other sections deal with the causes of increasing productivity. The third section focuses on technical progress, describing the main innovations and their adoption. However, efficiency depends also on how factors are allocated and techniques are used – and thus

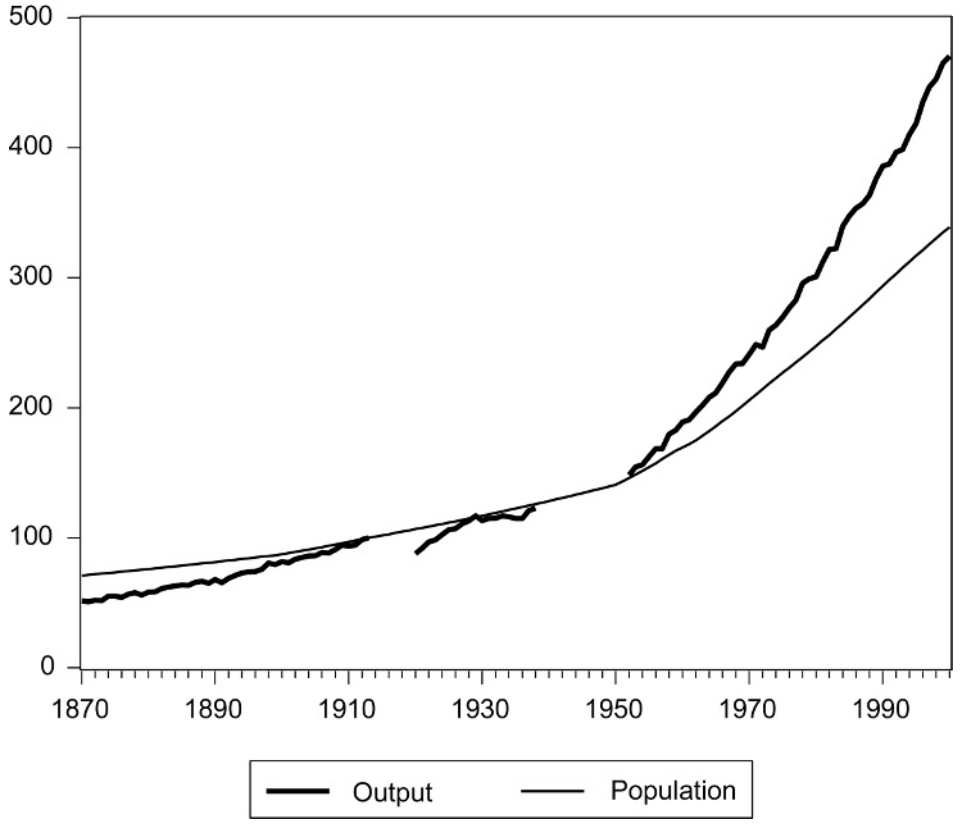

Figure 14.1 Agricultural output and world population (1913 = 100)
Source: Federico (2005).

ultimately also on institutions (the fourth section) and policies (the fifth section). The last section speculates about the prospects for the future.

How success was achieved: the growth of inputs

The evidence on the growth of inputs is fairly abundant, but incomplete. Before 1913 it refers mostly to Europe and North America, and during the interwar years the coverage, although greater, is still partial. All-world data are available from the FAO database since 1960. In order to minimize the impact of these differences in coverage, the tables report chained indexes, adding absolute figures for the reference year 2000.

Table 14.1 proxies the amount of labor with the number of workers, of both genders. In traditional rural societies, including all less developed countries (LDCs) before the 1960s, employment in agriculture grew as much as population. By definition, modern economic growth caused its share of total workers to decrease. However, the total number of workers, and thus the labor input, declined only in a handful of advanced countries and only long after the start of their modern economic growth. The agricultural work force did peak in the UK around 1850, but in other advanced countries of Europe and North America it peaked sometime in the first half of the twentieth century, and it collapsed only after the Second World

Table 14.1 Number of agricultural workers (Year 2000 = 100)

Continent	*Circa 1880*	*Circa 1910*	*Circa 1938*	*1960*	*2000*	*2000 (millions)*
Africa			31	51	100	197.1
Europe	240	358	359	309	100	17.6
North America	43	84	112	90	100	20.7
South America	2	36	69	88	100	26.9
Asia	12	43	68	64	100	1031.8
Oceania	24	35	42	59	100	2.8
Former USSR			203	178	100	21.7
World				64	100	1318.6

Sources: Van Zanden (1961), Federico (2005, Statistical Appendix Table IV), and Lains and Pinilla (2009).

