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Competitiveness, Productivity and Efficiency in the Agricultural and Agri-Food Sectors

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COMPETITIVENESS, PRODUCTIVITY AND EFFICIENCY IN THE AGRICULTURAL AND AGRI-FOOD SECTORS

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Abstract

This report reviews the literature on competitiveness, productivity and efficiency in the agricultural and agri-food sectors. It clarifies concepts and terminology used in this area, and provides a critical assessment of approaches and indicators used in the literature to measure competitiveness, productivity and efficiency at sectoral and farm levels. It also discusses recent findings on productivity growth, changes in relative competitiveness between sub-sectors and countries, and determinants of competitiveness, in addition to identifying the major knowledge gaps. This report suggests that more attention should be paid to the agri-food sector, non-price factors of competitiveness, and the impact of government intervention on competitiveness.

Keywords: Competitiveness indicators, domestic resource costs, comparative advantage, agriculture and agri-food sectors, farm productivity, productivity growth, determinants of competitiveness.

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COMPETITIVENESS, PRODUCTIVITY AND EFFICIENCY IN THE AGRICULTURAL AND AGRI-FOOD SECTORS

1. Introduction

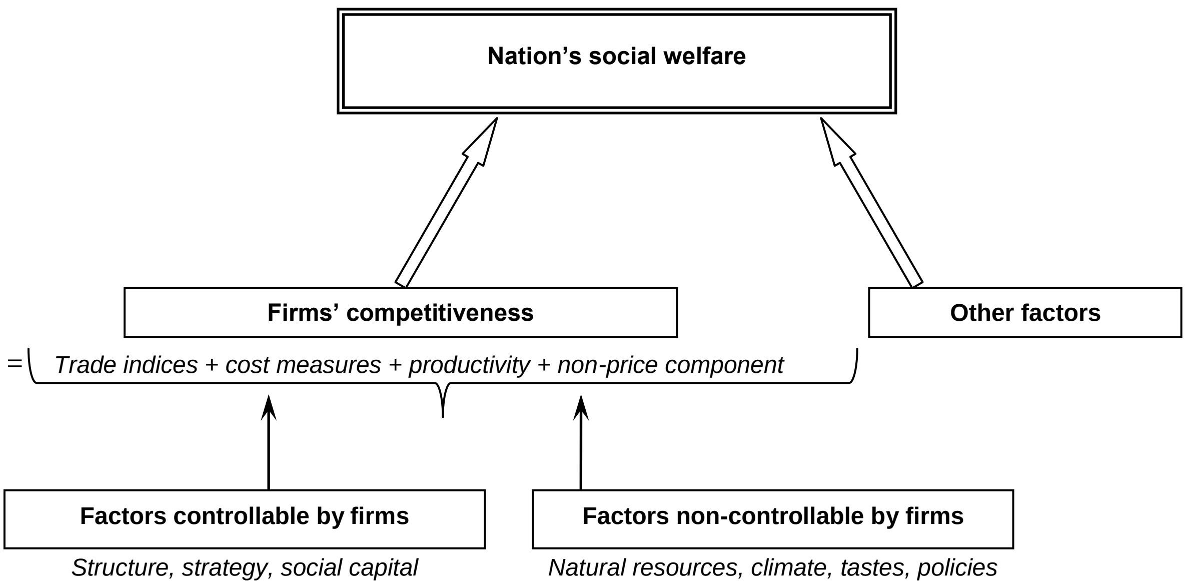
The main question that underlines research in economics is how to allocate resources in order to ensure social welfare, including full employment and high living standards. Researchers are interested in which sector can contribute the most to a nation's economic growth and they often turn to the concept of competitiveness as a basis for analysis. The Organisation for Economic Co-operation and Development (OECD) defines competitiveness as the "ability of companies, industries, regions, nations, and supranational regions to generate, while being and remaining exposed to international competition, relatively high factor income and factor employment levels on a sustainable basis" (Hatzichronologou, 1996). The European Commission uses the following definition: "a sustained rise in the standards of living of a nation or region and as low a level of involuntary unemployment as possible" (European Commission, 2009).

In parallel, the trade negotiations over the past couple of decades in the context of the General Agreement on Tariffs and Trade (GATT) and World Trade Organisation (WTO) have increased government interest in evaluating their country's competitiveness. In particular, the competitiveness of the agricultural sector, which in general has been protected in developed countries, is central, especially given the potential consequences if protection is reduced.

This report, based on a literature review, investigates the competitiveness of the agricultural and agri-food sectors. Definition and measurement methods are explained, and results from a few studies are given. The report does not claim to be exhaustive in reviewing all possible methods and existing empirical studies, but it presents a broad overview of the measures most often used in the literature to evaluate competitiveness, and illustrates these with a few examples. This overview allows a variety of conclusions to be drawn regarding the limitations of measurements, and suggestions as to where future research should be focused.

Several authors stress that competitiveness does not have a definition in economic theory (*e.g.* Sharples, 1990; Ahearn *et al*., 1990). Competitiveness can be defined as the ability to face competition and to be successful when facing competition. Competitiveness would then be the ability to sell products that meet demand requirements (price, quality, quantity) and, at the same time, ensure profits over time that enable the firm to thrive. Competition may be within domestic markets (in which case firms, or sectors, in the same country are compared with each other) or international (in this case, comparisons are made between countries). Competitiveness is therefore a relative measure. It is, however, a broad concept and there is no agreement on how to define it, nor how to measure it precisely. There is a profusion of definitions with studies often adopting their own definition and choosing a specific measurement method. There is, however, more or less a consensus on which measures could be used to assess competitiveness. Measurement can be made according to two disciplines: i) the neoclassical economics which focuses on trade success (Section 2) and which measures competitiveness with the real exchange rate, comparative advantage indices, and export or import indices; and ii) the strategic management school places which places emphasis on the firm's structure and strategy (Section 3). In the latter, competitiveness is defined as cost leadership and non-price supremacy, with cost competitiveness measured according to various cost indicators, as well as productivity and efficiency. Non-price competitiveness is not reviewed here as almost no empirical study deals with this. This paucity will be discussed in Section 5. In Sections 2 and 3, measurement methods are explained and examples from a few studies are provided to illustrate the methods. Particular emphasis is given to productivity (and its efficiency component), which is generally agreed to be a part of competitiveness, albeit not often cited as such in empirical studies. Section 4 reviews the determinants of competitiveness by first explaining the methods employed by researchers and then listing the main determinants found in the literature. The latter are separated into factors that can be controlled by firms (size, structure, and social capital) and factors for which firms have no control (national factor endowments and demand conditions, policies, location); Figure 1 conceptualises the measurement and determinants of competitiveness. Section 5 provides a discussion of the methods and findings, and Section 6 concludes by providing a few guidelines for future research.

Figure 1. Measurement, determinants and effect of competitiveness



2. Trade measures of competitiveness

Trade theory suggests that a nation's competitiveness is based on the concept of comparative advantage. Conceptualised by Ricardo and by the Heckscher-Ohlin model (in a two-country, two-input case), comparative advantage postulates that trade flows are the result of differences in production costs among countries and that a country will specialise in the production of a good in which it has a cost advantage. Such a concept is useful when comparing countries, that is to say when measuring international competitiveness.

2.1. Real exchange rate and purchasing power parities

The real exchange rate (RER) is a measure of international competitiveness. Brinkman (1987) explains that where the demand for the currency of a competitive country is high, this strengthens the currency's exchange rate. The RER is defined as follow:

$$\mathrm{RER} = \frac{p^{T}}{p^{NT}} \tag{1}$$

where p^{T} is the price index of tradable commodities and p^{NT} is the price of non-tradable ones.

Mulder *et al*. (2004) propose the relative real exchange rate, that is the exchange rate weighted by the countries' Gross Domestic Product (GDP) and evaluated in dollars for a specific base year. Ball *et al*. (2006) argue that a better measure for comparing different countries' relative prices is the purchasing power parity (PPP). They define the PPP for outputs as the number of units in the domestic currency that would be required to purchase the amount of the domestic industry's good for one unit of the second country's currency. The PPP for inputs can be defined in the same way. Bureau and Bultault (1992) are the first authors to have introduced this concept within the agricultural context and they define the PPP as the rate at which a given amount of national currency must be converted to purchase the same quantity of product in the two countries being compared.

2.2. Revealed comparative advantage and derived indicators

Revealed comparative advantage (RCA) was first formulated by Balassa (1965) and modified by Vollrath (1991) in order to avoid double counting between pairs of countries. RCA is sometimes called the Balassa index. Vollrath's modified version is called the relative export advantage (RXA) measure, as it is based on exports. This calculates the ratio of a country's export share of a commodity in the international market to the country's export share of all other commodities. For the *i*-th country and *j*-th commodity, the RCA is defined as follows:

$$\mathrm{RCA}_{ij} = \mathrm{RXA}_{ij} = \left(X_{ij} / X_{ik} \right) / \left(X_{nj} / X_{nk} \right) \tag{2}$$

where *X* are exports; *k* denotes all commodities other than *j*; *n* denotes all countries other than *i*.

An RCA index greater than 1 indicates that the country has a comparative advantage in the commodity under consideration, since it has a strong export sector. It reveals higher competitiveness.

Other comparative advantage measures have been proposed (Vollrath, 1991). The relative import advantage (RMA) index is similar to the RXA, but relates to imports (*M*) rather than exports:

$$\mathrm{RMA}_{ij} = \left(M_{ij} / M_{ik}\right) / \left(M_{nj} / M_{nk}\right) \tag{3}$$

In this case, an RMA index of less than 1 indicates revealed comparative advantage and thus higher competitiveness.

The difference between the indices is called the relative trade advantage (RTA), a more comprehensive indicator of revealed comparative advantage:

$$\mathrm{RTA}_{ij} = \mathrm{RXA}_{ij} - \mathrm{RMA}_{ij} \tag{4}$$

A positive value of RTA is an indication of comparative advantage.

When RXA and RMA are compared in logarithmic form, they are symmetric at the origin. Their difference is called the revealed competitiveness (RC):

$$\mathrm{RC}_{ij} = \ln\left(\mathrm{RXA}_{ij}\right) - \ln\left(\mathrm{RMA}_{ij}\right) \tag{5}$$

In their analysis of competitiveness in the agricultural sector of Central and Eastern European Countries (CEECs) *vis-à-vis* the 15 member states of the European Union (EU), Gorton *et al*. (2000) adapt the RCA indicator so that the CEECs' exports are compared with the rest of the countries throughout the world which export to the EU15. The authors name this modified indicator the commodity weighting index.

Pitts and Lagnevik (1998) note that the RCA index has been modified to account for foreign production; that is to say production generated outside the country by national firms. Two indices have been developed based on the opposing views of two authors, Porter and Dunning, as to where foreign production should be allocated.

The Porter-adapted index of RCA (PRCA) is as follows:

$$\mathrm{PRCA}_{ij} = \left(\left(X_{ij} + IPO_{ij}\right) / \left(X_{ik} + IPO_{ik}\right)\right) / \left(\left(X_{nj} + IPO_{nj}\right) / \left(X_{nk} + IPO_{nk}\right)\right) \tag{6}$$

where IPO_{ij} is the value of output *j* produced by country *i*'s firms outside this country (outbound production).

By contrast, the Dunning index of net competitive advantage index (DNCA) is as follows:

$$\mathrm{DNCA}_{ij} = \left(\left(X_{ij} + IPO_{ij}\right) - \left(M_{ij} + IPI_{ij}\right)\right) / \left(X_{ij} + IPO_{ij} - IPI_{ij}\right) \tag{7}$$

where IPI_{ij} is the value of output *j* produced by foreign (inbound) production within country *i*.

While PRCA adds foreign production to exports and thus assumes that national firms producing abroad retain their country of origin as their home base, DNCA treats domestic production by foreign firms in the same way as imports. Both indices are, however, rarely used in the agricultural and agri-food competitiveness literature. Although discussed below, it should be noted that RCA and derived indicators are distorted by government intervention, and often reflect price distortions rather than real competitiveness.

2.3. Other export and import indices

The export market shares (EMS) are a simple measure of competitiveness. EMS can be measured in terms of quantity or in terms of value.

The net export index (NEI) is the country's or sector's exports less its imports divided by the total value of trade (Banterle and Carraresi, 2007).

$$\mathrm{NEI}_{ij} = \frac{X_{ij} - M_{ij}}{X_{ij} + M_{ij}} \tag{8}$$

where X are exports; M are imports; j denotes a sector or product; i denotes the country considered. The NEI index lies between -1 (when a country imports only) and 1 (when a country exports only), with a value of 0 in the case of equality of imports and exports.

The export-to-import price ratio allows the difference in quality between exported and imported products to be assessed. It is defined as the ratio of the unit value per ton exported divided by the unit per ton imported (Bojnec, 2003). A ratio greater than 1 would indicate that exports are more expensive, and thus of higher quality, than imports. The opposite is true for a ratio less than 1.

The Grubel-Lloyd measure (GL) assesses the health of exports by accounting for the fact that a product is often exported and imported at the same time, the trade of this product being named intra-industry trade. The index is defined as follows (Banterle and Carraresi, 2007):

$$\mathrm{GL}_{ij} = 1 - \frac{\left| X_{ij} - M_{ij} \right|}{X_{ij} + M_{ij}} \tag{9}$$

where X are exports; M are imports; j denotes a sector or product, i denotes the country considered.

GL has a range between 0 and 1, with the value 0 indicating that all trade taking place inside the j-th product group is inter-industry (*e.g.* only exports, or only imports), while the value 1 indicates an intra-industry trade only (exports equal imports).

2.4. Evidence from studies using trade measures

Mulder *et al*. (2004) investigate the competitiveness of agriculture and the agri-food sector in the Mercosur countries and in the EU during 1991-99. They calculate RER and relative real exchange rates. They show that Mercosur countries (with the exception of Paraguay for which it was stable) experienced until 1998 a decrease in competitiveness (*i.e.* an increase in the exchange rate). In 1999, the devaluation of the Brazilian currency increased competitiveness. Regarding the EU countries, despite a convergence within the Euro countries since 1997, figures reveal a group of countries with low competitiveness: Ireland, Italy, Portugal and Spain.

Ball *et al*. (2006) calculate PPP for agricultural outputs and inputs for 11 EU countries relative to the United States in 1973-2002. In all countries, prices' evolution is cyclical. For example, output prices were high in 1976-84, dropped in 1985, and then were high again during 1986-99 before a small decrease in 2001. Output prices in the EU were higher than those in the United States until 1980, indicating lower competitiveness in the EU. The situation was then reversed, until 1986 when the competitiveness of the EU deteriorated again with high output prices. Moreover, lower input prices in the United States rendered the country more competitive than the EU during most of the period.

Carraresi and Banterle (2008) calculate several trade indicators (RCA, RXA, RMA, EMS, NEI) to assess the competitiveness of the agri-food and agricultural sectors (excluding agricultural non-foodstuffs, animal feeding and fisheries) in several EU countries for the period 1991-2006. Competitiveness is investigated relative to the EU, and therefore only intra-EU trade flows are considered. The use of a cluster analysis enables the authors to group countries into three categories on the basis of all competitiveness measures. The first group consists of Denmark, France, Greece, Ireland, Luxemburg, the Netherlands and the United Kingdom (UK), which had the lowest level of competitiveness of all EU countries; their competitiveness indices all decreased over the period, in particular the NEI for agriculture. The second group consists of Belgium, Finland and Portugal, which showed average performance, gaining competitiveness in agriculture but losing it in the agri-food sector. The third group, the best performers, consists of Austria, Germany, Italy, Spain and Sweden: all their competitiveness indices increased over the period, in particular NEI for the agri-food sector.

