Agriculture, development and international trade:
Lessons to be learned from the Common Agricultural Policy of the European Union

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1. Introduction

In 2005, the Economic Union of West African States (ECOWAS) decided to create a common agricultural policy (ECOWAP), with food sovereignty and the promotion of efficient family farms as its main aims. The structure and instruments of the policy still have to be elaborated. Because the ECOWAS countries have close relations with the European Union (EU), it may be natural for them to look to the common agricultural policy of the EU for guidelines. Today, the EU is pressuring the ECOWAS countries to open their markets within the context of a European Partnership Agreement. However, the EU has itself created a highly protective farm policy that has pursued aims similar to those that the ECOWAS has now adopted. This policy has worked well for several decades. However, it also had significant shortcomings, with serious negative effects for European tax payers and for other countries. These shortcomings have induced policy changes that also explain the current position of the EU towards its West African partners. This paper surveys the history of the common agricultural policy of the EU so that farmers and policy makers of the ECOWAS can draw their own conclusions.

2. National origins of European farm policies

Although the European Union was formed in 1958, government intervention in agricultural markets was nothing new to the member states. All countries that established the EU or joined it before 2004 had already been protecting their farmers for a long time before that. The common agricultural policy of the EU was an integration of these national policies. To understand the farm policy of the EU, therefore, one has to start with the origins of agricultural protection in Europe. This also reveals the interaction between farm policies and development in a phase in which European economies more closely resembled the ECOWAS economies today.

European countries started to protect their farmers from the late 19th century as a reaction to an international fall in the prices of agricultural products. Until that time, low prices had been less of a problem in Europe. Population growth increased the demand for food and clothing, which was the usual cause of rises in agricultural prices. It had encouraged farmers to invest in new crops and techniques that enabled a sustainable rise in farm production.

The resulting increase in supply had moderated the increase in food prices and created welfare that fuelled flourishing markets for industrial products. In this way, the Industrial Revolution, which started in Britain around 1800, arrived surfing on a wave of agricultural growth that was driven by rising agricultural prices. Under these conditions, there had been little need for agricultural protection. Rather, food imports were welcomed as a means of tempering the influence of population growth on food prices. Accordingly, many European countries had reduced or abandoned their import tariffs on agricultural products by the mid-19th century without this causing a price fall.

In the late 19th century, this whole situation underwent a radical change. The arrival of new railways and motor vessels cheapened the imports from distant countries. European ports were flooded with cereals from temperate zones in other continents where these new export opportunities led to a virtual explosion of reclamation activity. At the same time, the rise of the chemical industry resulted in cheap fertilisers that raised the yields in Europe itself. While these developments boosted the global supply of agricultural products, other developments curbed the increase in demand. In particular, electricity, internal combustion engines and artificial fibres caused fossil fuels to undercut the demand for farm-produced materials and energy sources. Rather than the increase in demand exceeding that in supply, as had been customary until that time, the increase in supply was now running up against a slower increase in demand. The upshot was over-abundance in the world markets of agricultural products, which caused successive falls in international agricultural prices (see Figure 1). Farm incomes declined, and in many places farm progress began to give way to stagnation. This in turn provoked calls for support from farmers, often backed by manufacturers who feared that rural stagnation would threaten their markets.

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1 This section is largely based on N. Koning, The failure of agrarian capitalism: agrarian politics in the UK, Germany, the Netherlands and the USA, 1846-1919. London and New York 1994.
Figure 1: Real wheat prices in England and the United States (5-year moving average; 1818 = 100)

Source: Own calculations based on data in Mitchell (1975:191-5, 736; 1990: 737-41, 756-7)

Under this pressure, all countries in Western Europe introduced protective tariffs. Most did so from the first price fall in the 1880s-90s. However, a few countries - Britain, Denmark and the Netherlands - kept to agricultural free trade until a second price fall in the 1920s-30s. It is instructive to examine what happened after these different policy choices:

- Denmark and the Netherlands weathered the first price fall without protection. They had small but productive farms, with low labour costs, also because industrial retardation had the effect of moderating farm wages. Both countries were favourably located to supply the growing cities in Britain and Germany with animal and horticultural products, whose prices fell less than those of other crops. When international agricultural prices recovered after 1900, rapid farm progress resumed, supported by government investment in agricultural research and education. However, the second price fall in the 1920s-30s caused a stagnation of farm progress and both countries then resorted to protection.