War. The number of workers may differ from labor inputs for a number of reasons, but these biases tend to compensate – so as a whole the headcount is a fairly accurate measure of total work.

Table 14.2 reports comparable indexes for the extension of cropland and tree-crops, the best available proxy for land input. Europe seems to have been an outlier. Before 1880, total acreage increased somewhat in "peripheral" countries such as the Iberian Peninsula, but afterwards it remained stable, and it even declined in some countries in the two last decades of the nineteenth century. In contrast, in other continents, cropland grew, albeit at a reduced rate, until the end of the twentieth century. The story of the settlement of the American West is well known thanks to many Hollywood movies, but the pattern has been repeated, with some delay, in all other regions of European immigration, such as Canada, South America, and Oceania. Cropland increased also in Asia and Africa, with little or no contribution from Europeans. Even in a supposedly overpopulated country such as China, there was a considerable amount of land to exploit. The figures do not include pastures nor take into account the quality of land. However, the scarce available evidence does not suggest any systematic bias from these omissions.

There is no good proxy for the total capital stock, which consists of a number of widely different items. An item-by-item analysis suggests that the stock has increased in all areas, according to four different paths:

Table 14.2 Acreage, cropland and tree crops (Year 2000 = 100)

Continent	*Circa 1880*	*Circa 1910*	*Circa 1938*	*1960*	*2000*	*2000 (millions of hectares)*
Africa		34	86	77	100	201.8
Europe	110	112	112	114	100	133.2
North America	41	77	90	97	100	268.1
South America		44	71	59	100	116.1
Asia	29	58	64	85	100	511.7
Oceania	7	22	34	66	100	53.0
Former USSR	48	52	55	110	100	217.5
World			81	90	100	1501.5

Sources: Van Zanden (1961), Federico (2005, Statistical Appendix Table IV), and Lains and Pinilla (2009).

1) By 1800, the capital stock in the Western Settlement countries was small, but colonization entailed massive investments. Following a lull, investments boomed after the 1930s with the start of massive mechanization.
2) The advanced, long-settled countries of Western Europe traditionally had a very substantial capital stock. Thus, it grew decidedly slower than in the Western Settlement countries until the Second World War and then boomed after the war.
3) In "backward," long-settled countries, most notably China, the capital stock around 1800 was quite large, possibly even greater than in Europe because rice growing needed extensive irrigation. Rice grew very slowly or did not grow at all until quite recently and then boomed, with the intensive use of fertilizers and also mechanization.
4) In "backward" unsettled countries (i.e. those in Africa), the capital stock was initially minimal, and it grew as much as population, probably until the Second World War. Since 1950, the per capita stock of capital has increased, but much less than in Asia.

Summing up, all inputs have been growing throughout the whole period, but there is evidence of a slowdown after 1950, at least for labor and land. This slowdown was to some extent balanced by the acceleration in the rate of growth of the capital stock. It seems highly unlikely that this was large enough to cause the total amount of inputs to increase faster after the Second World War than before it.

The conclusion implies that the acceleration in the growth of output after 1950 reflects an increase in efficiency – or total factor productivity (TFP). TFP is routinely measured as the difference between the rate of growth for output and a weighted average of growth rates for inputs. Table 14.3 reports the available estimates (in average yearly growth rates) for the period before the Second World War, by continent. Two stylized facts stand out. First and foremost, TFP grew almost everywhere, and this by itself is a major change from the (alleged) stagnation of traditional agriculture. A 0.5 per cent yearly growth rate may seem slow, but, when compounded over 40 years, corresponds to a 25 per cent increase, and this is far from trivial. Second, with very few exceptions, such as the Philippines, productivity growth has accelerated over time. A simple unweighted mean of all country estimates is "only" 0.6 per cent but this figure is lowered by the very poor performance of some African and former socialist countries. Indeed, the rate of growth of "world" TFP growth (i.e. the difference between growth of total output and total inputs) is decidedly higher. From 1960 to 2000, the estimates vary, according to the method of computation, between 1 per cent and 1.25 per cent per annum. The growth was decidedly faster in OECD countries than in the rest of the world. Indeed, for these developed countries, TFP growth was on average three times faster after the war than before,

Table 14.3 Growth in total factor productivity to the Second World War

	Before 1870		*1870–1910*		*1910–1940*	
	Number	*Average*	*Number*	*Average*	*Number*	*Average*
Europe	5	0.3	13	0.65	8	1
Europe (Van Zanden)			15	0.78		
Western Settlement	1	0.4	2	0.74	2	0.56
Asia			3	1.24	6	0.08
Africa	1	3.41	1	0.83	1	−0.21
South America			1	−1.9	2	1.57

Sources: Van Zanden (1961), Federico (2005, Statistical Appendix Table IV), and Lains and Pinilla (2009).

confirming the acceleration already detected in previous periods. Contrary to a widespread fear, the estimates for the 1990s and 2000s do not show evidence of slowdown in TFP growth (Headey *et al.* 2010).