Drescher and Maurer (1999) calculate EMS and RCA for several dairy products in Germany during 1983-93 compared to the other EU countries. The EMS calculated within the total EU exports reveal that Germany lost international market shares (both in terms of quantities and values) in milk, butter and cheese over the period. When considering all dairy products together, figures indicate a stagnation of export shares in terms of values, but a decrease in terms of quantities: 29.11% during 1983-84, 28.70% during 1985-87, 25.65% during 1988-90, and 26.65% during 1991-93. The RXA confirms the disadvantage in butter. Considering all dairy products together, the average RXA over the period was 0.50, the lowest figure being for Sweden (0.22) and the highest figure for Greece (2.99). The RXA for all countries were quite stable over the period: for example for Germany figures in 1983, 1985, 1987, 1988, 1989, 1990, 1991, 1992 and 1993 were respectively 0.51, 0.51, 0.48, 0.50, 0.49, 0.48, 0.53, 0.52 and 0.52. Grouping the EU countries, including Germany, based on their competitiveness indicators for all dairy products using clustering analysis, the authors conclude that Germany had one of the most competitive dairy sectors in the EU, in particular in milk and evaporated milk products.

Banterle and Carraresi (2007) assess the competitiveness of the prepared swine meat sector in the EU during 2000-03. Calculation of the EMS reveals that during 2000-03, Italy had the highest export share of the sector (20.6%) followed by Germany (18.8%). As for comparative advantage measures, Denmark had the highest RCA score, followed by Italy, while low RMA scores were found in Finland, Italy and Spain. The authors use the threshold of a GL of 0.5 to separate countries with major inter-industry trade and those with major intra-industry trade. Countries with a GL of less than 0.5, *i.e.* exhibiting strong inter-industry trade, are Denmark, Greece, Italy, Portugal, Sweden and the United Kingdom. The growth of all indicators compared to 1995-99 is also measured, with the highest growth in EMS and RCA shown by Austria. Clustering countries on the basis of all competitiveness indicators, the authors find that the most competitive group includes Italy and Denmark, and the least competitive group consists of Greece, Portugal, Sweden and the United Kingdom.

Wijnands *et al*. (2008) assess the competitiveness of the EU15 food industry *vis-à-vis* Australia, Brazil, Canada, and the United States for the period 1996-2004. Using trade data for individual countries, the authors calculate the growth of RCA and the growth of EMS in the world market for the EU15 and the other four countries. They find that the EU15 had very low competitiveness compared to Brazil in terms of both measures, but higher competitiveness than the in terms of world market share growth (although lower in terms of RCA growth).

Venturini and Boccaletti (1998) investigate the competitiveness of the Italian pasta processing sector during 1988-92 by calculating RCA for Italy and the other EU countries. Results indicate that the index for Italy is high and increasing, revealing the greatest competitiveness. Gorton *et al*. (2000) evaluate competitiveness with RCA for several food groups produced in Bulgaria and in the Czech Republic in comparison with the EU15 in 1997. They find that neither country was competitive regarding most arable crops and dairy products, while niche products such as jams (Bulgaria) and beer made from malt (Czech Republic) were more competitive. The authors, however, insist that such results may be due to the use of domestic export impediments by the EU and may thus not reflect true competitiveness.

Bavorova (2003) investigates the international competitiveness of the Czech sugar industry during 1988-99 with the help of RXA, RMA and RTA. Yearly RXAs are consistently less than 1, indicating the competitive disadvantage of the Czech sector, while RMA and overall RTA show competitive advantage for the period 1994-98. Fertö and Hubbard (2003) analyse the comparative advantage of the Hungarian agri-food sector (for 22 product categories) relative to the EU during 1992-98 using four trade indices: RXA, RMA, RTA and RC. All indices indicate that Hungary had a revealed comparative advantage for 11 of the 22 product groups, in particular cereals, meat, sugar, and live animals. During the period studied, the RCA average index (for all product categories) decreased consistently from 4.0 in 1992 to 2.0 in 1998, indicating a weakening of comparative advantage for the country.

Mulder *et al*. (2004) compare the competitiveness of the agriculture and agri-food sector for the Mercosur bloc and the EU between 1993 and 1999, in particular for products that are highly protected by either Mercosur's countries or by the EU. In terms of products that benefit from a high tariff and non-tariff protection from the EU, RCA measures show that the Mercosur bloc succeeded in exporting products in which it has a high competitiveness, despite the protection rates.

Bojnec and Fertö (2009) investigate the international competitiveness of agri-food sectors in eight CEECs and Balkan countries (Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia) in the period 1995-2007 using trade indicators (RXA, RMA, RTA). The analysis is performed for four product categories, depending on their degree of processing: raw commodities; processed intermediates; consumer-ready food; and horticulture. Export competitive advantage was highest for raw commodities and processed intermediates for all countries. Import competitive advantage was found to be rather low. The RTA also reveals that raw commodities performed better than consumer-ready food.

Qineti *et al*. (2009) assess the competitiveness of the Slovak and of the EU27 agri-food sectors *vis-à-vis* Russia and Ukraine during 2002-06 with the help of RCA growth. They find that the number of commodity groups with a comparative advantage in the EU27 *vis-à-vis* Russia and Ukraine has declined since enlargement in 2004. The case of Slovakia *vis-à-vis* Russia shows a similar decline, while for Slovakia *vis-à-vis* Ukraine the number with a comparative advantage has increased.

Toming (2007) and van Berkum (2009) use less standard trade indicators of competitiveness. Toming (2007) shows that the competitiveness of the Estonian agri-food industry, measured by the value of exports to the other EU countries, has increased since EU accession. In order to capture some quality effects, the author evaluates more precisely the value of exports of high-value products and concludes that only in the milk sector have exports of high-value foodstuffs increased. Van Berkum (2009) examines the dairy sector's competitiveness in the ten EU new member states and eight EU candidate countries by looking at their trade position and trends in that position. The author concludes that in 2006 all new member states were net exporters of dairy products, except for Cyprus, Malta and Romania which were net importers. Moreover, the Baltic countries and Poland had increased their export surpluses since the 1990s.

3. Strategic management measures of competitiveness

Porter (1990) was one of the first to underline the importance of firms' strategy and structure in developing their competitiveness. The author proposed the so-called "diamond model" according to which nations succeed in industries for which the national diamond is the most favourable. The four corners of the diamond are: i) factor conditions; ii) demand conditions; iii) presence of related and supporting industries; and, iv) firm strategy, structure and rivalry. In this framework, competitiveness is revealed by performance indicators such as cost superiority, profitability, productivity, and efficiency.

3.1. Cost measures

3.1.1. Domestic resource costs ratio

The domestic resource costs (DRC) ratio compares the opportunity costs of domestic production with the value added it generates (Gorton *et al*., 2001). In other words, it compares the value of the non-tradable domestic resources used to produce one unit of the good with what the good would earn if it was exported (Liefert, 2002). It was originally proposed for measuring the gain from expanding profitable projects or the cost of maintaining unprofitable activities through trade protection (Masters and Winter-Nelson, 1995). For commodity *j*, it is defined as:

$$\mathrm{DRC}_j = \frac{\sum_{l=k+1}^{n} a_{jl} P_l^D}{P_j^B - \sum_{l=1}^{k} a_{jl} P_l^B} \tag{10}$$

where a_{jl} is the quantity of the *l*-th traded input, if $l = 1$ to k, or non-traded input, if $l = k+1$ to n, used to produce one unit of the *j*-th commodity (a_{jl} is sometimes called the technical coefficient); P_l^D is the domestic price of the *l*-th input; P_j^B is the border price of the *j*-th commodity; P_l^B is the border price of the *l*-th input.

When the DRC ratio is strictly positive but less than 1, it indicates that domestic production of the specific good is internationally competitive: the opportunity costs of domestic production (the numerator) are less than the value added of output at world prices (the denominator). It also indicates that the country should export more of the good under consideration. A DRC greater than 1 or less than 0 (when the denominator is negative) shows a lack of competitiveness for the good, and thus the low desirability of domestic production compared to the international market. DRC ratios can also be used to compare countries: a country with a lower DRC is more competitive. The DRC indicator has been used frequently in the literature dealing with agricultural competitiveness, in particular for CEECs and farm-level data.

3.1.2. Social cost-benefit ratio

According to Masters and Winter-Nelson (1995) because the DRC ratio is based on the cost of non-tradable inputs, it understates the competitiveness of activities that use mainly such domestic factors in comparison to those that rely more on tradable inputs. To overcome this shortcoming, the authors propose the social cost-benefit (SCB) ratio. Using the same data as for the DRC ratio but in a different relationship, the SCB ratio is defined as the ratio of the sum of domestic (non-tradable) and tradable input cost to the price of the good considered:

$$\mathrm{SCB}_j = \frac{\sum_{l=k+1}^{n} a_{jl} P_l^D + \sum_{l=1}^{k} a_{jl} P_l^B}{P_j^B} \qquad (11)$$

where notations are the same as in the DRC definition (equation (10)).

Domestic production is competitive when the SCB is less than 1, as it reveals that total input costs are less than the revenue derived from the good. The opposite is true for an SCB greater than 1 (an SCB of less than 0 does not exist).

DRC and SCB may be related to the concept of comparative advantage as they allow cost differentials to be assessed and could therefore be included in the section of trade measures to promote competitiveness. It was, however, preferred to include these in the present section on strategic management measures since they depend on the structure and strategy of the firm and do not rely on trade data (exports and imports).

3.1.3. Agricultural costs of production

In general, costs of production are compared for specific commodities. The difficulty is then how to allocate joint inputs, *i.e.* inputs used to produce several outputs. Ahearn *et al*. (1990) calculate the costs of production for one commodity (wheat in the United States) based on farmers' records of purchased inputs and on farmers' reports of machinery time allocation among activities. In addition to relying on declarations by farmers, other methods exist for the allocation of joint production costs. For example, Cesaro *et al*. (2008) explain that land costs may be shared among various activities on the basis of how much land each activity uses, or that input costs may be calculated first for fully specialised farms and then applied to the considered activity in mixed farms.

Another method is based on econometrics and relies on estimating the following equation (Brunke *et al*., 2009):

$$x_{il} = \sum_j \beta_{lj} y_{ij} + u_{il} \tag{12}$$

where x_{il} is the observed total cost of the *l*-th input for the *i*-th farm; y_{ij} is the *j*-th output of the *i*-th farm; β_{lj} is the coefficient of the *l*-th input cost share relating to the *j*-th output; u_{il} is a random term.

Whatever method used, care must be taken over the costs of own inputs (labour in particular, capital, and land), which are usually not directly observable but which may influence the costs of production measures (Cesaro *et al*., 2008).

Gallagher *et al.* (2006) report Dornbusch's (1980) idea of comparing two countries' competitiveness in a specific production sector by comparing their costs of production, the latter being calculated as the ratio of domestic wages to labour productivity. A country with lower production costs has a competitive advantage over the other country considered. The inverse calculation can also be found in the literature. For example, Mulder *et al*. (2004) calculate unit labour cost by dividing labour productivity by wages. Sharples (1990) argues that competitiveness cannot be evaluated on the sole basis of costs of production, but that researchers should also take account of marketing costs, *i.e.* the additional costs arising from getting the commodity to the foreign buyer. Gallagher *et al.* (2006) build on this by extending Dornbusch's (1980) method. They consider not only the pure costs of production but also include transportation costs, and do not restrict production costs to the costs of one factor only (labour). Comparing the cost advantage of corn-based ethanol in the United States with sugar-based ethanol in Brazil, the authors define a competitiveness indicator *dif* as a differential in the costs of production:

$$dif = Cs + Cf - (Cc + Ce) \tag{13}$$

where:

Cs is the cost of sugar in ethanol production in Brazil, calculated as the price of sugar divided by the yield of ethanol from sugarcane; Cf is the cost of ethanol transport (freight) from Brazil to the United States, which should ideally include import tariffs (but they were not included in the authors' analysis);

Cc is the cost of corn in ethanol production in the United States, calculated as the price of corn, minus the price of distillers' grains divided by their yield from corn, this difference being divided by the yield of ethanol from corn;

Ce is the cost of energy in corn in ethanol production in the United States.

An indicator *dif* greater than 0 would reveal lower production costs, and thus the higher competitiveness of the United States ethanol.

3.1.4. Evidence from studies using cost measures

Banse *et al*. (1999) compute the DRC ratios for various crop (wheat, barley, maize, rapeseed and sunflower) and livestock (beef, pork and milk) sectors in Hungary during 1990-96. They find that the livestock sectors were almost never competitive during the period (DRC greater than 1) and that despite some fluctuations the competitiveness of these sectors was lower in 1996 (DRC of 2.53, 2.88 and 13.98 for beef, pork and milk respectively) than in 1990 (DRC of 1.78, 0.74 and 1.11 respectively). As for the crop sectors, DRC ratios fluctuated around 1 for barley and maize, but remained consistently below 1 for wheat (despite an increase from 0.59 to 0.89 between 1990 and 1996) indicating competitiveness.

Gorton *et al*. (2000) calculate the DRC for the main Bulgarian and Czech agricultural commodities during 1994-96 and adjust it using EU15 output and input prices, in order to assess the commodities' competitiveness with regard to the world and to the EU15. Using farm-level data, their findings indicate a high competitiveness of wheat and barley in both countries both worldwide and *vis-à-vis* the EU15. By contrast, while the milk and beef sectors were competitive relative to the EU, they were not competitive in the world markets. Also using the DRC ratio and farm-level data, Gorton *et al.* (2001) investigate how competitive Polish agriculture was between 1996 and 1998. They focus on eight commodities (bread wheat, rye, sugar beet, rapeseed, potatoes, milk, beef, and pork meat). They find that, during the period studied, crop production (five commodities analysed) was more internationally competitive than livestock production (three commodities analysed); DRC ratios for livestock commodities were in general above 1. However, international competitiveness worsened during the period.

Gorton and Davidova (2001) review several studies that investigated the international competitiveness of CEECs' (Bulgaria, the Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia) agriculture between 1992 and 1998, using DRC ratios with farm-level data. In general, studies calculated the indicators for several commodities, but not for the agricultural sector as a whole. Some studies compared commodities within the same countries and found in general that crop commodities were more internationally competitive than livestock commodities, and that within the arable sector wheat and sunflower were the most competitive crops. Moreover, some studies compared the competitiveness of commodities in the CEECs with the EU by adjusting the DRC ratio with EU output and input prices. Such adjustment resulted in a higher level of competitiveness of the CEECs' agriculture. From his review of studies calculating DRC for the same CEECs between 1989 and 1998, Bojnec (2003) also concludes that livestock production was less internationally competitive than crop production, a result that the author attributes to the greater disruption and disorganisation that the more capital-intensive livestock sector experienced during transition.

Nivievskyi and von Cramon-Taubadel (2008) calculate the DRC and SCB of dairy production in Ukraine in 2004-05 using farm-level data. Results indicate that in 2004 only 16% of the farms had a DRC between 0 and 1 (competitiveness); the figure increases to 20% in 2005. The SCB calculation reveals that in 2004 19% of the farms were competitive (SCB less than 1) and 15% were competitive in 2005. Liefert (2002) analyses Russian agriculture's competitiveness in 1996-97 by calculating SCB ratios for several agricultural outputs (poultry, pork, beef, wheat, barley, sunflower) and several agricultural inputs (fertilisers, crude oil, natural gas). Results indicate that Russia was less competitive in meat commodities compared to crops and in outputs than in inputs in general, although it was highly competitive in natural gas. The author concludes that Russia's trade behaviour during this period was rational since it was a major importer of meat but a major exporter of energy products.

Mulder *et al*. (2004) compare unit labour cost for Brazil and for the EU in 1995. Respective figures are 0.17 and 1.07, that is to say Brazil's costs are only 15.5% of those of the EU and 5% of those of France, indicating higher competitiveness. The authors also compare overall production costs between the Mercosur bloc and the EU for several products that are highly protected either by Mercosur or by the EU. Using the output unit value ratio (that is to say output prices excluding taxes, subsidies, transportation costs and retailers' margins) as an indicator of production costs, the authors show that Mercosur countries are more competitive (*i.e.* lower costs) for all products except bananas.

As explained above, Gallagher *et al*. (2006) studied the competitiveness of corn-based ethanol in the United States *vis-à-vis* sugar-based ethanol in Brazil based on the original competitiveness indicator *dif* explained above. Using sector level data for the period 1973-2002, the authors show that the competitiveness indicator *dif* varied considerably around 0, from -0.50 to 0.40 USD per gallon of ethanol. Time series methods reveal that about 75% of the variation was periodic in nature (cyclical factors), 15% from current year shocks (random factors), and 10% from seasonal factors.