- Britain also kept to agricultural free trade until 1930. This country possessed the most technically advanced agriculture in the world. Before the price fall in the 1880s-90s, farmers were raising their productivity by adopting underdrainage, fertilizer, purchased feeds and agricultural machinery. However, Britain was also the world’s first industrialised country, and strong industrial competition for labour was pushing up agricultural wages. The fall in international agricultural prices was a heavy blow to British farmers. Efforts to maintain soil fertility decreased. Almost one million hectares of arable land degraded into rough grazings. The maintenance of buildings and equipment was neglected, drainage activity came to a halt, and the demand for heavy farm machinery plummeted. For half a century, productivity growth in agriculture stagnated (see Figure 2). Fortunately, British industry was sufficiently developed to provide alternative employment to farm workers; otherwise the consequences would have been disastrous. In 1930, Britain started to support its farmers, and productivity growth in agriculture recovered.

- The other countries of Western Europe started to protect their farmers from the first price fall in the late 19th century. In France and Italy, farm progress fared no better than in Britain (Figure 2). Tenure relations gave little security to farmers, and agricultural research and education were at a low level. Nevertheless, the protection of agriculture seems to have sustained the demand for industrial products. This was important, because the French and Italian industries were more dependent on the domestic market than their British counterpart, which had gained an established position in the world market as the ‘first workplace of the world’.

- Germany also protected its farmers from the late 19th century. Unlike France and Italy, it had an outstanding system of agricultural education and research, and went through significant land reform. In this country, the introduction of protection entailed a rapid growth in productivity in agriculture. Around 1880 its productivity was

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2 Bairoch (1976).
still far behind that in Britain, Denmark and the Netherlands. Forty years later, German farmers had largely caught up with their Danish and Dutch colleagues, while British farmers had fallen far behind (Figure 2). Farm progress involved the growth of sugar factories, breweries and other food industries, and farmers were significant buyers of industrial goods. In all probability, the protection of agriculture helped Germany to outpace Britain as an industrial nation.¹

Advocates of agricultural trade liberalization do not like to be reminded of the successful development in protectionist Germany and the poor performance of free-trading Britain between 1880 and 1930.⁴ Nevertheless, the German experience has meanwhile been repeated in Japan, South Korea and Taiwan,⁵ while Britain never again stopped supporting its farmers after 1930. Only Denmark briefly tried to return to the free market in the mid-1950s. Considering that normal times had returned, it abandoned its price support policy. The result was falling farm incomes, slowing productivity growth, labour unrest, and a farmer boycott of meat factories. In 1960 the Danish government hastily reintroduced protection.⁶ Apart from this brief experience, all countries in Western Europe have protected their farmers in the post-World War II period.

![Figure 2: The growth of agricultural productivity per head and per hectare in eight countries of Western Europe, 1870-1910 (in wheat units and 1870 prices)](source: Van Zanden (1991)).

3. The General Agreement on Tariffs and Trade (GATT)

When European countries began protecting their farmers in the late 19th century, they did so on a purely national basis. However, the introduction of protection was a response to falling prices that were due to global overproduction. If countries just shielded their own farmers against this price fall, the growth of their farm production continued unhampered, which exacerbated the overproduction at the international level. Until the 1930s, countries that protected their farmers did not bother about this. Most were importers of farm products, and if their policies added to low international prices they could simply raise their protective tariffs even further. However, once a country produced more than its domestic consumption, it was left with a surplus that could only be disposed of in the world market. This involved a loss or a subsidy to bridge the difference between the protected domestic prices and the lower world market prices (‘dumping’).