Innovations and their adoption

The thousands of innovations adopted in agriculture over the last two centuries can be grouped into four main categories: new practices of cultivation, new plants and animals, chemicals, and machines.

Most new practices aimed at reducing the length of periods of rest, which was the traditional way to restore the soil fertility depleted by cultivation. Thus, in traditional agriculture, the number of crops per year (or cropping ratio) was usually below one, down to 0.05 in the so-called slash-and-burn systems (i.e. two or three crops followed by long periods of rest, up to 40–60 years). In most of Europe, the ratio was around 0.6 – that is, land was left idle (fallow) 1 year out of 3. The ratio was increased by substituting rest with fertility-restoring plants, such as grass or roots. In the late eighteenth and early nineteenth centuries, the practice spread in the UK and all over Europe. Fallow disappeared and later in the century the succession of crops (rotation) become increasingly sophisticated. On the eve of the Second World War, cropping ratios were slightly below 1 in Europe and the United States, and over 1.3 in Asia. Since then, the ratio has increased further, approaching 1 worldwide at the end of the 1990s.

New plants (or animals) can come from three different sources – the casual discovery of a new species or variety, the transfer from other areas, and the production of a new variety of a known species via the hybridization of existing ones. Casual discoveries have always been rare and they played a minor role in the last two centuries, with the sole exception of the sugarbeet, discovered around 1750 and cultivated since the early nineteenth century. Long-range transfers were still important in the nineteenth century. European migrants to the New World brought with them the seeds and plants of native countries and many governments tried to foster the economic potential of agriculture with systematic collection and testing of varieties all over the world. Their attempts often failed, but there were some notable successes. Early experiments of hybridization had started in the mid-nineteenth century, but with poor results. The first great success was the production of hybrid corn in the 1930s. In the 1940s, researchers started to work on varieties suitable for poor countries. The effort paid off handsomely: the new varieties, aptly named high-yield varieties (HYV), in the right conditions, produced up to eight times the traditional ones. The results were stunning enough that they have been called the Green Revolution. Since the 1980s, the potential for improvement has been boosted by genetic engineering.

The major contribution of the chemical industry to agricultural progress was the solution, apparently for good, of the problem of restoring soil fertility. The production of phosphates started in the 1840s and of potash fertilizers in the mid-1850s, while production of nitrogen took off only after the discovery of the Haber-Bosch method of producing ammonium sulfate in 1909. Chemical products were used since the late nineteenth century to fight diseases and parasites, but results were rather poor until the 1940s and the discovery of DDT.

The first modern animal-powered machine for fieldwork was the wheat harvester, or reaper, which Hussey and McCormick patented independently in 1833–4. In the next decades, investors focused on increasing labor productivity in harvesting, with some notable success, but mechanization was delayed by the lack of a suitable source of inanimate power. Neither water nor steam was, for different reasons, really suitable. The mechanization of agriculture really took off only after the introduction of tractors powered by internal combustion engines in the early

1900s, and of the power-take-off shaft (or PTO), which transformed the pulling power of the engine into a rotatory movement.

All innovations cut production costs by reducing the amount of factors per unit of product, but in different ways. Some innovations save all factors in the same proportion (neutral), others save prevalently one factor (say land), and some others need more of a factor to save others. With the possible exception of crop rotation, agricultural innovations needed additional investments (i.e. were capital intensive). Machinery saved labor, by definition, while chemical products and new varieties augmented yields and thus reduced the need of land per unit of product. Thus, one would expect the transfer of technologies from advanced to LDC countries to have been hampered by LDC's scarcity of capital and by the poor development of their financial institutions. One would also expect that the countries of land-scarce Europe were on the forefront of the adoption of fertilizers and new varieties, while labor-scarce Western Settlement countries pioneered mechanization.