Ahearn *et al*. (1990) compare the competitiveness of wheat production in the United States and Canada by calculating costs of production in 1986-87. The results indicate that costs per acre were higher in both years in the United States than in Canada, and that in both countries costs decreased between 1986 and 1987. Bureau and Butault (1992) calculate the costs of production for the EU countries in 1984 to assess their competitiveness in the soft wheat, sugar beet, hog and milk sectors. Results indicate that France and the UK were the most competitive for wheat production, Belgium and France for sugar beet production, Ireland, the Netherlands and the United Kingdom for hog production, and Greece for milk production. Bureau *et al*. (1992) investigate the competitiveness in wheat production of EU countries and the United States in 1984-86, by calculating costs of production as an average over the period. They find that the United States had by far the lowest cost of production, while the highest costs were experienced by Italy.

Thorne (2005) measures the competitiveness of cereal production in Denmark, Germany, France, Ireland, Italy and the United Kingdom during 1996-2000 by calculating various cost indicators: total costs as a percentage of the value of total output (including area payments); margin over costs per 100 kilograms of output volume; and margin over costs per hectare of cereal production. According to the author, the first indicator enables differentials in quality and transport costs to be accounted for. Costs of production were defined either by excluding or by including imputed resource costs for family labour, equity capital and owned land. Based on data for farms specialised in cereals, oilseeds and protein crops (COP), results indicate that Italy had the lowest cost structure when family assets' costs were taken into account, but the highest cost structure when they are included, due to the large opportunity cost of labour. The author concludes that a country's relative position depends largely on the unit of measurement, in particular whether family costs are included or not.

Bavorova (2003) analyses the change in concentration in the sugar industry in the Czech Republic between 1989 and 1999, and concludes that the apparent higher concentration of sugar refineries is a step in the right direction towards the increasing competitiveness of the Czech sugar sector *vis-à-vis* the EU, since the higher concentration results in larger scale economies and lower production costs.

3.2. Profitability

3.2.1. Profitability measurement

Profitability is obviously related not only to costs of production but also to revenue. Profitability can be defined in several ways, such as the difference between revenue and costs (gross margin), or the ratio between cost and revenue.

As Harrison and Kennedy (1997) argue, firms with positive profits indicate that they are able to create barriers preventing the entry of new firms (whose entrance would result in profits decreasing to zero for all firms in the industry), that is to say they are able to maintain their market shares and thus possess some type of competitive advantage. Market shares are sometimes mentioned as a way of assessing a firm's competitiveness, but the concept is often quantitatively measured by profitability variables.

3.2.2. Evidence from studies using profitability measures

In order to assess the competitiveness of Canada's agri-food industry in 1986, van Duren *et al*. (1991) use three profit measures. Profits are calculated by the ratio of value added to sales; value added to workers; or value added to plants. These three indicators are then aggregated to compare the competitiveness of Canada, the EU and the United States, according to their ranking with each indicator. Results indicate that overall the US food industry was more competitive than the Canadian, which in turn was more competitive than the EU. Canada was the most competitive regarding the meat sector, while the EU and the United States were similarly highly competitive for the beverage sector.

Viaene and Gellynck (1998) evaluate the competitiveness of the pigmeat processing sector in Belgium during 1987-93 by looking at several profitability measures: the net sales margin (*i.e.* the net profit relative to the level of sales); the business assets turnover (*i.e.* sales divided by business assets); the ratio of net profits on own funds; and the financial leverage. Results indicate poor profitability as net sales margins are less than 1, and the ratio of net profits to own funds and the leverage are both negative.

To evaluate the competitiveness of the Czech dairy industry, Bavorova (2003) computes for the sector a yearly profitability measure as a percentage of total profit in total costs. She concludes that profitability fluctuated over 1990-2000, but increased greatly in the last year studied. Davidova *et al*. (2003) calculate the profitability of Czech farms in 1998-99 with the ratio of costs (paid, or paid plus unpaid) to total revenue (including or excluding subsidies). They find that most of the farms were not profitable (ratio greater than 1) even when unpaid costs (*i.e.* for family inputs) were not considered.

Van Berkum (2009) discusses the competitiveness of the dairy sector in the 12 EU new member states and in eight EU candidate countries in 2006 based on several measures. One of these, the gross margin, is computed at the farm level as the difference between total revenues (from milk, calves and beef meat from dairy cows) minus variable costs. To facilitate comparisons, gross margin is given as a percentage of total revenue. Only three countries present a gross margin rate higher than the EU15 average of 62% (67% for Slovenia and Bosnia-Herzegovina, and 63% for Poland), while the lowest figure by far is exhibited by Malta (25%).

Although not referring explicitly to competitiveness, Bezlepkina *et al*. (2005) estimate a profit function for Russian dairy farms during 1995-2001 using panel data and instrumental econometric techniques. The authors specify the profit as a function of input and output prices, fixed input quantities, and subsidies. They find that the shadow prices of land and labour are not significantly different from zero, and that dairy producers were not responsive to milk prices during the period studied.

3.3. Productivity and efficiency

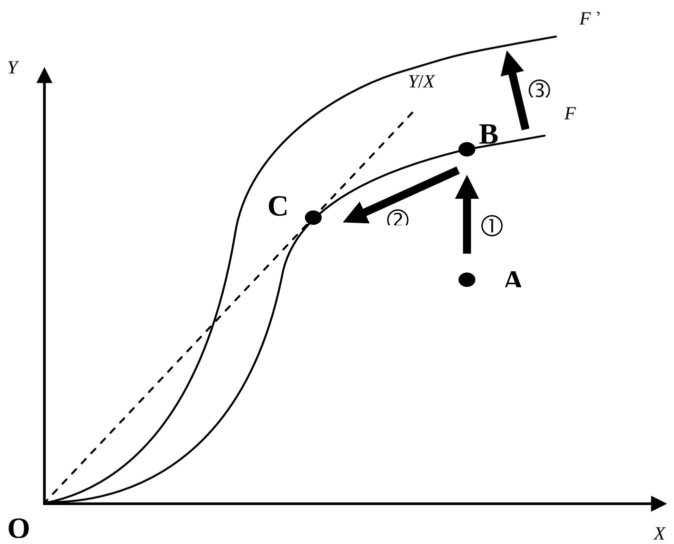
3.3.1. A general definition of productivity

Productivity and efficiency are often cited as indicators or measures of competitiveness, and the European Commission considers it as the most reliable indicator for competitiveness over the long term (European Commission, 2008). However, in general, in empirical studies of productivity and efficiency, no explicit reference to competitiveness is made. A general definition of productivity is the ability of production factors to produce the output. It can be simply measured as a partial productivity indicator, relating output to one input (*e.g.* yields or partial productivity of labour), but this does not account for the possibility of either factor substitution or output substitution. By contrast, the more comprehensive measure of total factor productivity (TFP) (sometimes called the multi-factor productivity, MFP) is a ratio that relates the aggregation of all outputs to the aggregation of all inputs. This concept is often used in a dynamic framework, where change in TFP, that is to say productivity improvement, is investigated.

3.3.2. The components of productivity improvement

Potential productivity improvement is evaluated when firms are compared to a benchmark: in cross-section data, firms are compared with each other in the same period, while in a time-series approach one firm is considered during two periods. In the first case, a firm can increase its productivity in comparison with other firms by improving its efficiency and/or by reaching an optimal scale of operation. In the second case, all firms can increase their productivity owing to technological progress. This can be seen in Figure 2 which depicts a simple single output-single input case. The production function *f* relating the output produced, *y*, with the input used, *x*, indicates the maximum output produced for a given level of inputs (the production possibilities). Productivity improvement can be of the three following kinds.

Figure 2. Three possible productivity improvements for firms



Source: Based on Coelli *et al.*, 2005.

Efficiency increase

In comparison with other firms, productivity improvement can result from more efficient use of the existing technology. In Figure 2, firm *A*, for example, would be able to produce more output with the same input use, that is to say it could use its input in a more efficient way. This is depicted by a movement from *A* towards the frontier *f*, parallel to the *y*-axis (movement ①). The movement could also be parallel to the *x*-axis and would correspond to a decrease in input use while the same output is produced. Clearly, the closer a firm operates to the frontier, the more efficient it is. Efficiency is therefore a measure of the distance from a given observation to the frontier. Firms operating on the frontier are said to be fully efficient in their use of inputs, *e.g.* firms *B* and *C*, and those operating beneath it are inefficient, *e.g.* firm *A*. This notion of efficiency refers to the neoclassical efficient allocation of resources and the Pareto optimality criterion. Considering a firm that uses several inputs and produces several outputs, it is efficient in the way it allocates its resources if a reduction in any input requires an increase in at least one other input or a reduction in at least one output (Lovell, 1993).

Exploiting economies of scale

A second productivity improvement for a firm when compared with other firms can be achieved by exploiting economies of scale. Potential economies of scale can be identified by the scale elasticity, calculated as the ratio of the proportionate increase in output to the proportionate increase in all inputs. At point *C* the elasticity of scale is one and therefore firm *C* has an optimal scale. Firm *B* by contrast has an elasticity of scale less than one and therefore exhibits diseconomies of scale, while a firm situated on the left of *C* would have a scale elasticity greater than one and hence exhibit economies of scale. Exploiting economies or diseconomies of scale is therefore a productivity improvement, characterised by a movement on the frontier *f* (movement ② for example).

Technological progress

The third possibility of productivity change refers to the long term and is called technological change. Technological progress, that is to say improvement in the state of technology, happens for example when a new and higher performing production or transformation process is available on the market. It results in an upward shift of the production frontier from *f* to *f* ’ (movement ③). This progress should be able to apply to all firms (assuming that they all have the same access to the new technology), and implies that they would be able to produce more using the same level of input. On the other hand, technological regress, for example due to a deterioration of worker qualifications, would imply a downward shift of *f* and therefore a decrease in the output produced per input used.

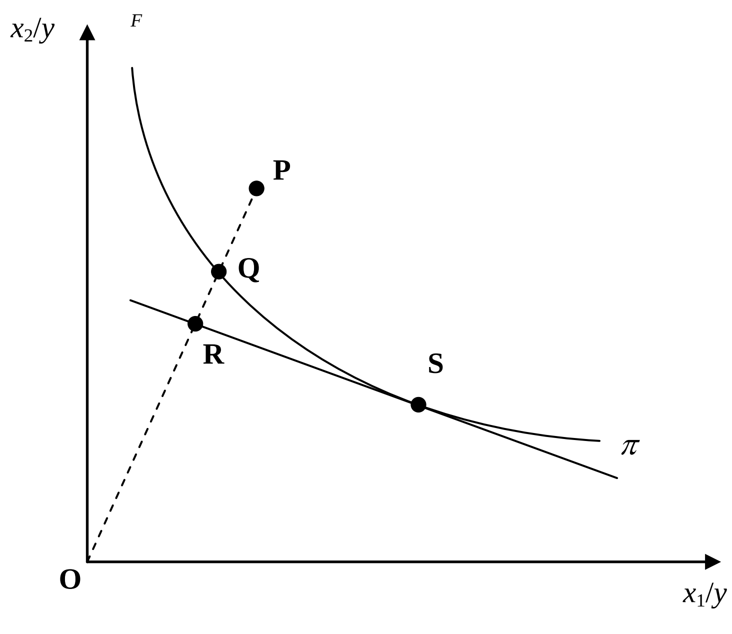
3.3.3. Measurement of efficiency

Mathematical representation

Efficiency gives an indication of whether firms are able to use the existing technology in the best way. It has three components: scale efficiency, technical efficiency and allocative efficiency. Scale efficiency gives insights into whether the firm operates at an optimal or sub-optimal size. Firms that are scale efficient operate under constant returns to scale (CRS) and have a scale elasticity of one, while scale inefficient firms could exploit scale economies or diseconomies. Technical efficiency (sometimes referred to as pure technical efficiency, as opposed to scale efficiency) assumes variable returns to scale (VRS) and shows whether a firm is able to attain the maximum output from a given set of inputs. It refers to a physical notion, independent of input and output prices. By contrast, the allocative efficiency of a firm (also called its price efficiency) reflects its ability to use inputs in their optimal proportions given their respective prices, or to produce an optimal combination of outputs given their respective prices. A firm is allocatively efficient if its outputs and inputs maximise its profit (or minimise its costs) at given prices. Allocative efficiency implies technical efficiency, as in order to maximise its profits, the firm must firstly lie on the production frontier. However, technical efficiency does not necessarily imply allocative efficiency, since the combination of outputs and inputs can be optimal with respect to the production possibilities, but not be profit maximising. This can be seen in Figure 3 described below. Technical, scale and allocative efficiency scores multiplied by each other make up the overall efficiency of a firm, sometimes called its economic efficiency.

The mathematical description of technical and allocative efficiency was firstly formulated by Farrell (1957). The author described the efficiency in an input-orientation context, that is to say in terms of potential input reduction holding the output level unchanged (by contrast to the output-orientation case, which relates to a potential output increase while keeping the same level of input use). Figure 3, based on Farrell (1957), depicts the case of a firm producing one output y with two inputs, x_1 and x_2. The production frontier f characterises the isoquant describing the minimum possible combinations of the two inputs that firms can use for producing one unit of output. The frontier bounds the observations, in the sense that the observed firms lie on or beyond it, *e.g.* Q and P (while R is not a firm). f is the technical efficiency frontier: firms lying on the frontier have no possibility of reducing one input without increasing another input, and are therefore technically efficient.

Figure 3. Input-orientated representation of technical and allocative efficiency of firms



Source: after Farrell, 1957.

Firm *P* is technically inefficient as it lies beyond the frontier. However, *P* and the technically efficient firm *Q* use the same proportion of inputs, as they both lie on the ray *OP* which represents a constant ratio of the two inputs. *P* could therefore reduce both inputs by *PQ* and still produce the same level of output. Proportionally, the potential input reduction is:

$$\frac{PQ}{OP} = \frac{OP - OQ}{OP} = 1 - \frac{OQ}{OP} \tag{14}$$

The technical efficiency of firm *P* is then defined by:

$$TE = \frac{OQ}{OP} \tag{15}$$

This measure is bounded by 0 (exclusive) and 1 (inclusive), and takes the value 1 (or 100%) for a fully technically efficient firm (*e.g.* for firms *Q* and *S*). In this case the potential input reduction is 0. The less technically efficient a firm is, that is to say the further from the frontier it operates, the lower the measure *TE*. (1–*TE*)×100 is the potential equiproportionate reduction of inputs in percentage terms.

In Figure 3, the straight line π represents the input price ratio, which is the isocost, that is to say the least costly combination of inputs for producing one unit of output. Firm *S* is allocatively efficient as the slope of *f* equals the slope of π at *S*. However, firm *Q*, is technically but not allocatively efficient. It could reduce its input costs by *QR* and still produce the same level of output. Proportionally, the potential input reduction is:

$$\frac{QR}{OQ} = \frac{OQ - OR}{OQ} = 1 - \frac{OR}{OQ} \tag{16}$$

Firm *Q*'s allocative efficiency is then defined by:

$$AE = \frac{OR}{OQ}. \tag{17}$$

Allocative efficiency is also bounded by 0 (exclusive) and 1 (inclusive), with 1 for fully efficient firms and a lower score indicating lower efficiency. Allocative efficiency is equal for firms using inputs in the same proportion, that it to say firms lying on the same input ratio line. Therefore, *P* and *Q* have equal allocative efficiency.

Measuring efficiency means measuring the potential input reduction, or potential output increase, relative to a reference. The major issue is therefore to define this reference, that is to say, to construct the efficient frontier. In practice, however, only inputs and their output realisations are observed. The production function that defines the frontier is unknown. Techniques for defining the frontier can be categorised as parametric and non-parametric methods.

Measurement with non-parametric methods

In the non-parametric approach, the efficiency frontier is empirically constructed piece-wise in the output-input space by enveloping all observations in the sample, based on Farrell's (1957) graphical decomposition. But the space depiction becomes more complex in a multi-output multi-input framework as an envelopment surface is required. The introduction of a method using mathematical programming allows the calculation of the distance in such complex cases. The most popular method is the Data Envelopment Analysis (DEA). Introduced by Charnes *et al*. (1978), the underlying concept is to use linear programming to construct the efficiency frontier with the best performing firms among the observations. Inefficient firms are projected on the frontier along a ray of constant input ratio and the distance to their projection gives their efficiency score as in Figure 3.