² Liberal historians have depicted agricultural protection in Germany as a policy that hampered growth and hurt consumers and small farmers (e.g. Tracy 1989), but new research contradicts this view (see Koning 1994 and literature referred to). When confronted with the stagnation of agriculture in Britain, liberal economists mostly explain that this was caused by the loss of comparative advantage. However, according to their own theory, loss of comparative advantage can only explain the shrinking of British agriculture, not the stagnation of productivity.
³ See Koning (forthcoming) and literature referred to.
⁴ See Koning (1988) and literature referred to for this episode.
The new fall in agricultural prices in the 1920s-30s was coupled to a great depression that squeezed the domestic demand for farm products. As a consequence, several countries were left with increased surpluses that they could no longer sell in their own markets. The fall in world market prices also raised the costs of dumping these surpluses, the more so because dumping itself drove world market prices down even further. To moderate the resulting cost increase, several countries introduced supply management to reduce their export surpluses. Thus France controlled the production of wheat, and the Netherlands that of livestock and vegetables. On the other side of the ocean, the US did the same with cotton and tobacco. These measures soon became linked to international trade negotiations. Many policy makers realised that some multilateral system of supply management was needed to bring world market prices back to a desirable level. This led to the first international commodity agreements for products like wheat, sugar, tea and rubber. The same idea was of influence on the new international trade treaty that was concluded after WWII. This treaty, the General Agreement on Tariffs and Trade (GATT), did not prescribe free trade for farm products but allowed countries to protect their farmers provided that they controlled their production and exports.7

4. Creation of the Common Agricultural Policy of the EU

So when the EU was formed in 1958, two important conditions already existed. Firstly, all the countries that established the EU or joined it before 2004 had already been protecting their farmers. Secondly, these countries had signed the GATT that asked to combine agricultural protection with supply management. The EU simply harmonized and integrated the existing farm policies of its member countries, so that one common policy was created instead of a patchwork of national policies. In doing so, it adopted a number of guiding principles:

- The first one was that of a unified market. Within the EU, the borders were opened. Farm products could freely move from one country to another. It was only at the outer border that import tariffs were imposed to protect EU farmers against cheap imports from the world market.8

- The second principle was that of communitarian preference. This closely resembles the principle of food sovereignty that ECOWAS farmers and policy makers are discussing today. It meant that farm products that were consumed in the EU and that could reasonably efficiently be produced in the EU itself should come from the EU rather than from the world market. The external tariffs should be sufficiently high to ensure this.

- The third principle was that of parity and productivity. Parity meant that farm incomes should be equal to those in other sectors. This should partly be achieved by price support, but prices should not be too high, for affordable food prices for consumers were also important. Therefore, the productivity of agriculture should be stimulated so that farmers would be able to produce at lower cost.9

- The fourth principle was that of financial solidarity. All costs of the common agricultural policy were financed out of a communal treasury, which in turn was filled with funds originating from import tariffs and some other government revenues.

To support the prices that European farmers received, the EU took measures for four major products: cereals, dairy, beef and (beet) sugar. For cereals, milk and beef, it applied a system of intervention storage (see Figure 3 for a schematic representation). The EU bought all lots that were offered to it at a fixed ‘intervention price’. This became the effective floor price in the market, for no seller would accept a lower price for his product. Import tariffs were applied at the external border to make imported cereals, dairy and beef more expensive than this floor price. Export subsidies that bridged the gap between the internal price and the lower world market price were provided to sell possible surpluses in world markets.

A somewhat different system was used to support the prices of sugar beets. Every farmer received a guaranteed price for a certain amount of sugar beets that corresponded to his share in the EU consumption. Sugar that exceeded this quota had to be exported to the world market and farmers only received the lower world market price for it.

The support of these four major products sustained the prices of other farm products too. For example, potatoes and onions were not directly supported. But if farmers earned less from these crops than from cereals, they would decrease their production of potatoes and onions, and increase their cereal production. As a consequence, the supply of the former would decrease and their prices increase, until they could give comparable incomes to those that could be earned through the supported cereal crop. Additional measures were taken for some specific products. For example, fruits and vegetables were protected by seasonal import tariffs, while pig and poultry farmers were compensated for the increased feed costs resulting from cereals protection (cereals are a major input of feed in the EU).

7 See Henningson (1981) for the political backgrounds of the agricultural aspects of the GATT.
8 In practice, before the introduction of the Euro, measures to compensate changes in exchange rates of the currencies of different member countries led to deviations from this internal free trade.
9 The parity principle was not specifically included in the Rome Treaty (1957) by which the EU was founded. However, it was laid down in key policy documents of the European Commission and in the conclusions of the Stresa Conference (1958), where the main principles of the common agricultural policy were elaborated.
Together, these measures would ensure prices that allowed farmers and labourers in modern farms to earn incomes equal to those in non-farm sectors. To be sure, many farmers were too small to earn such a ‘parity income’ even when prices were supported. They would then receive advice and financial support to modernise their farms or find jobs outside the agricultural sector. By such ‘structural policies’, the average farm size would be enlarged to create room for mechanisation and an increase in productivity.