The evidence confirms these hypotheses. The difference in patterns of adoption of new technologies between Europe and the United States were huge before the Second World War and, although reduced, are still sizeable today. In a controversial book, Hayami and Ruttan (1985) go a step further along this line of reasoning. They argue that factor endowment affects not only the adoption of innovations but also their production. Land-scarce countries invest more in research on land-saving innovations, and vice versa. However, Olmstead and Rhode (2008) disagree, stressing the relevance of research in land-saving innovations in the United States.

Most innovations are the outcome of expensive investments in research. Chemical and engineering firms can recover the costs while they sell fertilizers or machinery to farmers, but this is often not the case for new varieties or new practices of cultivation. They can be imitated fairly easily and thus inventors risk the loss of part of the potential returns from their investments. Expenditures on research and development (R&d) may not be socially optimal. This problem has been mitigated by granting patenting rights for plants – first in the European Union in 1960, then in the United States in 1970–1, and afterwards in most countries. As of 2011, 69 countries have joined the international association for the mutual recognition of plant patents (UPOV). Under this new regime, private expenditure in agricultural R&D grew steadily, to become the main source of funding in advanced countries – in the United States as early as the late 1980s.

Before the 1970s, much research was financed by non-profit organizations or by the state. A few enlightened landlords funded research in their own estates, while many others gathered in learned societies, such as the Royal Agricultural Society of England. The research in high-yielding varieties started in Mexico with funds from the Ford and Rockefeller Foundations of the United States. Governments funded agricultural R&D research indirectly via universities and directly by setting up specialized agencies, called agricultural stations. The first station was established in Mockern (Saxony) in 1851 and in the second half of the century the United States and most European countries imitated this example. At the turn of the century, colonial powers funded R&D in tropical cash crops for exports (cocoa, rubber), while research in food crops took off after the Second World War. The total investment was substantial. In the United States, expenditures increased from the equivalent of 0.03 per cent of gross agricultural output in 1883 to over 2 per cent in the late 1990s. According to the best estimates, worldwide public expenditure in agricultural R&D increased by 150 per cent in the 1960s, by 50 per cent in the 1970s and by a further half from 1980 to 1995. Expenditure on agricultural extension (i.e. the diffusion of best practices among farmers) doubled from 1959 to 1971 and increased by 25 per cent in the next decade. Since the late 1990s, public expenditure in R&D has stagnated or declined.

Institutions and agricultural performance in the long run

Institutions can be defined as the set of formal or informal rules that determine the ownership of goods and factors (property rights) and regulate the interactions among individual agents or households (contracts, markets, and other forms of distribution). There is a wide consensus among historians, economists, agricultural experts and policy makers on the relevance of institutions as a whole for agricultural growth, but also wide differences of opinion about the importance of each type of institution and their effects.

1) Economists believe that modern property rights are necessary to exploit the full potential of an economy (De Soto 2000). They argue that modern property rights on land – including the right to sell and bequeath it – prevent an excessive exploitation of land for short-term gains (the so-called "tragedy of the commons"), stimulate location-specific investments (e.g. buildings, tree-crops) and allow the use of land as collateral for borrowing. By 1800, these individual rights extended to only a minor part of agricultural land – in Western Europe, in the countries of the Western Settlement, and in some areas in Asia, including most of China (Pomeranz 2008). Elsewhere, the rights to land were jointly held by several individuals. In some areas, feudal lords or other powerful people had the right to claim a part of the product and/or of the time of workers. In others, the rights to land were owned collectively by tribes of hunter-gatherers or by communities of farmers. In this latter case, each household was allocated a plot of land for its sole use for a pre-determined period.

   In the last two centuries, these traditional property rights have been disappearing. The process has been slow, featuring massive reversals, such as the collectivization of previously private land in the Soviet Union in the 1930s and in China in the late 1950s, and is not yet fully over. In the first half of the nineteenth century, the feudal estates of Eastern Europe were divided between the former serfs and the former lords. In other areas, temporary allocation of land to members of farming villages was slowly turned into permanent ownership. In contrast, the rights of hunter-gatherers or slash-and-burn (swidden) agriculturalists in Africa and Asia were ignored by European colonizers. The areas of the New World with temperate climate attracted large numbers of European settlers and thus the natives lost almost all their rights. In tropical countries, the demand for land by Europeans was smaller and thus the native tribes managed to keep most of the land. Colonial administrations started to register the ownership of individual native farmers ("titling") in the 1940s and the process has continued since then, with strong support by international organizations such as the World Bank. The benefits, although substantial, may have been smaller than hoped for. In some cases, titling was unfair or blatantly rigged and peasants lost their rights. Furthermore, anecdotal evidence suggests that traditional property rights were not as inefficient as assumed, because farmers found ways to circumvent their shortcomings.
2) Historians and agricultural experts tend to pay a lot of attention to the patterns of size and ownership of farms. They generally deem the concentration of land in the hands of absentee landlords (latifundia) as a major hindrance to technical progress. However, the evidence for this conclusion is very weak to non-existent. Presumably absentee landlords will introduce innovations whenever profitable. On the other hand, large farms rarely enjoy any advantage in cultivation (processing is altogether different, but it has become an industrial activity). The economies of scale are small, if any, and large farms manned by hired workers are less efficient than family farms. Family farmers have strong incentives to work hard, while preventing wage workers from shirking is much more difficult in agriculture than in