Calculating technical efficiency with DEA allows a decomposition of technical efficiency (then called total technical efficiency) into pure technical efficiency and scale efficiency. Total technical efficiency is measured under the assumption of CRS and represents the technical efficiency in a long-term optimum, that is to say when the firm has an optimal scale of operation. The pure technical efficiency component is calculated under the VRS assumption and relates purely to management practices. It is a result of the operator's management behaviour rather than the firm's operating scale. Scale efficiency is the residual between the measure under CRS and the measure under VRS.

The (total, *i.e.* under CRS assumptions) technical efficiency score $\hat{\theta}_i$ for the *i*-th firm in the input-orientation framework is the solution of the following linear programming model:

$$\min_{\lambda,\hat{\theta}_i} \ \hat{\theta}_i \tag{18}$$

subject to

$$-y_i + y\lambda \geq 0$$

$$\hat{\theta}_i x_i - x\lambda \geq 0$$

$$\lambda \geq 0$$

where x and y are respectively the input and output matrices of all observed firms; x_i and y_i are respectively the input and output vectors of the *i*-th firm; λ is a $n\times1$ vector of constants, with n the number of firms in the sample.

To incorporate the possibility that firms operate under VRS, the following constraint is added to the CRS model:

$$n1\times\lambda = 1 \tag{19}$$

where $n1$ is a $n\times1$ vector of ones, whose components' sum should be equal to 1.
This enables pure technical efficiency to be computed. Scale efficiency is then calculated as the ratio between total technical efficiency and pure technical efficiency.

DEA results may be affected by sampling variation, implying that efficiency estimates are likely to be biased towards higher scores. This bias arises when the most efficient firms within the population are not contained in the sample at hand. As a consequence, inefficient firms form the envelopment frontier. The efficiency degree of all other firms is then measured relative to the sample frontier instead of the true population frontier, and therefore might be biased. Recently, bootstrapping techniques have been proposed to remedy the sampling problem. The rationale behind bootstrapping is to simulate a true sampling distribution by mimicking a data generating process. The procedure relies on constructing a pseudo-data set and re-estimating the DEA model with this new data set. Repeating the process many times allows a good approximation of the true distribution of the sampling to be achieved. The method has been developed by

Simar and Wilson (1998, 1999, 2000a, 2000b). It enables confidence intervals for each efficiency score (or for each Malmquist TFP index, see definition below) to be constructed.

Measurement with parametric methods

While DEA using linear programming constructs the efficiency frontier with the best performing farms of the sample, parametric methods rely on specifying a production function and estimating its parameters with econometrics. However, by assuming that all deviations from the frontier are the result of technical inefficiency, this simple deterministic model takes no account of the possible noise upon the frontier. The stochastic frontier model was then developed to account for noise. It was simultaneously proposed by Aigner *et al*. (1977) and by Meeusen and van den Broeck (1977). It assumes a double random error by adding to the deterministic model an additional random error:

$$\ln(y_i) = f(x_i, \alpha) + v_i - u_i \tag{20}$$

where y_i is the observed output quantity of the i-th firm; f is the production function; x_i is the vector of the input quantities used by the firm; α is a vector of parameters to be estimated; v_i is an error term; u_i is a non-negative random term accounting for inefficiency.

The technical efficiency of the i-th firm, TE_i, is then given by:

$$TE_i = \exp(-u_i) \tag{21}$$

Since only the difference between both random terms (that is to say $w_i = v_i - u_i$) can be observed, u_i is predicted by its conditional expectation given the estimated value of w_i (Coelli *et al*., 2005):

$$u_i = \mathrm{E}\{u_i | w_i\} \tag{22}$$

where $w_i = v_i - u_i$ from equation (20).

3.3.4. Measurement of productivity and technological change

Index number approach

As mentioned above, a general measure of productivity is given by TFP indices that compare an aggregate output index to an aggregate input index. The main issue is how to aggregate together various outputs and various inputs. The index number approach proposes explicit methods for aggregation. Several ways of aggregation lead to different TFP indices. The main indices used are the Laspeyre, Paasche, Fisher, Tornqvist and Eltetö-Köves-Szulc indices. In general, price weights are used in the construction. These account for the relative share of each output in the firm's revenue and for the relative share of each input in the firm's costs. Each index implicitly assumes a specific underlying production function. For example, the Laspeyre index implies a Leontief production function, while the Tornqvist index is consistent with a translog function (Capalbo *et al*., 1990). As an illustration, the following formula explains how the Tornqvist index is calculated, generally defined in its logarithmic form (Coelli *et al*., 2005):

$$\ln(TFPC_{t,t+1}) = \frac{1}{2}\sum_{j=1}^{J}\left(r_{j,t+1}+r_{j,t}\right)\left(\ln y_{j,t+1}-\ln y_{j,t}\right)-\frac{1}{2}\sum_{k=1}^{K}\left(s_{k,t+1}+s_{k,t}\right)\left(\ln x_{k,t+1}-\ln x_{k,t}\right) \tag{23}$$

where $TFPC_{t,t+1}$ is the change in TFP between periods t and t+1; y_{jt} is the quantity of the j-th output in the t-th period, with J the number of different outputs; x_{kt} is the quantity of the k-th input in the t-th period, with K the number of different inputs; $r_{jt} = \frac{p_{jt}y_{jt}}{\sum_{j=1}^{J} p_{jt}y_{jt}}$ is the share of the j-th output in the total revenue in the t-th period, with p_{jt} the j-th output price in the t-th period; $s_{kt} = \frac{\omega_{kt}x_{kt}}{\sum_{k=1}^{K}\omega_{kt}x_{kt}}$ is the share of the k-th input in the total cost in the t-th period, with ω_{kt} the k-th input price in the t-th period.

Production function estimation

A standard approach to calculate productivity growth and technological change is the econometric estimation of a production function. For example, assuming that the production function is Cobb-Douglas as follows:

$$y_{it} = A_t \prod_k x_{kit}^{\beta_{kit}} \tag{24}$$

where y_{it} is the production level for the i-th firm in the t-th period; x_{kit} is the k-th input of the i-th firm in the t-th period; A_t is a parameter that represents the technology; β_{kit} are parameters whose sum is equal to 1.

The standard practice is to estimate its log-linear form:

$$\ln y_{it} = \ln A_t + \sum_k \beta_{kit} \ln x_{kit} + u_{it} \tag{25}$$

where u_{it} is an error term.

In this framework, the rate of TFP change for the whole sample is given by $\ln A_t$.

However, this basic specification does not allow to distinguish noise from variables that are observed by firms when making decisions, *e.g.* managerial ability, expected down-time due to machine breakdown, expected rainfall at a farm's location (Ackerberg *et al*., 2006). In order to account for the change in production over time due to such effects, or to firm efficiency, the error term is decomposed into a firm-specific effect and a random term (*e.g.* Dhawan and Gerdes, 1997; Sauer *et al*., 2006; Ruan and Gopinath, 2008).

Moreover, as argued by Jorgenson (*e.g.* Jorgenson, 1995; Jorgenson and Motohashi, 2003), the basic aggregate production function does not account for changes in relative prices. In order to separate TFP change from output price effects and input price effects in output growth, the authors propose to calculate TFP change with the following equilibrium condition:

$$\sum_j \bar{\omega}_{Yj} \Delta Y_j = \sum_k \bar{\omega}_{Xk} \Delta X_k + \Delta \ln A \tag{26}$$

where Δ denotes the change between two adjacent periods; Y_j is the *j*-th output ; X_k is the *k*-th input ; $\bar{\omega}_{Yj}$ and $\bar{\omega}_{Xk}$ denote respectively average value shares of outputs and inputs in adjacent periods; $\Delta \ln A$ represents the change in TFP between two adjacent periods.

In other words, the sum of share-weighted growth of outputs is the sum of share-weighted growth of inputs and growth in TFP. Such specification is close to the Tornqvist index number specification [equation (23)]. Shares are usually derived from input-output matrices.

Malmquist indices

The index number approach assumes that firms are efficient and therefore the above-mentioned TFP indices measure only the technological change. In contrast, Malmquist indices provide a decomposition of the productivity change into efficiency change and technological change. In addition, data about prices, costs and revenues are not necessary. The Malmquist indices were introduced by Caves *et al.* (1982), and their decomposition into efficiency change and technological change was proposed by Nishimizu and Page (1982) and Färe *et al*. (1992). The Malmquist index of productivity change between periods *t* and *t* + 1, $MQ_{t,t+1}$, is defined as follows:

$$MQ_{t,t+1} = \left[\frac{D^t\left(x_{t+1}, y_{t+1}\right)}{D^t\left(x_t, y_t\right)} \frac{D^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D^{t+1}\left(x_t, y_t\right)} \right]^{\frac{1}{2}} \tag{27}$$

where $D^t\left(x_{t+1}, y_{t+1}\right)$ is the distance from observations in the *t*+1 period to the frontier of the *t*-th period; $\left(x_t, y_t\right)$ is the input-output vector in the *t*-th period.

This measure is the geometric mean of the TFP change index when considering the firm in period *t*+1 relative to period *t* (first ratio in the brackets) and the TFP change index when considering the firm in period *t* relative to the period *t*+1 (second ratio in the brackets). As the choice of the benchmark is arbitrary, and both ratios are not necessarily equal, it is the convention to take the geometric mean of them (Coelli *et al*., 2005). Malmquist TFP indices can further be decomposed into technological change and technical efficiency change, itself being decomposed into pure technical efficiency change and scale efficiency change:

$$
\begin{aligned}
MQ_{t,t+1} &= \left[\frac{D_{VRS}^{t+1}\left(x_{t+1},y_{t+1}\right)}{D_{VRS}^{t}\left(x_t,y_t\right)}\right] \\
&\times\left[\frac{D_{VRS}^{t+1}\left(x_{t+1},y_{t+1}\right)/D_{CRS}^{t+1}\left(x_{t+1},y_{t+1}\right)}{D_{VRS}^{t+1}\left(x_t,y_t\right)/D_{CRS}^{t+1}\left(x_t,y_t\right)}\frac{D_{VRS}^{t}\left(x_{t+1},y_{t+1}\right)/D_{CRS}^{t}\left(x_{t+1},y_{t+1}\right)}{D_{VRS}^{t}\left(x_t,y_t\right)/D_{CRS}^{t}\left(x_t,y_t\right)}\right]^{\frac{1}{2}} \\
&\times\left[\frac{D^{t}\left(x_{t+1},y_{t+1}\right)}{D^{t+1}\left(x_{t+1},y_{t+1}\right)}\frac{D^{t}\left(x_t,y_t\right)}{D^{t+1}\left(x_t,y_t\right)}\right]^{\frac{1}{2}}.
\end{aligned}
\tag{28}
$$

The first bracket measures the change in pure technical efficiency, the middle bracket represents the change in scale efficiency, and the third bracket indicates technological change.

All computed indices (Malmquist TFP, total technical efficiency, pure technical efficiency, scale efficiency, technological change) are compared to 1. An index equal to 1 indicates no change over the period considered. An index greater than 1 indicates progress, with the difference with 1 giving the percentage progress, while an index less than 1 indicates deterioration, with the difference with 1 giving the percentage deterioration. Malmquist indices can be calculated by parametric and non-parametric methods, as in the case of efficiency measurements.

3.4. Evidence from studies measuring partial productivity, efficiency or productivity change

Gopinath *et al*. (1997) propose their own definition of competitiveness, based on the rate of growth of agriculture's GDP. If the differential between the agricultural GDP's rate of growth and the economy's GDP rate of growth for country A is higher than the same differential measured for country B, then country A is said to be gaining bilateral agricultural competitiveness over country B. This can be formally written as follows:

$$
\frac{d\left(\ln GDP_{agriculture,A}\right)/dt}{d\left(\ln GDP_{economy,A}\right)/dt} > \frac{d\left(\ln GDP_{agriculture,B}\right)/dt}{d\left(\ln GDP_{economy,B}\right)/dt}
\tag{29}
$$

The authors then separate GDP growth into price effects, input effects and TFP growth, and compare the agricultural competitiveness of the United States and four EU countries (Denmark, France, Germany, and the UK) during 1973-93. The authors use aggregated data for three outputs (grains, other crops, animal products) and eight inputs. Results indicate that in all countries studied TFP is the major source of growth in agricultural GDP, but that the rate of growth for the United States is lower than that for the EU countries, indicating lower bilateral agricultural competitiveness. Investigating TFP growth during four- or five-year periods, the authors find that all EU countries had a higher TFP growth in 1974-83 than in 1984-93: for example, TFP growth in France was 9.12% and 11.02% in 1974-78 and 1979-83 respectively, while it was only 2.08% and 1.94% in 1984-88 and 1989-93 respectively. Figures for the UK for these four sub-periods were 13.83%, 10.07%, 2.49% and 2.13%. By contrast, figures for the United States were 2.48%, 1.92%, 2.65% and 1.51%.

Bureau and Butault (1992) investigate the competitiveness of EU countries in 1984 in the soft wheat, sugar beet, hog and milk sectors. Along with costs of production, the authors calculate the inverse of partial productivity ratios, which they call unit volume costs. The figures reveal that the highest level of competitiveness was exhibited by France and the United Kingdom for wheat production, by France for sugar beet production, by the Netherlands for hog production, and by Belgium, Ireland, the Netherlands and the United Kingdom for milk production.

Besides using competitiveness indicators relying on trade data, Wijnands *et al*. (2008) calculate the growth of labour productivity in the food industry in the EU15, Australia, Brazil, Canada and the United States during 1996-2004. Labour productivity is calculated as the real value added per employee, but only growth is compared between countries to avoid biases due to different purchasing power parities. Results indicate that Brazil had the lowest indicator, the United States the highest, and the one for the EU15 was only average. Bavorova (2003) assesses the competitiveness of the Czech sugar industry compared to the EU15 during 1996-2000 by calculating labour productivity as the value added per employee. The author shows that such productivity multiplied six-fold, and increased from making up 54% of the whole food sector's labour productivity to 223%. Moreover, the author compares yield of sugar from the beets during 1989-2000. The yield increased more in the Czech Republic than in the EU15, but the 2000 level in the Czech Republic was still lower than the level in the EU15: 72.3% and 86.4% in the Czech Republic and in the EU15 respectively in 1989, against 81.9% and 89.2% respectively in 2000.

In addition to unit labour cost, Mulder *et al*. (2004) compare partial labour and land productivities for the agriculture of Mercosur countries and for the EU in 1995. Productivities are calculated with the agricultural output valued firstly with the exchange rate and then with the output unit value ratio; the latter uses production prices instead of consumption prices as in the exchange rate, and thus avoids taxes, subsidies, transportation costs and retailers' margins. Results indicate that Mercosur's labour productivity was only 13%, when using the exchange rate, and 21.8% when using the output unit value ratio, of the EU's productivity. Figures for land productivity are respectively 8.8% and 14.7%. The authors also report that Mercosur countries used only 0.06 tractor per agricultural worker, against 0.91 in the EU. All these findings reveal a lower competitiveness for Mercosur countries than for the EU, when partial productivities are considered; while the opposite was shown with unit labour cost. In addition to calculating costs of production for cereal production in Denmark, Germany, France, Ireland, Italy and the UK during 1996-2000, Thorne (2005) computed partial productivity measures for assessing competitiveness: wheat yield; cereal output plus allocated area payments per hectare of cereal area; and cereal output plus allocated area payments per annual working unit devoted to cereal production. Using data for farms specialised in COP, partial productivity measures indicate that Italy greatly lagged behind the other countries in terms of yield and labour productivity.

Besides profitability, van Berkum (2009) compares cow milk yield in 2007 between the 12 EU new member states and eight EU candidate countries, as a measure of competitiveness of the dairy sector in these countries. All figures were computed with a base of 100 for the EU25 average. Only in the Czech Republic, Hungary and Estonia was cow yield close to the EU25 level (respectively 101, 97 and 96). All other countries lay far behind, with the lowest attained by the Balkan candidate countries (around 40). Without referring to competitiveness, Alston *et al*. (2008) provide figures for crop yield growth during 1961-2006 in developing and developed countries. Maize yield growth was 2.53% per year during 1961-89 and 1.92% per year during 1990-2006 for developing countries, while figures were 2.50% and 1.67% respectively in developed countries.