5. Lack of supply management

For a few decades, the above policy worked quite well. The EU became more self-sufficient for food, and although farm incomes remained below non-agricultural incomes they at least kept pace with the rapid rise in the latter. The implementation of structural policies lagged behind that of price policies. However, much expansion and modernization of farms still occurred, and productivity in agriculture rose faster than in most other developed countries.

The importance of the common agricultural policy for economic development was well illustrated by Ireland. Before this country joined the EU in 1973, it was much less developed than the rest of Western Europe. Agriculture was still the largest sector, but farm-gate prices were much lower than in the EU. Ireland’s entry into the Union was followed by a miraculous growth of its agriculture and economy.

Until the mid-1980s, the agricultural policy of the EU was maintained with minor adaptations. Some features were added when the entry of new member countries posed new challenges. When Britain joined the EU in 1973, it wanted to continue to provide preferential access to imports from countries from the British Commonwealth. This concurred with similar wishes of France, and one outcome was the Lomé Conventions (from 2000 the Cotonou Agreement), which gave preferential access to imports from ACP countries, which include the ECOWAS countries. Other modifications were the introduction of special supports for hill farmers (also linked to the British entry) and the introduction of integrated development programmes for less-favoured areas (linked to the entry of Spain and Portugal in 1986).

Meanwhile, a basic flaw of the common agricultural policy was the lack of supply management. All member countries had signed the GATT, thereby obliging themselves to combine agricultural protection with production and export controls. Nevertheless, the common agricultural policy included no effective instrument for supply management. Those member countries that had applied production controls in the 1930s had abandoned them during World War II, and the EU did not reintroduce them. Only the price quota system in sugar, which was introduced at the demand of French farmers, was meant to prevent oversupply. However, sugar factories in other member countries wanted to increase their turnover. They enforced an opting out rule that allowed them to pay a ‘mixed price’, thereby eliminating the incentive for farmers to limit their production.

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For this purpose, a distinction was often made between ‘viable’ and ‘unviable’ farms. The former would be helped with modernisation, while the latter would be abandoned and their workers helped to find non-farm jobs. It should be noted that many small farmers whose farms were deemed ‘unviable’ resisted this policy.

Meester & Strijker (1985).

Van der Meer (1989).
As a consequence, the export surpluses of major farm products increased unrestrained. This had serious effects on other countries. Subsidized exports of butter and milk powder hurt dairy farmers in New Zealand and in many developing countries. Growing sugar exports caused the International Sugar Agreement, which sought to stabilise world sugar prices, to collapse. After 1980, surpluses also arose in beef and cereals. Large amounts of frozen beef were dumped onto West African markets, hurting cattle farmers in the Sahel countries. This increased dumping also resulted in increasing costs to the European treasury in the form of export subsidies or losses on exports out of public stocks (see Figure 4). To moderate this rise in costs, EU policy makers began to lower the European support prices to reduce their distance from the lower world market prices and decrease the cost of dumping per tonne of product. However, this eroded the aim of parity incomes for farmers. Farmers protested, demanding that the costs of dumping be reduced by supply management rather than by cuts on internal prices. Responding to this pressure, a system of milk quotas was introduced in 1984. Each farmer was only allowed to produce a certain amount of milk, based on his output in a base period. This system still exists and has effectively reduced the European dairy surpluses (see the evolution of the expenses for dairy in Figure 4). However, the introduction of a similar policy in cereals was impeded by the grain trade and a minority of big grain farmers. The traders wanted to expand their turnover and didn’t mind that farmers would receive lower prices, while big grain farmers did not suffer from lower prices because they were the most competitive producers. As a consequence, the European cereals surpluses continued to grow unabated.

The situation was exacerbated by a hole in the European wall of protection. In the 1960s, the US had pressured the EU into accepting that oilseeds and grain substitutes (maize gluten, citrus pulp etc.) could enter the European market free of tariffs. This undermined the agricultural policy of the EU, because imported oilseeds competed with European butter, and imported grain substitutes competed with European feed grains. As a consequence, the EU was able to sell less butter and cereals in its own market, so that it was left with larger surpluses that had to be dumped onto world markets.