manufacturing. It is possible to effectively monitor agriculture workers only while they perform simple tasks, most notably harvesting.

The superiority of family-owned farms is revealed by their growing share of agricultural land. In the nineteenth century, they prevailed in Western Settlement countries, in many countries of Europe, especially in the North, and possibly in China. In the late 1930s, according to the agricultural censuses by the FAO, "farms managed by owners" accounted for about 55 per cent of acreage in the 1930s, and this figure rose to almost 80 per cent at the end of the twentieth century. In a number of countries, the diffusion of family farms was helped by the intervention of government, by titling and land reform – that is, the forcible division of large estates. The first reforms were enacted in the early 1920s by new countries of Eastern Europe and they multiplied rapidly after the Second World War. However, the share of owner-operated farms rose also in countries or areas where states did not intervene in land ownership.

3) When landowners are not willing (or forced) to sell, the advantage of small-scale self-monitoring cultivation may be captured by hiring a tenant and his family, for a pre-determined sum (fixed rent tenancy) or for a share of the product (sharecropping). Sharecropping is a very contentious institution. Many historians argue that it hinders technical progress, while economists, following Marshall, suspect it to be inefficient. Marshall's argument spawned a huge but ultimately inconclusive theoretical literature. Hard data are scarce, but show that sharecropping was less diffused than fixed rents in the nineteenth century and that its share of total tenanted land, and thus *a fortiori* on total acreage, has been declining in the twentieth century (Federico 2006). The few available tests have uncovered no evidence that sharecropping is less efficient or less innovation-fostering than fixed rent contracts.
4) Agriculture is plagued by serious problems of asymmetric information. Farmers have much more information than buyers about the quality of their products, and more information than providers of credit about their own creditworthiness. Thus, buyers and investors may refrain from purchasing or lending, or may ask farmers, who cannot pledge real assets, very high interest rates. This behavior can be economically rational, but it reduces output and investments below their potential. A quite frequent institutional solution to the asymmetric information problem is cross-monitoring among farmers via cooperation in production and banking. The members of a production cooperative can monitor each other to avoid cheating, which could endanger the quality of the product; those of a cooperative bank can assess the credit risk of another farmer in the same village much better than a bank clerk from the city. Thus, cooperatives have been a great success story. The first were set up in the early nineteenth century, and, in spite of some setbacks, they have been growing since then. In the mid-1990s, when world agriculture employed about 1.3 billion people, agricultural cooperatives had 180 million members. About 80 per cent of these people were in LDCs – over 140 million in India alone. However, advanced countries, including Japan, accounted for 80 per cent of the total value of output by cooperatives. In these countries, cooperatives now have very high market shares in perishable or not homogenous products, such as fruit and vegetables, wine, and, above all, dairy products. Some of them have built highly successful consumer brands, becoming, in some extreme cases, a threat to competition.
5) Last but not least, both technical progress and specialization need the development of markets. The evidence on the development of markets for capital and labor is too sketchy to be of much use, and overall trends, such as the increase in family farming, have affected factor markets in a complex way. In contrast, there is no doubt that the markets for agricultural products have experienced extensive development. In fact, the gross output per worker has increased well beyond the consumption needs of farming households, while urban

population, which has to be fed via markets, has been rising throughout the whole period. Worldwide, its share of total world population has increased from about 30 per cent in 1950 to above a half in 2000. This argument is supported by evidence on the share of marketed production in total output, which shows a steady increase in all countries. In the 1960s, it exceeded 95 per cent of output in the United States and 80 per cent in all advanced countries, and it hovered around 40 per cent in the least developed African countries. It is likely that the share has increased since then.