Similar discrepancies between both time periods are shown for wheat and rice yield growth. The authors also indicate that partial land and labour productivity in agriculture grew faster in the United States before 1990 than after. For example, partial labour productivity growth was 2.38% and 4.11% during 1911-49 and during 1949-89 respectively, while it was only 1.59% per year during 1990-2006.

Besides measures of agricultural output and input PPP, Ball *et al*. (2006) calculated agricultural TFP in 11 EU countries and in the United States to assess their relative competitiveness in agriculture during 1973-2002. The authors find that TFP indices have increased for all countries, almost consistently (except for a few years where TFP decreased compared to the preceding years). For example, for the United States TFP was 0.5730 in 1973 and 1.0476 in 2002 (the reference year being 1996 with a TFP of 1.000). Only Sweden and Spain had a faster rate of productivity growth than the United States. At the end of the period (2002), no country had a TFP index greater than 1 except for the United States; the highest TFP was achieved by the Netherlands (0.9489) and the lowest by Ireland (0.5924). The authors also note that low levels of productivity in the EU explain the high output prices, and thus low competitiveness, of the EU countries.

There are a few studies that investigated TFP or TFP change for the farm sector without referring explicitly to competitiveness. For example, Davidova *et al*. (2003) use Tornqvist indices to calculate the TFP of Czech farms in 1998-99. They report that only 40% of the farms were productive (*i.e.* with a TFP greater than 1). Ball *et al*. (1997) investigate the evolution of the US agricultural sector's productivity during the period 1948-94 using Fisher TFP indices. Results indicate that productivity increased at an average 1.94% annual rate. Dividing the whole period in nine sub-periods, the authors show that the lowest increases were in the first two sub-periods (0.48% during 1948-53 and 0.75% during 1953-57, and the highest increases were during 1966-69 (2.75%) and in the last sub-period 1989-94 (2.87%).

Ball *et al*. (2001) calculate Eltetö-Köves-Szulc TFP indices to assess the productivity of agricultural sectors in nine EU countries during 1973-93 relative to the United States. All indices are calculated with respect to the TFP index of the United States in 1990, which was assigned the value of 1.000 as a benchmark. Yearly country indices show that all countries experienced almost consistent increases in TFP over the period. France enjoyed the largest gain in relative productivity over the period with an increase from 0.644 in 1973 to 1.058 in 1993. Average TFP for the United States increased from 0.636 to 1.001, while Ireland remained largely behind with an increase from 0.483 to 0.710. Figures indicate that Belgium had always a TFP index greater than the benchmark (US TFP in 1990), and its TFP increased from 1.080 in 1973 to 1.385 in 1993; the same finding is provided for the Netherlands except for the year 1973. Results also give evidence of convergence productivity levels for the nine countries.

Brümmer *et al*. (2002) calculate the Malmquist TFP change for three dairy farm samples, located in Poland, Germany and the Netherlands, between 1991 and 1994. Results reveal that Polish farms experienced a productivity deterioration of about 5%, mainly due to a technological regress of about 7%. In the same period the authors identify a productivity increase of about 6% for German farms and of about 3% for Dutch farms. Hadley (2006) calculates technological change for eight farm types in England and Wales during 1982-2002, and show that over the period it was positive for all types. The strongest progress was experienced by cereal and mixed farms (5.8% and 5.2% respectively) and the smallest progress by poultry farms (1.6%). Alston *et al*. (2008) report a TFP average of 1.56 during 1911-2002 for the US agriculture. During the sub-periods 1911-49, 1959-89 and 1990-2002, the average TFP was respectively 1.24, 2.11 and 1.01. Carroll *et al.* (2009) calculate TFP growth for several production types in Ireland during 1996-2006 (2000-06 for sheep type): the average growth over the period was 2% for cattle rearing, 1.4% for dairy, 0.9% for cattle finishing, 0.4% for sheep and -0.2% for cereals. Latruffe *et al*. (2008a) analyse Malmquist productivity change for Polish farms during 1996-2000. Figures indicate a productivity and technological deterioration. In the four periods (1996/97, 1997/98, 1998/99 and 1999/2000), TFP change was 0%, -7%, -8% and 8% and technological change was -19%, -7%, -3% and 7%. Over the whole period, the average TFP change and technological change was respectively -2% and -6%. The authors stress that, based on the construction of confidence intervals, there is large uncertainty in the results.

Fogarasi and Latruffe (2009) compare Malmquist TFP change of COP and dairy farms between France and Hungary over the period 2001-04. All four samples experience productivity stagnation, with technical efficiency improvement offsetting a slight technological deterioration, except for the Hungarian dairy sample for which productivity decreased. Galonopoulos *et al*. (2008) calculate Malmquist indices for 32 European and Mediterranean countries that formed part of the Euro-Mediterranean Free Trade Zone during 1966-2002. They conclude that there are two clubs of performers: a high productivity club including mainly EU15 countries and CEECs, and a low productivity club that consists of Albania, Algeria, Libya, Morocco, Tunisia and Syria. They also indicate that there is evidence of convergence in TFP from 1990 onwards. Some other studies calculating TFP or TFP change are reviewed in Section 4 as their objective is the investigation of the determinants (*e.g.* Yee *et al*., 2004; Skuras *et al*., 2006).

There is a profusion of studies investigating technical efficiency, and to a lesser extent allocative efficiency, for farms in various countries. They are not listed here, as in general not only are absolute levels of efficiency calculated but determinants of efficiency variation are also analysed. Section 4 reviews these determinants. A few examples of results of efficiency calculation over time, all using farm-level data, can nevertheless be provided. In general, while TFP change and technological change are generally positive over time, technical efficiency scores vary largely. Nasr *et al.* (1998) analyse technical efficiency of Illinois grain farms during 1988-94. For each year, the average scores for the sample are 0.765, 0.824, 0.837, 0.804, 0.846, 0.813 and 0.869. Giannakas *et al.* (2001) indicate the following yearly averages of technical efficiency for crop farms in Saskatchewan during 1987-95: 0.775, 0.664, 0.682, 0.780, 0.838, 0.804, 0.810, 0.820 and 0.827.

Besides Malmquist TFP change, Brümmer *et al*. (2002) calculate yearly technical efficiency for dairy farms in Poland, Germany and the Netherlands during 1991-94. Average technical efficiency scores for each year are respectively 0.843, 0.609, 0.722 and 0.853 for Poland, 0.954, 0.998, 0.990 and 0.879 for Germany, and 0.887, 0.898, 0.896 and 0.904 for the Netherlands. Latruffe *et al*. (2005) separate Polish farms into crop specialised farms and livestock specialised farms, and show that both samples' average technical efficiency decreased between 1996 and 2000: 0.85 and 0.71 for livestock in both years, and 0.66 and 0.57 for crops.

Hadley (2006) calculates yearly technical efficiency for eight farm types in England and Wales during 1982-2002. Results indicate that over the whole period the average scores for all samples were relatively high (between 0.745 for mixed farms, and 0.905 for poultry farms). As for technical efficiency change, on average it was 0% at most (for cereal and poultry farms) or negative (the worst figure being -0.95% for general cropping and mixed farms).

Zhu *et al*. (2008) calculate technical efficiency during 1995-2004 for dairy farms in three EU countries. The authors find that the average technical efficiency during the period was 0.594, 0552 and 0.788 for Germany, the Netherlands and Sweden respectively, while the average technical efficiency change (*i.e.* the change between two years) was 1%, 2.8% and -1.1% respectively. Carroll *et al*. (2009) report technical efficiency change for several production types (cattle rearing, cattle finishing, cereals, dairy, sheep) in Ireland during 1996-2006 (2000-06 for sheep). All types experienced the worst technical efficiency change (deterioration) in the first periods and the best change (progress) in the last periods. When technical efficiency change is averaged over all types of farms, figures indicate that the strongest deterioration was in the first period 1996/97 (-1.564%) and the strongest progress was in the last period 2005/06 (1.365%).

In the agri-food sector, Furtan and Sauer (2008), although not explicitly referring to competitiveness, calculate the level of sales per employer as a proxy for value added for Danish firms in 2005. Schiefer and Hartman (2008) compare the return on asset and return on sales for a sample of surveyed food processors in Germany in 2006. Both studies focus on investigation of determinants (Section 4). Without referring to competitiveness, Gopinath (2003) calculates TFP growth for the food processing industry of 13 OECD countries during 1975-95. Results indicate that the United States had the highest TFP average over this period, but that the largest TFP growth was recorded by Denmark. Similarly, Ruan and Gopinath (2008) calculate TFP growth of five food processing industries in 34 (developed and developing) countries during 1993-2000. They find that meat, fish, fruits and dairy processing industries had a positive TFP growth, while the rate was negative for the industry of oils and fats. Moreover, the United States had the highest TFP growth for all five industries.

Chan-Kang *et al*. (1999) compare the TFP growth of the United States and Canadian food manufacturing sector during 1963-92, and conclude that Canada was lagging behind during that period. Buccola *et al*. (2000) investigate the productivity of US grain processing industries during 1958-94, and find that productivity grew steadily over the period, except for the baking industry where it declined. Fischer and Schornberg (2007) evaluate the competitiveness of the food and drink manufacturing sector (ten main products) in 13 EU countries between 1995-98 (using average data for this period) and 1999-2002 (also using average data). They use a multidimensional definition of competitiveness, including profitability, productivity and output growth. They define profitability as the share of gross operating surplus in turnover, productivity as the value added per employee, and output growth as the annual change in the value of production. They then aggregate the three components into a single competitiveness index per country and product based on the method used by the United Nations to calculate the Human Development Index; that is to say, attributing scores depending on the maximum and minimum values among countries. Results indicate that the average EU competitiveness increased slightly between the two periods studied and that the index has converged across countries.

4. Determinants of competitiveness

4.1. Methods to investigate the determinants

4.1.1. Regressions on competitiveness scores

Determinants of competitiveness may be investigated with the help of an econometric regression of the scores obtained for the observations over a set of explanatory variables. This approach is standard in the efficiency and productivity literature, and has also sometimes been used to explain cost measures of competitiveness.

In the case of investigating the determinants of technical efficiency scores calculated with DEA, the standard model used in the second-stage regression is Ordinary Least Squares (OLS). However, the bounded nature of DEA (efficiency scores bounded at 1) has prompted researchers to use other models that can take this into account. The literature is not, however, clear whether the efficiency distribution is censored at 1, in which case a Tobit model can be preferred (*e.g.* Nasr *et al*., 1998; Lissitsa and Odening, 2005; Davidova and Latruffe, 2007) or whether the distribution is truncated at one, in which case a truncated regression may be used (*e.g.* Simar and Wilson, 2007; Bojnec and Latruffe, 2009).

In the case of the stochastic frontier approach, the two-stage approach may produce biased results and for this reason efficiency determinants are simultaneously estimated with the frontier, using the following parameterisation (Battese and Coelli, 1995):

$$\mu_i = \delta_0 + \delta Z_i \qquad (30)$$

where *i* is the farm or firm; μ_i is the mean of the conditional distribution of $u_i | w_i$ [see equation (22)]; Z_i is a vector of explanatory variables; δ_0 and δ are parameters to be estimated.
Given the definition of u_i, this parameterisation attempts to determine the sources of inefficiency (and not of efficiency).

In general, determinants of TFP growth are investigated at the macroeconomic level with country, regional or sectoral data (*e.g.* Makki *et al*., 1999; Ball *et al*., 2001; Rao *et al*., 2004; Yee *et al*., 2004; Hall and Scobie, 2006). A few studies analyse the determinants at the farm level, by running regressions on farms' individual TFP indices (*e.g.* Zhengfei and Oude Lansink, 2006; Balcombe *et al*., 2008; Fogarasi and Latruffe, 2009). While some factors are found to have a significant influence on farms' TFP specific index, they mainly show which farmers are able to quickly adopt the new technologies (the technological change component of TFP) and to use them efficiently (the efficiency change component of TFP). When sources of technological change and TFP are assessed using aggregated data, macroeconomic variables such as public investments in R&D can be highlighted.

4.1.2. Correlation and ranking analysis

Instead of carrying out an econometric regression, some authors prefer to apply a simple correlation analysis between competitiveness scores and determinants (*e.g.* Bojnec and Latruffe, 2007 for the correlation between farm technical efficiency and size). Simple visual ranking may also be used, for example were the competitiveness score in specific years is compared with the level of subsidies in the same years (*e.g.* Lachaal, 1994; Banse *et al.*, 1999). However, the sense of causality (what determines what) with such methods is not certain.

4.1.3. Calculations on separate samples

The investigation of farm competitiveness can be performed for separate groups of farms/firms, and their competitiveness levels compared using statistical tests. For example, it is common to calculate technical efficiency for farms separately according to their specialisation (*e.g.* crop *vs.* livestock, COP *vs.* beef *vs.* dairy), their technology (*e.g.* conventional *vs.* organic; various pig producing technologies), or their legal status (*e.g.* individual farms *vs.* corporate farms in CEECs). In general, such separation is done on the grounds that production technologies, and therefore efficiency frontiers, differ between the samples. In the case of farm-level data, the separation of farms according to their specialisation is, for example, made by Mathijs *et al.* (1999) in the Czech Republic in 1996 (livestock, crop, mixed), Mathijs and Vranken (2001) in Hungary in 1998 (crop and dairy), Latruffe *et al*. (2004, 2005) in Poland during 1996-2000 (livestock, crop), Hadley (2006) in England and Wales during 1982-2002 (cereals, dairy, sheep, beef, poultry, pig, general cropping, mixed farms), Carroll *et al.* (2009) in Ireland during 1996-2006 (cattle rearing, cattle finishing, cereals, dairy, sheep), Fogarasi and Latruffe (2009) in Hungary during 2001-04 (COP, dairy), and Latruffe *et al*. (2009) in France in 2000 (COP, beef).

The calculation of efficiency scores for organic and conventional farms separately is, for example, done by Tzouvelekas *et al*. (2001) for Greek farms in 1995-96, Oude Lansink *et al*. (2002) for Finnish farms in the period 1994-97 and Sipiläinen *et al*. (2008) for Finnish crop farms during 1994-2002. Within the pig farming sector there are several types of technologies (*e.g.* farrow-to-finish, farrow-to-weanling, finishing), for which separate efficiency frontiers can be constructed, *e.g.* by Larue and Latruffe (2009) for France and by Tonsor and Featherstone (2009) for the United States, both in 2004. Regarding the legal status in transition countries, calculation of technical efficiency under separate frontiers for individual and corporate farms was, for example, done by Davidova and Latruffe (2007) for the Czech Republic in 1999.

Some authors compare competitiveness scores across periods, for example to investigate the impact of policy reforms on technical efficiency or productivity (*e.g*. Morrison Paul *et al*. 2000; Brümmer *et al*., 2006; Lambarra *et al*., 2009). However, differences across periods may be caused by other factors than policy reforms.

4.1.4. Cluster analysis

Clustering implies grouping observations that have similar characteristics based on their relative distance from each other. In the farm productivity and efficiency literature, two methods can be found. In the first, farms are clustered on the basis of several characteristics of the farms and farmers, and then the average performance scores of each cluster are compared using statistical tests (*e.g.* Davidova *et al*., 2003). In the second method, the opposite is done: clustering is performed on the basis of several performance indicators, and then the average of several characteristics of the farms and farmers are compared among the clusters (*e.g.* Latruffe *et al*., 2008a).

4.1.5. Other methods

Wijnands *et al*. (2008) investigate the effect of food legislation in various EU countries on the competitiveness of their food sectors, using a survey of stakeholders. The latter were chosen within national producing firms and foreign countries exporting to the EU. They had to state their perceptions of the effect.

4.2. Determinants controllable by firms/farms

4.2.1. Size

The question of whether small farms perform better than large farms is still a topical issue in the world. The debate started with the empirical evidence of an inverse relationship between farm size and productivity (Cornia, 1985). The main argument used to explain this relationship is that small farms are not affected by labour supervision and organisation problems and that family labour is highly motivated as it stands to benefit from farm profits (Buckwell and Davidova, 1993). However, the inverse relationship between size and performance is regularly questioned, as large farms are claimed to achieve economies of scale and to benefit from preferential access to output and input markets (Hall and LeVeen, 1978). Although the debate initially started for developing countries, it intensified after the fall of communism in CEECs. The co-existence of very small subsistence farms and large corporate holdings at the beginning of the transition raised the issue of which farm size would prevail after restructuring. The link between farm size and competitiveness is particularly important in assessing directions of structural change.