6. The Uruguay Round and its aftermath

These problems came to a head in the Uruguay Round of GATT negotiations (1986-93). The increased dumping of European cereals damaged the interests of the United States - the world’s number one grain exporter. Until the 1970s, the US had a policy similar to that of the EU, with import restrictions and intervention storage to support farm-gate prices. Like the EU, there was insufficient supply management, and it was dumping large surpluses onto the world market. Nevertheless, it had an acreage reduction programme to avoid the complete ruining of its export market. The US accused the EU of freeriding on this programme for dumping its own surpluses, and demanded that the EU eliminate its export subsidies for cereals. The EU were willing to to discuss this matter only if the US would consent to European import tariffs on oilseeds and grain substitutes, arguing that much of its grain surplus was caused by the unbridled increase in imports of these products. The US rejected this because it wanted to retain free access to the European market to dispose of its surpluses of soybeans and maize gluten.

The result was an increasingly acrimonious trade conflict. As a strategic response to this, the US reduced its own farm-gate prices of major export crops, and compensated its farmers with price subsidies out of the treasury. Because its farm-gate prices were now close to world market prices, it needed less export subsidies to sell its surpluses in the world market. The US called this a step towards ‘liberalization’ and formed a coalition with the ‘Cairns group’ of agricultural exporting countries (New Zealand, Australia, Canada and several middle-income countries) that had always condemned export subsidies. With this backing, it set liberalization of agricultural trade at the top of the agenda of the Uruguay Round, demanding that all countries eliminate their export subsidies and import restrictions.

The agro-industrial corporations that resisted supply management in the EU silently welcomed this pressure. For examples, the big dairy factories did not want a full elimination of agricultural protection, which supported their own supply of raw materials. However, they hoped to use the American pressure to get the internal prices in the EU reduced, so as to decrease the costs of dumping and appease the ministers of finance without stricter production controls being introduced. In line with their wishes, the EU declared that it was willing to discuss some reduction in import tariffs and export subsidies, if the US were to accept European tariffs on oilseeds and grain substitutes. However, the US kept to its demand for a full elimination of tariffs and export subsidies. Six years of stalemate followed. At the end, the whole the Uruguay Round seemed to have failed, including the non-agricultural negotiations. This threatened the interests of non-farm industries on both sides of the ocean. Under their pressure, the EU and the US concocted a compromise in a bilateral meeting (the Blair House agreement of 1992) which the rest of the world was made to undersign after some minor modifications. This became the Agreement on Agriculture of 1994. It decreed that all protective measures had to be reduced by certain percentages, but that direct payments were exempted from this obligation.

This agreement in the first place made a solution of the EU-US trade conflict possible. The EU reduced its cereals prices and compensated its farmers through direct payments. This price decrease stimulated European feed mills to use more European cereals and to use less imported grain substitutes, as the EU had wanted. As a consequence, the European grain surplus was moderated. Moreover, the lower grain prices resulted in much less export subsidy being needed to export this surplus. In this way, the American demands were partly able to be met while the direct payments ensured the continuity of the support that was given to European farmers.

Figure 5: Evolution of EU expenses for arable agriculture, 1980-2002

![Figure 5: Evolution of EU expenses for arable agriculture, 1980-2002](source: Data European Commission (taken from Lapperre 2006))

However, it soon appeared that the exemption of direct payments by the Agreement on Agriculture had much wider consequences. The fact that the US and the EU had failed to combine the protection of their agriculture with adequate supply management violated the spirit, if not the letter of the old GATT treaty. The Agreement on Agriculture now permitted direct payments without supply management, provided that they were ‘decoupled’ from current production. As a consequence, the violation of the GATT by the US and the EU was officially sanctioned as long as they shifted from price protection to protection through direct payments. In 1996, the US passed a new bill that abandoned the acreage production programme – its last vestige of supply management – while substituting ‘decoupled’ payments for price subsidies. It allowed it to maintain its exports although its cost price exceeded the world market price. Since then, both the US and the EU have strongly increased their direct payments support. In the EU, almost all farm income, and in the US, one-third of farm incomes now comes directly from the exchequer. (Figure 5 showing the increase in the share of direct payments in the EU’s expenses for arable agriculture.) The EU has used
direct payments to avoid production controls in cereals and beef, and some member countries hope to eliminate the milk quota system, although this is being strongly resisted by farmers. Both the EU and the US have refused any restriction on ‘decoupled’ payments in the WTO (the organization that is responsible for the GATT and the Agreement on Agriculture). They call this shift to direct payments ‘liberalization’, arguing that they would be less trade-distorting than export subsidies. In reality, this shift is a mere change in the form of protection by which both blocs continue to export large volumes below their own cost of production.