Agriculture and the state

The list of policies that may affect agriculture is very long. Some of them, such as support for R&d, have been discussed previously. Thus, this section concentrates on policies that directly affect farmers' income.

At the beginning of the nineteenth century, state intervention was very limited. Production and domestic commerce in agricultural products were almost everywhere uninhibited by the state, and this was true also for international trade, with the notable exception of protection against imports of wheat in the UK and some other European countries. These duties were abolished in the 1840s and 1850s and were re-imposed in most countries, excluding the UK, after the 1880s. As a rule, other products were affected much less than cereals. A compact measure of the effects of product-specific policies is the nominal rate of assistance (NRA) – that is, the difference between the domestic price and the world price as percentage of the latter. The ratio remained very low or even negative in European countries until the First World War (Swinnen 2009) and, after a short spell of war-time regulations, also in the 1920s.

The outbreak of the Great Depression caused a fall in relative prices of agricultural goods, triggering an epoch-making change. The European countries protected farmers by increasing duties and by adding quantitative restrictions and regulations of the markets, pushing their NRAs well above 50 per cent. Overseas exporters such as the United States tried to help farmers by setting up marketing boards to prop up exports or by subsidizing their incomes. State intervention was not phased out after the war, for different reasons – the fear of shortages in Europe and the successful lobbying of farmers in the New World. In Europe, the level of protection declined relative to the peaks of the 1930s, but it increased again in the 1960s under the Common Agricultural Policy. Some newly developed countries, such as South Korea, imitated the European countries, while other developed countries continued to subsidize producers. In contrast, poor countries in Latin America and former colonies in Africa and Asia used agriculture, especially the production of cash crops for exports, as a cash cow to finance their dreams of industrialization. In the 1960s, the NRAs for developing countries were heavily negative – that is, domestic prices were lower than world ones (Anderson *et al.* 2009). Since the 1990s, state intervention has been slowly phased out, although not entirely. Poor countries liberalized their domestic markets and dismantled state-owned marketing boards, while advanced OECD countries switched from price setting and market intervention to directly subsidizing farmers. Thus, in advanced countries, the NRAs, which had peaked at around 80 per cent in the 1980s, declined to about 40 per cent, while in developing countries they became moderately positive.

Economists generally take the view that state intervention is justified only when it can foster competition or redress some market failure. Neither criterion applies to these policies. In the 1980s, consumers in OECD countries lost on average 1.35 per cent of their income because of artificially high prices for agricultural products. According to other estimates, about three-quarters of these sums accrued to farmers, while the rest was a net loss for the whole economy

(Federico 2009). The liberalization of the 1990s reduced consumer losses by about two-thirds. The effects of policies in LDCs were the opposite: producers lost and urban consumers gained. In all likelihood, the welfare losses were greater than in advanced countries, although there are not really representative estimates. Cline (2004) estimates that, in 1997, simply liberalizing agricultural trade, without modifying other domestic subsidies, would have increased world income by 0.5 per cent.

Conclusions: the challenges ahead

In spite of its past achievements, the prospects for world agriculture are not bright and there are myriad problems that need to be addressed. World agriculture must increase production at least as rapidly as world population, which according to United Nations forecasts by 2050 will be 20 to 65 per cent larger than in 2000. On top of this, the increase in income is bound to shift demand towards fruits, vegetables, and, above all, dairy and meat, which use land more intensively than cereals per unit of calories produced. Unfortunately, however, available land is scarce, and it is constantly reduced by urbanization, even neglecting the possible losses from climate change. A massive extension of cropland is possible only at the expense of forests, but massive deforestation would cause huge environmental and social problems. Scarcity of land is not the only problem. Agricultural manpower is bound to decrease in the future as workers migrate to cities. Thus, the only solution to the problem of production increase seems to be a further increase in capital intensity and technical progress. Unfortunately, modern techniques, although extremely efficient, often damage the environment. Irrigation may cause losses of land, chemical products are harmful for farmers and for the whole population, and the massive adoption of selected seeds and improved breeds threatens biodiversity and thus the stock of potentially useful varieties. The impact of genetically modified organisms is controversial. Thus, the needs of increasing production and of preserving the environment are in conflict. This conflict cannot be solved with a return to traditional agriculture, which, although environmentally more sustainable, would be unable to feed the current and projected world population. Developing efficient and environmentally sustainable techniques is the great challenge for the future of agriculture and of humankind.

Notes

1 The chapter relies heavily on Federico (2005) and quotes only additional material and references.

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