The effect of farm size on technical efficiency, allocative efficiency or on productivity change is investigated using various indicators of size, since there is no consensus on the best measure for size in agriculture. Indicators used include: total output produced (*e.g.* Latruffe *et al*., 2004); utilised agricultural area (*e.g.* Nasr *et al*., 1998; Munroe, 2001; Helfand and Levine, 2004; Hadley, 2006; Rios and Shively, 2006; Latruffe *et al*., 2008a; Carroll *et al.*, 2009); herd size or number of cows or pigs (Weersink *et al*., 1990; Sharma *et al*., 1999; Brümmer and Loy, 2000; Hadley, 2006; Tonsor and Featherstone, 2009); European Size Units (ESU) where one ESU represents EUR 1 200 of standard gross margin (*e.g*. Emvalomatis *et al*., 2008; Zhu *et al*., 2008a and 2008b; Latruffe *et al*., 2009); farm value added (Hallam and Machado, 1996); labour used or assets (*e.g.* Bojnec and Latruffe, 2007); and real productive capacity based on rental rate (Huffman and Evenson, 2001; Yee *et al*., 2004).

A wide range of results can be found: i) larger farms are better performers (*e.g.* Weersink *et al*., 1990, for dairy farms in Ontario in 1987; Hallam and Machado, 1996, for dairy farms in Portugal during 1989-92; Nasr *et al*., 1998, for Illinois grain farms during 1988-94; Sharma *et al*., 1999, for swine farmers in Hawaii in 1994; Brümmer and Loy, 2000, for German dairy farms during 1987-94; Hufmann and Evenson, 2001, for the US livestock agricultural sector in the period 1953-82; Yee *et al*., 2004, for several US states' agriculture during 1960-96; Latruffe *et al*., 2004 and 2008b, for crop farms in Poland during 1996-2000; Hadley, 2006, for various production types in England and Wales during 1982-2002; Rios and Shively, 2006, for coffee farmers in Vietnam in 2004; Emvalomatis *et al*., 2008, for Greek cotton farms in 1996-2000; Zhu *et al*., 2008a, for dairy farms in Germany and Sweden during 1995-2004; Carroll *et al.*, 2009, for farms specialised in cattle rearing, cattle finishing, cereals and dairy in Ireland during 1996-2006); ii) smaller farms are better performers (*e.g.* Munroe, 2001, for Polish farms in 1996; Hufmann and Evenson, 2001, for the US crop agricultural sector during 1953-82; O'Neill and Matthews, 2001, for Irish farms in the period 1984-98; Zhu *et al*., 2008b, for Greek olive farms during 1995-2004); iii) the relationship between performance and size is U-shaped (Helfand and Levine, 2004, for Brazilian farms in 1995; Latruffe *et al*., 2005, for Polish livestock farms in the period 1996-2000; Tonsor and Featherstone, 2009, for US feeder-to-finish pig producers in 2004); iv) results depend on the size variable used (*e.g.* Bojnec and Latruffe, 2007, for Slovenian farms during 1994-2003).

Regarding the effect of size on other measures of farm competitiveness, in their review of several studies that have investigated the international competitiveness of CEECs' agriculture using DRC ratios between 1992 and 1998, Gorton and Davidova (2001) report that a few studies investigated the relationship between international competitiveness and farm size, by calculating the DRC ratios for various farm size categories, where size is measured in hectares. Results indicate that larger farms were more internationally competitive than smaller farms within the arable sector. Nivievskyi and von Cramon-Taubadel (2008) calculate the SCB of dairy production in Ukraine in 2004-05 using farm-level data. In a second step, the authors investigate the determinants of farm competitiveness, with a regression on SCB scores. Among other determinants, herd size is found to influence competitiveness positively.

In the agri-food sector, the size effect is not such an issue as in the farming sector, although it is generally recognised that small manufacturing firms may be constrained by labour-intensive technologies due to factor prices differing by firm size (*e.g.* Söderbom and Teal, 2004). Skuras *et al*. (2006) use the total assets as a size proxy for explaining the technical efficiency of food and beverage manufacturing firms in Greece for the period 1989-94. However, results reveal that the proxy has a non-significant effect.

4.2.2. Other structural characteristics

The organisational type of the farm is commonly included as an explanatory variable in studies about transition economies, although existing results do not reveal any clear efficiency superiority of either family farming or corporate type of structures (see Gorton and Davidova, 2004). Legal status is also used to explain the technical efficiency of farms in Western countries by comparing sole proprietorship with partnerships and corporations (*e.g.* Weersink *et al*., 1990, for dairy farms in Ontario in 1987; Latruffe *et al*., 2009, for French farms in 2000). In the case of agri-food firms, Furtan and Sauer (2008) do not find any significant impact of the farmers' cooperative form on the level of sales per employer in Denmark in 2005. Galdeano-Gomez and Cespedes-Lorente (2008) report that firm size measured by total sales had a positive impact on the technical efficiency of Spanish agri-food firms during 1995-2003. Schiefer and Hartmann (2008) find that for German food processing firms in 2006 the size in terms of total sales has no influence on the return on assets, nor on the return on sales.

The effect of factor intensity on farm technical efficiency is often investigated (*e.g.* Weersink *et al*., 1990; Hallam and Machado, 1996; Mathijs and Vranken, 2001; Latruffe *et al*., 2004; Carroll *et al*., 2009; Latruffe *et al*., 2009). Factor intensity is usually defined in terms of capital to labour or to animal ratio, or in terms of land to labour or to animal ratio. However, conflicting findings are provided by the studies on technical efficiency. Regarding other competitiveness measures, in their regression of SCB of dairy production in Ukraine in 2004-05, Nivievskyi and von Cramon-Taubadel (2008) find that labour intensity and feed land per cow has a negative influence.

Resorting to factors external to the farm is often considered as a determinant of farm technical efficiency. For this, the share of hired labour in total farm labour, the share of rented land in total land used, and the indebtedness level (measured by the level of debts or the debt to asset ratio) are used in the regression of technical efficiency. Conflicting results are found regarding the share of hired labour and rented land (*e.g.* Weersink *et al*., 1990; Latruffe *et al*., 2004; Hadley, 2006; Zhu *et al*., 2008a and 2008b; Lambarra *et al*., 2009; Latruffe *et al*., 2009; Tonsor and Featherstone, 2009). Hired labour may imply better educated workers or workers with specific skills, but may result in supervision problems. Renting land in may give farmers an incentive to be productive in order to pay rentals, but may prevent them from applying long-term improvements. An ambiguous effect also holds for the indebtedness level. Some researchers report that indebtedness has a positive impact on technical efficiency: for example, Nasr *et al*. (1998) for Illinois grain farms in the period 1988-94, Giannakas *et al*. (2001) for crop farms in Saskatchewan during 1987-95, O'Neill and Matthews (2001) for Irish farms during 1984-98, Davidova and Latruffe (2007) for Czech livestock farms in 1999, Zhu *et al*. (2008a) for dairy farms in the Netherlands during 1995-2004, and Latruffe *et al*. (2009) for French COP farms in 2000. This suggests that farmers who are indebted need to meet their repayment obligations and, therefore, are motivated to improve their efficiency. However, highly indebted farmers might incur high credit costs and thus be less technically efficient. Such negative impact is found by Weersink *et al*. (1990) for dairy farms in Ontario in 1987, Morrison Paul *et al*. (2000) for farms in New Zealand during 1969-91, Hadley (2006) for various production types in England and Wales during 1982-2002, Davidova and Latruffe (2007) for Czech crop farms in 1999, and Zhu *et al*. (2008a) for dairy farms in Germany and Sweden during 1995-2004. In terms of productivity change, debts may help farmers to invest in new technology. A positive impact of the long term debt to asset ratio on productivity change is found by Zhengfei and Oude Lansink (2006) for Dutch farms in the period 1990-99.

Several authors have investigated the effect of farm specialisation on technical efficiency. Farm specialisation might be beneficial to technical efficiency since it enables farmers to concentrate their attention on a few tasks, and therefore improves management practices. It also avoids conflicts in crop rotations, and prevents competition for the same resource, such as land. This effect is found by Brümmer (2001) for Slovenian farms in 1995-96, Mathijs and Vranken (2001) for the dairy sector in Hungary in 1997, Zhu *et al*. (2008a) for German and Swedish dairy farms during 1995-2004, and Carroll *et al*. (2009) for Irish farms specialised in dairy and cereals during 1996-2006. On the other hand, diversification may improve efficiency by reducing the risk related to the loss of all crops to disease. Evidence of this is provided by Hallam and Machado (1996) for Portuguese dairy farms in the period 1989-92, Mathijs and Vranken (2001) for Hungarian crop farms in 1997, Hadley (2006) for cereal, dairy, sheep, beef and pig farms in England and Wales during 1982-2002, Bojnec and Latruffe (2009) for Slovenian farms in 1994-2003, and Carroll *et al*. (2009) for Irish sheep farms during 2000-06.

The impact of a high degree of commercialisation (in contrast to subsistence farming) on farm technical efficiency is often investigated for transition countries. The impact can be expected to be positive in the sense that commercialisation increases the cash proceeds and therefore allows farmers to purchase high quality inputs. Such a positive impact on the level of sales or the share of marketed output in total output is, for example, reported by Mathijs and Vranken (2001) for Bulgarian family crop farms in 1997, Latruffe *et al*. (2004) for Polish farms during 1996-2000, and Bojnec and Latruffe (2009) for Slovenian farms in the period 1994-2003.

4.2.3. Social capital

In the explanation of farms' technical efficiency or productivity change, the farmer's age, education level/type, gender, and time spent on farm are often included as proxies of the farmer's management capacities which are not directly observable. The consideration of social capital in the explanation of the performance of agri-food firms' is rare.

The effect of the farm manager's age on technical efficiency or productivity change may be negative due to the reluctance of older farmers to change and their unwillingness or inability to adopt technological innovations, as found for example by Brümmer and Loy (2000) for German dairy farms during 1987-94, by Hadley (2006) for various production types in England and Wales during 1982-2002, by Latruffe *et al*. (2008a) for Polish farms in the period 1996-2000, and by Lambarra *et al*. (2009) for Spanish COP farms during 1995-2003. However, the opposite impact of age on technical efficiency can also be expected, as older farmers are more experienced and can use their knowledge to use inputs more efficiently, as evidence given by Mathijs and Vranken (2001) for Hungarian dairy farms in 1997, by Munroe (2001) for Polish crop farms in 1996, and by Chen *et al*. (2009) for Chinese farms during 1995-99 shows. The number of years of experience of the farmer may also be included as a determinant of efficiency: for example, Sharma *et al*. (1999) find that it increased the technical efficiency of swine farmers in Hawaii in 1994.

The effect of education should be unambiguously positive since better educated farm managers can be expected to have more skills to run their farm efficiently. For example, Mathijs and Vranken (2001) and Latruffe *et al*. (2004) confirm that education positively influences technical efficiency in family farms in Hungary and Bulgaria in 1997 and in Polish farms during 1996-2000 respectively, and Latruffe *et al*. (2008a) report that education positively influences productivity change for Polish crop farms in the period 1996-2000. However, Sotnikov (1998) reports the opposite for Russian farms during 1990-95 using aggregated regional data. The author explains this finding by the specificity of agricultural education in Russia at that time, that concentrated more on technological aspects than on management practices. Using aggregated data, Makki *et al*. (1999) show that the level of schooling of farmers has a positive impact on US agricultural growth in the period 1930-90, while Rao *et al*. (2004) find that the share of illiterate people in the countries' population had a negative impact on Malmquist TFP indices for 111 industrialised and developing countries during 1980-2000. In the agri-food sector, Furtan and Sauer (2008) give evidence of a positive impact of the share of employees with a university degree on the level of sales per employer for Danish firms in 2005. As for Schiefer and Hartmann (2008), they report that the qualification level of staff at executive levels had a positive impact on the return on assets and the return on sales of German agri-food firms in 2006.

Concerning the effect of gender, Quisumbing (1996) explains that, in general, studies investigating male-female differences in technical efficiency show no difference. This is the case for the study by Chavas *et al*. (2005) for Gambia's farmers in 1993. By contrast, Timothy and Adeoti (2006), find that for cassava growers in Nigeria in 2004 female farmers showed superior technical efficiency than male farmers, but lower allocative efficiency. The authors attribute the differentials to different access to inputs. Mathijs and Vranken (2001) report that the share of women in the household had a positive impact on the technical efficiency of Hungarian crop farms in 1997.

Regarding the time spent concentrating on farming, the effect on performance is ambiguous. Off-farm work may reduce the time spent on managerial activities that would improve farm efficiency work. However, spending time off the farm might improve the farmer's abilities through the acquisition of information and knowledge. Brümmer (2001) for Slovenian farms in 1995-96, Mathijs and Vranken (2001) for family crop farms in Hungary in 1997, O'Neill and Matthews (2001) for Irish farms during 1984-98, Rezitis *et al*. (2003) for Greek farms in the period 1993-97, and Tonsor and Featherstone (2009) for US feeder-to-finish pig producers in 2004, all find that full-time farmers are more technically efficient than part-time. Similarly, Goodwin and Mishra (2004), for farms in the United States in 2001, report that involvement in off-farm labour markets decreases on-farm performance, proxied by the ratio of gross sales to variable input costs.

Evidence of the same effect on TFP is given by Huffman and Evenson (2001) for the US crop sector during 1953-82 (using the share of farm operators reporting any day of off-farm work), and by Yee *et al*. (2004) for US state-aggregated agricultural data for 1960-96 (using the proportion of farm operators who worked 200 or more days off-farm). The opposite effect, namely that pluriactivity increases farm technical efficiency or TFP, is found by Huffman and Evenson (2001) for the US livestock sector during 1953-82, by Mathijs and Vranken (2001) for Hungarian family dairy farms in 1997, and by Tonsor and Featherstone (2009) for US farrow-to-weanling farms. Chavas *et al*. (2005) do not find any statistical difference between full-time and part-time farmers in the Gambia in 1993. Likewise, Lien *et al*. (2008) report the same lack of statistical difference for grain producing farmers in Norway during 1991-2005, and Carroll *et al.* (2009) for Irish farms during 1996-2006.

4.3. Determinants beyond firms'/farms' control

4.3.1. National factor endowments and demand conditions

A nation's competitiveness is largely determined by factor endowments (*i.e.* resources in labour, land and capital), and by demand conditions (*i.e.* the population's tastes and preferences for products), as suggested by Porter (1990).

Although not referring directly to the concept of competitiveness nor to any measures explained in Sections 2 and 3, Peterson and Valluru (2000) investigate the determinants of agricultural trade patterns using aggregated data for 40 countries in 1992. In a simple regression on net trade flows, the authors include as explanatory variables: four categories of the national area based on climatic differences; the national capital stocks (estimated from gross domestic investment); the number of workers in the country according to three classes (skilled, agricultural, and other workers); and national energy reserves. Results indicate that the endowment of skilled labour increases net trade flows of grain, oilseeds, cotton and fresh meat products. Only for the latter does the number of agricultural workers have a positive influence on net trade flows. By contrast, capital endowment has a negative impact on the net trade flows of grain, oilseeds and cotton, being thus a source of comparative disadvantage. As for sugar, only the type of land significantly influences its net trade flow. For the whole agricultural net trade flow, the significant sources of comparative disadvantage are capital endowment and the number of other (*i.e.* unskilled, not agricultural) workers, and significant sources of comparative advantage are two categories of land (tropical and humid mesothermal).

According to Venturini and Boccaletti (1998), the strong competitive position of the Italian pasta processing sector during the period 1988-92 is due to the increasing perception by consumers that pasta are a healthy (low-fat, low-cholesterol, low-calorie) food, in other words is due to the increasing sophistication of consumers. As Porter

(1990) underlines, the presence of sophisticated and demanding buyers is important in creating and sustaining competitive advantage. Viaene and Gellynck (1998) explain that the decrease in competitiveness of the pigmeat processing in Belgium during 1987-93 is partly due to a change in demand conditions: young people consume less meat in general, and in particular less pigmeat. Banterle and Carraresi (2007) argue that the success of EU countries that exhibit a strong competitiveness for swine meat products during 1990-2003 (*e.g.* Italy and Spain) is to be related to the internationalisation of food habits and growing consumer interest in quality and product of origin.