While the US and the EU are thus replacing open dumping with disguised dumping, other countries are being compelled to reduce their tariff defenses. Developing countries get ‘special and differential treatment’, which leaves them some leeway for protecting their farmers through import tariffs. However, the World Bank, the IMF, and the governments of the US and the EU are pressuring them not to use this room. The EU is trying to use European Partnership Agreements to make ACP countries open their markets for its surpluses. In doing so, it is echoing World Bank economists who are claiming that liberalization of their own trade policies would be good for developing countries. Yet the farm policy history of Europe itself casts serious doubts on this argument as has been shown above.

It should be noted that the EU has made a serious error of judgment. Direct payments support is more expensive for governments than price support, which is largely paid for by the consumers (see Figure 5 showing that the shift to direct payments led to a strong increase in expenses). Therefore, direct payments support is only feasible for countries with rich treasuries where farmers are no longer more than 2 or 3 percent of the population. The US is such a country and Western Europe too, but in 2004 the EU was enlarged by ten Eastern European countries where small farmers are a significant part of the population. EU politicians had thought that direct payments could be withheld from Eastern European farmers by reforming the common agricultural policy before East European countries joined the Union. East European farmers would then have no right to direct payments, because these were a compensation for the reduction of supported prices that they had never had. Not surprisingly, this narrow-minded idea proved politically infeasible. It has meanwhile been decided that Eastern European farmers will also receive payments. This makes the shift to direct payment support much more costly for the EU budget than for the US budget. It largely explains why the EU is resisting a more far-reaching dismantling of its protective tariffs in the WTO negotiations. Indeed, this makes the European pressure on the ECOWAS countries to open their markets even more questionable.

7. Conclusion

The beginnings of agricultural protection in Europe shed doubt on the idea that countries can develop their agriculture in a free market. Agricultural productivity in free-trading Britain stagnated while protectionist Germany saw rapid farm progress between 1880 and 1930. Fortunately for Britain, its industrial growth had become robust enough to provide new jobs to rural workers, otherwise agricultural stagnation might have had effects similar to that in poor countries today. It suggests that countries may need to protect their farmers against cheap imports if they want to get their agriculture moving. Yet it does not mean that protection alone will do the job. The sluggish growth of farm productivity in France and Italy between 1880 and 1930 indicates that protection will only really stimulate farm innovation when combined with strong government investment in rural infrastructure, agricultural research and education, and with land tenure relations that give sufficient income and security to the tillers.

In the 1960s, the farm policies of the countries that founded the EU were integrated into a common agricultural policy. The prices of farm products were supported to allow modernised farms to earn incomes equal to those in the non-agricultural sectors. This was combined with measures to help small farmers to modernize their farms or find non-farm jobs. The communitarian preference principle of this policy and the protection against cheap imports closely resembled what ECOWAS farmers are demanding today. This may hearten West African farmer organizations, and should make European policy makers who are asking ECOWAS to open its borders more self-conscious.

A basic flaw in the agricultural policy of the EU was the lack of supply management. This was at odds with the original principles of the GATT treaty, which obliged countries to combine agricultural protection with production and export controls. It caused increasing export surpluses that were dumped onto world markets, which hurt the interests of other countries. The shift from price support to direct payments that the EU (and the US) are now engaged in is no solution for this problem. It is a strategy designed to continue dumping in disguised forms while the rest of the world is subjected to tariff disarmament. Conversely, the milk quota system that was introduced in 1984 (and that still exists) was a step in the right direction.

15 ‘Decoupled’ payments are coupled to a farmer’s production in a certain base year rather than his current output. The idea is that such payments would have no influence on current production. In reality, they still have an influence, because they ease the financing of investment for farmers (see e.g. Gardner 2002). Moreover, farmers anticipate that after some time, the base year will be updated (as the US already did in 2002), which encourages them to increase their production so that they have a good position in the new base year.
16 Ray et al. (2003).
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