4.3.2. Government intervention in the agricultural sector

Public policies and regulations influence producers' decisions regarding resource allocation. They may also distort firms' competition (OECD, 2001). Therefore, they may have an effect on competitiveness. The literature on the effect of government intervention on agricultural competitiveness is more profuse than that on agri-food competitiveness.

In their investigation of the determinants of agricultural trade patterns for 40 countries in 1992, Peterson and Valluru (2000) include some policy indicators beside factor endowment proxies in the econometric regression of net trade flows. In order to investigate the effect of agricultural policy intervention, the authors use commodity-specific producer subsidy equivalents (PSE) proxies (PSE, weighted PSE, PSE compared to consumer subsidy equivalents). Similarly, to investigate the effects of environmental regulations, they use several variables representing the stringency of environmental regulations (a dummy for countries with high Gross National Product, the number of environmental treaties, the proportion of endangered species, the proportion of land in parks and protected areas, the proportion of population with access to safe water, and a dummy for countries that have published an environmental report). None of the policy variables are significant in the regression. The authors note that the results regarding the environmental regulation proxies are consistent with expectations, since policies for environmental protection often do not increase production costs. Regarding the agricultural support policy, the authors include a weighted average producer price for cereals instead of the PSE variables, on the assumption that such a price is a proxy for the level of government subsidisation. Contrary to the expectation of a positive effect of government intervention, the price variable has a negative influence, which the authors attribute to the consistent reason that higher prices mean domestic supply shortage and thus imports. The authors conclude from their general finding of non-significant effect of government support that the latter may in fact affect trade volumes instead of net trade flows.

Banse *et al*. (1999) compare the DRC ratios for various crop and livestock sectors in Hungary during 1992-96 and correlate them with the rate of producer PSE. They show that there is a negative correlation between international competitiveness and protection.

Using farm-level data for dairy production in Ukraine in 2004-05, Nivievskyi and von Cramon-Taubadel (2008) regress SCB scores on various determinants. Among other results, they find that subsidies received by farms negatively influenced their competitiveness.

The two-stage approach and the use of farm-level subsidies followed by Nivievskyi and von Cramon-Taubadel (2008) is similar to the one followed by Bezlepkina *et al.* (2005) in investigating the role of subsidies on profit of Russian dairy farms during 1995-2001. They find a positive effect. The approach is also followed in studies investigating the impact of agricultural policy support on farm efficiency using farm-level data. Using a regression on the farm-specific efficiency scores, researchers usually include as the policy variable either the level of subsidies received by farms (*e.g.* Rezitis *et al*., 2003; Emvalomatis *et al*., 2008), or the share of farm income stemming from government support (e.g. Giannakas *et al*., 2001), or a ratio relating the amount of subsidies to the level of output or gross margin in order to avoid size effects (*e.g.* Hadley, 2006; Zhu *et al*., 2008a and 2008b; Bojnec and Latruffe, 2009; Fogarasi and Latruffe, 2009; Latruffe *et al*., 2009; Bakucs *et al*., 2010). The impact on technical efficiency is almost consistently negative across the literature, *e.g.* Giannakas *et al*. (2001) for crop farms in Saskatchewan during 1987-95, Rezitis *et al*. (2003) for Greek farms in 1993 and 1997, Hadley (2006) for cereal, sheep, general cropping and mixed farms in England and Wales during 1982-2002, Emvalomatis *et al*. (2008) for Greek cotton farms during 1996-2000, Zhu *et al*. (2008a) for dairy farms in Germany, the Netherlands and Sweden during 1995-2004, Zhu *et al*. (2008b) for Greek olive farms in the period 1995-2004, Bojnec and Latruffe (2009) for Slovenian farms during 1994-2003, Fogarasi and Latruffe (2009) for French and Hungarian dairy and COP farms during 2001-04, Latruffe *et al*. (2009) for French COP and beef farms in 2000, Bakucs *et al*. (2010) for Hungarian farms during 2001-05. Only Hadley (2006) finds a positive impact for dairy and beef farms in England and Wales during 1982-2002.

Lachaal (1994), using annual data for the US dairy sector during 1972-92, finds that yearly technical efficiency has been lowest when yearly government expenditure on dairy support have been highest. Such negative impacts might arise from the reduced effort of farm operators resulting in an increase in input waste or in the choice of inefficient input or output combinations (with the consequence of overproduction, for example). But Serra *et al*. (2008) have shown that the sign of the impact is not unambiguous, since it depends on the farmer's risk aversion and on whether the effect is towards risk-increasing or risk-decreasing input. Regarding the effect of farm support on farm productivity change, the effect is ambiguous: the effect on the component technological change may be positive as extra income might help farmers overcome their credit constraints and invest in new technology, but the effect on the component efficiency change is not straightforward.

A positive effect of total subsidies on Malmquist productivity change indices is found by Fogarasi and Latruffe (2009) for Hungarian and French COP farms during 2001-04. Sauer and Park (2009) also report the positive influence of organic subsidies on technical efficiency change and technological change for organic dairy farms in Denmark in the period 2002-04. By contrast, the effect of the average level of commodity payments per farm had no significant effect on US agricultural TFP calculated by Yee *et al*. (2004) with state-aggregated data for 1960-96. The same finding is reported by Makki *et al*. (1999) for US agricultural TFP calculated with national data for 1930-90. However, Huffman and Evenson (2001), using US state data for 1953-82, find a positive influence of crop price support (proxied by a weighted ratio of support price to market price) on the crop sector's TFP growth. The same effect is shown for the livestock price support on the livestock sector's TFP growth. As for the level of crop diversion payments, it has a positive effect on the TFP growth of the crop, but a negative effect on the TFP growth of the livestock, sector.

A few studies have investigated the effect of agricultural support policy reforms on farm technical efficiency or productivity change, using as explanatory variables dummy variables for specific years or periods that capture policy changes. This approach is, for example, followed by Morrison Paul *et al*. (2000) to assess the effect of the 1984 liberalisation reform on the agricultural sector in New Zealand during 1969-91, by Carroll *et al*. (2009) to analyse the role of the introduction of decoupling with the 2003 CAP reform on Irish farms during 1996-2006, and by Lambarra *et al*. (2009) to investigate the impact of the Agenda 2000 on Spanish COP farms during 1995-2003. Similarly, Brümmer *et al*. (2006) analyse whether five periods of agricultural reform have influenced the productivity change of Chinese farms during 1986-2000 by comparing productivity indices for these five periods. However, it is difficult to be confident in the results provided by the approaches as many other economic or institutional changes may be captured by the year or period dummies.

Apart from income support, the effect of other types of interventions (programmes and regulations) on farm technical efficiency has been investigated. For example, Makki *et al*. (1999) investigate the effect of the government programme encouraging the diversion of acres from production and of conservation reserve programmes, on US agricultural TFP during the period 1930-1990. Both have a negative effect.

Brümmer and Loy (2000) and Rezitis *et al*. (2003) analyse whether the European farm credit programme has reached its objective of increasing the productivity of farms. Using data for German dairy farms for 1987-94, and a dummy proxying past participation in the programme in the determinants of technical efficiency, Brümmer and Loy show that the programme has decreased participants' technical efficiency. The same finding is provided by Rezitis *et al*. for Greek farms during 1993-97, by measuring efficiency before and after participation in the programme. Larue and Latruffe (2009) investigate the effect on the technical efficiency of French pig farms in 2004, of environmental regulations that required livestock producers to spread manure on only a minimum area of land. The authors include in the explanatory variables a proxy for environmental pressure in the farm's own subcounty (the ratio of the quantity of nitrogen discharged by all livestock in the farm's own subcounty, over the available area for spreading manure in this subcounty) and its spatial lag in the neighbouring subcounties. The positive sign of the environmental proxy and the negative sign of its spatial lag bring the authors to conclude that environmental regulations encourage pig farmers to be more efficient, but that this effect may be counteracted when legal dispositions are too stringent (*i.e.* when farmers are forced to spread their manure outside their subcounty).

Regarding the agri-food industry, Skuras *et al*. (2006) investigate the effect of regional capital subsidies on the technical efficiency of food and beverage manufacturing firms in Greece in the period 1989-94. The policy variable used, namely the ratio of capital subsidies to total investment costs (which the authors call the rate of assistance) has a negative influence on the technical efficiency. Alpay *et al*. (2002) analyse the impact of environmental regulations on the profitability of the Mexican and the US agri-food sectors during 1962-94. In addition, they analyse the impact of the environmental regulations on the productivity growth in these sectors during 1971-94. Their econometric regressions based on the countries' data reveal that pollution abatement expenditures, the proxy for environmental regulations, had a negative impact on both performance indicators in Mexico, but no significant impact in the United States. Ruan and Gopinath (2008) analyse the effect of trade liberalisation on TFP of five food processing industries in 34 countries (developed and developing) with annual data during 1993-2000. Using a second-stage regression with imports as explanatory variables, the authors show that a greater exposure to trade increases productivity, a process that is faster in low productivity countries than in high productivity countries. Based on a survey of the opinion of 63 stakeholders in the food industry, Wijnands *et al.* (2008) conclude that EU regulation in the sector (which they claim is the third most regulative after the automotive and the chemical sectors) is not a strong obstacle to the competitiveness of the EU15 food sector.

4.3.3. Public expenditures in research, extension and infrastructures

Public expenditures in research and development (R&D) enable the creation of new technologies that may improve firms' productivity and lower their costs of production, e.g. crop varieties and livestock breeds with higher yields or more effective pesticides for the farming sector. They may also help the diffusion of new technologies. This may be more the case for the agricultural sector than for the agri-food industries where designing a public R&D programme may be a more complex task. Harrison and Kennedy (1997) suggest for example that the manufacturing sector is too heterogeneous for a public R&D programme to be successful.

Mullen *et al*. (2006) explain that studies which have investigated the role of public expenditures in R&D on agricultural TFP usually regress a country's or sector's TFP indices on a weighted sum of current and past expenditures on R&D. Indeed, expenditures in a given year may have an impact on TFP for many years. The weighted sum of expenditures is called the stock of research (Yee *et al*., 2004) or the stock of knowledge (Hall and Scobie, 2006; Mullen and Crean, 2006). It may be calculated using the perpetual inventory method and a depreciation rate with the Koyck transformation, or with a polynomial lag structure (Hall and Scobie, 2006). The weighted-sum approach is followed by Yee *et al*. (2004) for US state-aggregated data during 1960-96 and by Hall and Scobie (2006) for New Zealand's agricultural sector data between 1927 and 2001. Both studies find that public investments in R&D have had a positive impact. Alston *et al*. (2008) argue that the recent decrease (beginning of the 90es) in crop yield and TFP growth in the United States and in the world in general can be attributed to the slowdown in the growth of public expenditure in R&D.

Mullen and Crean (2006) report a discrepancy between the upward trend in productivity in the Australian sector and the stagnation of public R&D expenditures. They explain that this may be related to the long lags of effects. Another explanation may be found in the type of research expenditure. Ahearn *et al.* (1998) mention that not only public expenditure but also private research expenditure play a role in agricultural productivity. They show that in the United States since 1975, private expenditure surpasses that of the public sector. Hall and Scobie (2006) add private expenditure in R&D to their econometric regression, and find that private investment has a higher impact and rate of return than public expenditure. Makki *et al*. (1999) also include public expenditure in research and extension, as well as private expenditure in research and development, in their regression of US agricultural TFP during 1930-90. They find that both types of expenditure had a positive effect, but calculate that the rate of return of public investment exceeded that of private investment (27% *vs*. less than 10%). Huffman and Evenson (2001) find that both public and private expenditures on crop research had a positive impact on the TFP growth of the US crop sector in the period 1953-82. By contrast, their research reveals a negative impact for livestock research on the livestock sector's TFP growth. In addition to the domestic knowledge stock, Hall and Scobie (2006) include in their regression of TFP the stock of foreign knowledge, proxied by current and past patent numbers in the world. The positive effect of the variable allows the authors to conclude that there are international knowledge spillovers.

Yee *et al*. (2004) find that the US agricultural TFP is positively influenced by public expenditure in extension. Huffman and Evenson (2001) report that public extension stock with a crop commodity focus had a negative impact on the crop sector's TFP growth, whereas that with a livestock commodity focus had a positive impact on the livestock sector's TFP growth. At the farm level, research from Tchale and Sauer (2007) shows that the frequency of extension visits increased the technical efficiency of farmers in Malawi in 2003, and the study by Carroll *et al*. (2009) indicates that extension use by dairy farms in Ireland had a positive effect on their technical efficiency during 1996-2006. Ahearn *et al*. (1998) explain that the agricultural extension system allows the time lag between the development of new technologies and their adoption to be reduced, and thus should have a more immediate impact on productivity. However, as for R&D, private extension services are becoming increasingly available and used by farmers, although information and data on them are rare (*e.g.* Desjeux, 2009). This may offset the significant effect of public expenditures in extension observed in empirical studies. Hall and Scobie (2006) investigate the impact of the number of extension workers in New Zealand on the country's agricultural productivity during 1927-2001, but do not find any significant influence. They attribute this finding partly to the imprecision of the data, which are difficult to obtain now that the extension service has been privatised.

Finally, public investments in infrastructures may help productivity growth, in particular when investment is in public transportation (Ahearn *et al*., 1998). For example, the impact of public expenditures on highways is found to be positive on the productivity of US agriculture by Yee *et al*. (2004). Rao *et al*. (2004) included government expenditures as a percentage of GDP in their regression of Malmquist TFP indices calculated with national data for 111 industrialised and developing countries during 1980-2000. They claim that such a variable is a proxy for expenditures in R&D and in infrastructures. Results indicate a positive impact of government expenditures on productivity. In the agri-food sector, Bernstein and Mamuneas (2008) specifically investigate the impact of public investment in infrastructure on the Canadian food processing industry for the period 1963-97, and find that such investment is a positive contributor to TFP growth by acting as a substitute for technological change.

While it is recognised that public expenditures increase productivity in the farming sector, the impact on competitiveness *per se*, or on competitiveness measures other than productivity, is not debated in the literature. Only Harrison and Kennedy (1997) claim that agricultural competitiveness can be improved by technological innovations introduced by public programmes. The authors give the example of the Land Grant system in the United States that has developed improved seed varieties and fertilisers, and has permitted the transfer of information and the adoption of new technologies.

4.3.4. Location of activities

Competitiveness variations between firms or farms may be explained by their locational and environmental characteristics, that is to say the operating environment over which managers have no control. Location may imply different climate or altitude conditions, different soil quality, but also different physical and market infrastructure and conditions. Available research has mostly concentrated on the effect of location on farm technical efficiency.

Several authors include location dummies (*e.g.* at the state, regional or county level) in their regression of farm technical efficiency scores, *e.g.* Weersink *et al*. (1990), Hallam and Machado (1996), Sharma *et al*. (1999), O'Neill and Matthews (2001), Rezitis *et al*. (2003), Helfand and Levine (2004), Latruffe *et al*. (2008b), Zhu *et al*. (2008b), Tonsor and Featherstone (2009), and Bakucs *et al*. (2010). Specific dummies capturing harsh operating conditions may also be included. For example, Zhu *et al*. (2008b) find that being located in Less Favourable Areas (LFA) decreased the technical efficiency of Greek olive farms during 1995-2004. The same effect is found by Hadley (2006) for dairy farms in England and Wales during 1982-2002, but the author finds a positive effect for cereal, beef and general cropping farms. Brümmer (2001) reports that location in altitude above 600 metres reduced Slovenian farms' technical efficiency in 1995-96. When available, soil quality indicators are used and show that higher technical efficiency is associated with higher soil quality. For example, Nasr *et al*. (1998) employ soil productivity measures to explain technical efficiency of Illinois grain farms in the period 1988-94, while soil quality indices are used by Latruffe *et al*. (2004) for Polish farms during 1996-2000 and Bakucs *et al*. (2010) for Hungarian farms during 2001-2005. Climatic conditions are also shown to have a significant effect on the agricultural sector's TFP of several US states in the period 1960-96: Yee *et al*. (2004) give evidence of a negative effect of both drought and flood conditions.

Regarding physical infrastructure, Sotnikov (1998) shows that road density is positively related to the technical efficiency of Russian farms during 1990-95. As for market infrastructure, Larue and Latruffe (2009) investigate the effect of the availability of upstream and downstream facilities on the technical efficiency of pig producers in France in 2004, and find that a higher capacity of slaughterhouses increases efficiency more than does the availability of industrial feed. Tchale and Sauer (2007) conclude, using a farm-level data set for 2003, that those Malawian farmers who have better market access are more technically efficient.

Larue and Latruffe (2009) report that a county's pig farm density had a positive effect on pig producers' technical efficiency, which suggests that proximity of farms increases knowledge spillovers. Such a finding is also provided by Tveteras and Battese (2006) for Norwegian salmon farms in the period 1985-95, using regional farm density.

Location dummies may also be used in the case of agri-food firms, e.g. by Furtan and Sauer (2008) to explain the level of sales per employer for Danish firms in 2005.

5. Discussion

5.1. The fuzzy concept of competitiveness

Although several papers investigate competitiveness empirically or discuss its merit for social welfare such as living standards improvement, there is no agreement on its definition or on exact methods to measure it, as mentioned in Section 1. The definition may range from the ability to compete, to the capacity of ensuring high firm profitability, or the aptitude to gain market shares. Several schools of thought have proposed their own definitions of competitiveness, such as international and trade economics and the strategic management school. The literature investigating competitiveness, whether at the country, region, sector or enterprise level, proposes many different measures for evaluating it: trade indicators (*e.g.* RER, EMS, RCA), and economic performance indicators (*e.g.* DRC, costs of production, profitability, productivity, efficiency).

Most authors recognise that one indicator is not sufficient to assess the broad issue of competitiveness. Some studies have attempted to create a complex measure of competitiveness using several measures. For example, Wijnands *et al*. (2008) calculate five indicators, then standardise them so that all have the same mean (0) and the same variance (1), and use the (unweighted) mean value of these standardised scores to compute an overall measure of competitiveness. While indicators based on trade theory (in terms of growth of indices) show that Brazil's food sector was by far the most competitive compared to that of the EU15, Australia, Canada and the United States, indicators based on economic performance (in terms of growth of indices) reveal the complete opposite. The overall index of competitiveness smoothes the picture, by bringing all countries closer together and revealing the United States as the country with the highest competitiveness. Another study, by Fischer and Schornberg (2007), evaluates the competitiveness of the food and drink manufacturing sector in 13 EU countries by calculating profitability, productivity and output growth, and aggregating them into a single competitiveness index per country and product following the United Nations' Human Development Index method, that is to say attributing scores depending on the maximum and minimum values among countries.

However, there is no consensus on whether indicators listed in this report are *quantitative measures* of competitiveness, *methods to measure* competitiveness, *components* of competitiveness, or *determinants*/*drivers* of competitiveness. For example, DRC may be considered as a method of calculating competitiveness, the figure obtained being the measure of competitiveness. But DRC may also be seen as a component of competitiveness, the method being the choice of specific prices. Also, van Duren *et al*. (1991) explain that profits measure competitiveness, that the method for measuring them is the calculation of various value added to input ratios, and that one crucial driver is productivity. By contrast, Fischer and Schornberg (2007) claim that both profitability and productivity are determinants of competitiveness, the latter being even expressed as a function of the former. Wijnands *et al*. (2008) also explain that labour productivity is a crucial determinant of competitiveness, while Ball *et al*. (2006) calculate productivity as a measure of competitiveness. If productivity is viewed as a determinant of competitiveness, the picture becomes even more complex as several papers investigate the determinants of productivity, *i.e.* the determinants of the determinants of competitiveness. Based on this review, it is concluded here that competitiveness is the general indicator or concept, while RER, EMS, RCA, DRC, SCB, profitability, costs of production, efficiency, productivity, etc., are all components of competitiveness, themselves being determined by factors which can be at the firm or farm level (*e.g.* size, structure, social characteristics) or at the macroeconomic level (factor endowments, tastes, government intervention, public investments, climatic conditions). This is illustrated in Figure 1.

It is also worth noting that, while in theoretical papers productivity and efficiency are recognised as components of competitiveness, in the empirical literature (at least for agriculture and the agri-food sector), only a few papers measuring productivity or efficiency claim that it is with the purpose of assessing competitiveness (*e.g.* Hallam and Machado, 1996; Brümmer and Loy, 2000; Ball *et al*., 2006; Zhu *et al*., 2008a). In general, productivity and efficiency are calculated *per se* without referring explicitly to competitiveness. However, productivity and efficiency, by contrast to competitiveness, have a precise definition and a consensus on the methods available to measure them.

Although in this paper an attempt has been made to classify the various indicators based on the schools of thought, several other classifications could be undertaken. A first example of categorisation is where international competitiveness is contrasted with domestic competitiveness. In the first case, all components based on trade data, as explained in Section 2, would be included, but some components lying on the strategic management foundations would as well. For example, indicators computed with border prices (*e.g*. DRC), or in an international comparison (*e.g.* production costs or TFP growth across countries) could reflect international competitiveness. By contrast, components measured with data for one country only, for example comparing sectors within a country or firms within a country, would show domestic competitiveness. Cook and Bredahl

(1991) even propose three levels of competition, instead of two: in international markets, in the domestic market for the product, and in the domestic market for resources. A second example of classifying competitiveness components is by comparing them according to the data they are based on, that is to say according to the level of observation. Competitiveness may be assessed for a country as a whole (the macroeconomic level), but may also be investigated at sub-levels: either vertically, that is to say for different industries or commodity groups (mesoeconomic level); or for different firms or farms (microeonomic level); or horizontally, that is to say for various geographical regions. In the macro- and mesoeconomic cases, aggregated data would be needed. By contrast, using microeconomic data allows competitiveness to be evaluated at the level of the decision-making unit, which could be the firm or the farm, or even more refined, the level of the specific activity in the firm/farm. A third classification may be based on the concept of *ex ante* or *ex post* competitiveness, as advocated by some authors (*e.g.* Frohberg and Hartmann, 1997; Siggel, 2006). *Ex post* competitiveness measures the outcome of the competition, while *ex ante* measurement reflects the potential competitiveness. *Ex post* measures are for example components based on trade data (*e.g.* RER, EMS, RCA). By contrast, firm performance indicators (*e.g*. DRC, costs measures, productivity) are *ex ante* measures as they show the ability to compete.

5.2. Limitations of the competitiveness measures

5.2.1. Limitations of specific measures

In the literature arguments for or against the measurement of a specific measure to assess competitiveness are frequently found. For example, according to several authors, trade measures (*e.g.* EMS, RCA, RMA, RTA) do not account for a country's or sector's size, and render their use inappropriate for comparing countries or sectors (Pitts *et al.*, 1995; Drescher and Maurer, 1999; Banterle and Carraresi, 2007; Fischer and Schornberg, 2007). Banterle and Carraresi (2007) stress that, for this reason, investigating trends in trade indices is more appropriate. Regarding the comparative advantage indices, using RXA alone or RMA alone, instead of RTA, excludes the possibility of intra-industry trade. For this reason, calculating at the same time GL indices is more appropriate. However, using import indices may hide some advantages of being importer. For example, Ruan and Gopinath (2008) show that increased imports improve agri-food firms' productivity growth when using data for 34 countries during 1993-2000, and Kasahara and Rodrigue (2008) although not focusing specifically on the agri-food sector, find that importing foreign intermediates increases Chilean manufacturing industries' productivity in 1979-96. The RC, which is a logarithmic measure of RTA, has the advantage of being symmetric through the origin, but the shortcoming of being nonexistent when either exports or imports are zero, and sensitive to small values (Banterle and Carraresi, 2007). RCA is sometimes considered more as an indicator for international specialisation of countries rather than a component of competitiveness (Fischer and Schornberg, 2007). It is also referred to as the "specialisation index".

The DRC presents the advantage of evaluating competitiveness without using data from other countries than the one considered (Siggel, 2006). However, Masters and Winter-Nelson (1995) argue that DRC ratios are budget-based indicators, and for this reason they ignore substitution and cross-price effects, that could be accounted for by using elasticities for example. The same authors point out the weakness of DRC in assessing the competitiveness of activities using mostly non-tradable inputs, and for this reason they created the SCB ratio. They also bring forward another advantage of SCB ratios: contrary to DRC, SCB ratios do not need to separate traded and non-traded inputs in the data (they cite the case of transportation), an empirical step which is usually difficult and may lead to errors in measures and thus to incorrect conclusions. The authors provide an example to support their theoretical demonstration. They calculate DRC and SCB for 31 crops in Kenya in 1990, and show that the ranking between crops is very different depending whether the DRC or SCB is used. The results also highlight the fact that DRC indices are more favourable for tradable-input-intensive crops such as wheat and less favourable for more-labour intensive productions such as maize, while the opposite is found for the SCB. Moreover, the correlation between ranking discrepancy between DRC and SCB, and the share of tradables in total cost was high (about 70%).

Profitability measures are sometimes regarded as imprecise for international comparison, in particular because: revenues do not account for the output consumed on-farm or generated by the grey economy which is crucial in transition or developing countries (Bojnec, 2002); input costs such as labour costs differ a lot between countries (Fischer and Schornberg, 2007); and input costs rarely account for family shadow prices which also differ largely between countries. Moreover, some firms may have to experience negative profit in the short-run in order to reach high positive profits in the longer-run (Harrison and Kennedy, 1997; Toming, 2007).

Profitability is however sometimes viewed as a better measure than costs of production. As stated by Brinkman (1987), countries do not produce and trade commodities for which they have the lowest costs of production, but which are profitable. According to the author, the absolute concept of costs of production is too narrow to assess competitiveness, as it accounts only for the supply side, while profitability measures include the demand side as well (through revenues). Firms that experience low costs of production, and which may be viewed as highly competitive, may on the other hand have small market shares due to low demand. Capalbo *et al*. (1990) suggest that productivity measures are preferred indicators of competitiveness over costs of production measures for agriculture. According to the authors, the former better reflect the economic tradeoffs and agricultural diversity, while the latter are less reflective of real cost differences among sectors. Moreover, Ahearn *et al*. (1990) argue that care must be taken when calculating costs of production as a measure of competitiveness in particular when commodities (or sectors) are considered. Indeed, it is often difficult to allocate shared inputs (*e.g.* capital) to the various outputs that a firm or a farm produces. According to the authors, managers do not keep records on a commodity-by-commodity basis, and such allocation is thus often left to value judgement. Several methods, however, have been proposed for allocating the joint inputs per production based on analytical accounting systems or econometric models (Cesaro *et al*., 2008; Brunke *et al*., 2009).

5.2.2. General limitations of the measurement of competitiveness

Critiques over one or other measures of competitiveness may be appropriate if one considers that they are competing indicators of competitiveness. However, the understanding from this review is that they are all components of competitiveness, as one alone is not sufficient to prove a certain assessment, and they should all therefore be calculated together. The limitations described above should not guide researchers in their choice of components to measure, but in their choice of data and in their interpretations and conclusions of quantitative results. Some general limitations to the measurement of competitiveness can nevertheless be discussed here.

Static nature

The methods developed by the literature to measure the various components of competitiveness are of a static nature. However, the conditions in which firms and farms operate are constantly changing, and therefore it can be expected that their competitiveness does too. Moreover, competitiveness is generally defined as the ability to sustain a dominant position in the long term, or in a sustainable way. Measurement of the evolution of components may thus be preferred. For example, Wijnands *et al.* (2008) do not calculate the RCA, the export share or the labour productivity as such, but use the growth of these factors to assess a sector's competitiveness. Also, Computable General Equilibrium (CGE) models and partial equilibrium models, sometimes in conjunction with a policy analysis matrix (PAM), can be used to simulate the evolution of countries' or sectors' competitiveness. As explained by Kavcic *et al*. (2003), a PAM enables tradable (fertilisers, seeds, pesticides) and non-tradable (land, labour, local capital) inputs to be distinguished, and values (revenues, costs, profits) using both private (market) prices and social (shadow/opportunity costs) prices to be evaluated. For example, using a CGE and a partial equilibrium model (the ESIM model), Banse *et al.* (1999) project the development of international competitiveness of Hungary's agricultural and agri-food sector between 1995 and 2005, particularly in view of the adoption of the Common Agricultural Policy (CAP) by this country. The authors forecast that the international competitiveness, proxied by DRC, of both agriculture and food processing under CAP conditions would be reduced. Using a partial equilibrium model (the APAS model) and a PAM, Kvacic *et al*. (2003) evaluate the change in DRC for several agricultural commodities in Slovenia in 2004 after EU accession. DRC figures indicate that grains and cattle production would become more competitive than other sectors in Slovenia, due to the high direct payments resulting in high revenues in proportion to domestic opportunity costs. With the help of a CGE model (the model GTAP), Wijnands *et al.* (2008) investigate how the EU15 food industry's competitiveness might change between 2004 and 2010, in terms of trade-based indices and economic performance. Whatever the scenario (continued CAP reform; enhanced productivity in food industries; full trade liberalisation in all sectors), the EU15 competitiveness remains lower than that of Australia, Brazil, Canada and the United States.

Problematic use of exchange rate

The use of the exchange rate in international comparisons of competitiveness may be problematic. Sharples (1990) warns that, when making international comparisons, the exchange rate used may affect the conclusions. The author explains that volatile exchange rates may show very high or low competitiveness relative to other countries, and therefore advises that measures of competitiveness that are averaged over a certain length of time should be compared. Bureau *et al*. (1992) explain that comparing costs of production among countries is made difficult by the variation in exchange rate, across time periods and countries. For this reason, the authors suggest to use PPP. Liefert (2002) also underlines the exchange rate problem in his investigation of Russia's agriculture competitiveness using the SCB. As official Russian foreign trade data are given in US dollars for the time period studied (1996-97), border prices need to be converted to roubles. However, due to an unstable exchange rate, the author prefers to keep border prices in US dollars. In this case, the author explains that Russia's competitiveness cannot be assessed *vis-à-vis* the world market, but instead commodities can only be compared with each other. Harrison and Kennedy (1997) explain that exchange rates may influence competitiveness measurement in the way that devaluation of the domestic currency results in the decrease of the price of domestically-produced goods sold on the world market, and thus in the increase of domestic firms' profits and market shares. This is also stressed by Krugman (1994) who underlines that a nation's competitiveness may be falsely created by devaluing the domestic currency and so increasing exports, whereas the nation's standard of living may actually decline if the purchasing power is not favourable.

Distortion by government intervention

Several authors highlight that the competitiveness measures should be interpreted with care, as they may be distorted by government intervention. For example Gorton and Davidova (2001) stress that if CEECs' farmers had received in the pre-accession period as high direct payments as farmers in the EU15, their competitiveness *vis-à-vis* the EU might have been higher than calculated. Toming (2007) underlines the fact that trade indices, in particular exports, depend largely on the regulations of the foreign countries which constrain the domestic firms' ability to export, *e.g.* tariffs, or the EU strict hygiene and veterinary standards. Gorton *et al*. (2000) quote the example of Bulgarian and Czech crop production which does not present high competitiveness *vis-à-vis* the EU15 during transition when it is measured with RCA: the authors explain that this is due to trade restrictions, since the EU15 had given the countries only limited preferential access to its agricultural markets. Frohberg and Hartmann (1997) explain that RMA may also be distorted by protection measures on domestic markets. For example, in the case of a prohibitively high import tariff, the measure would indicate a high level of competitiveness, which may not in reality be true. Sharples (1990) argues that export subsidies would raise production costs for domestic producers: export subsidies raise prices received by producers, and in return increase input prices, such as land values which would have greater returns. By contrast Harrison and Kennedy (1997) claim that export subsidies increase firms' competitiveness by enabling them to gain market shares in world markets. Harrison and Kennedy (1997) also explain that government policies subsidising raw agricultural commodities increase domestic firms' competitiveness relative to foreign firms, as they decrease input costs.

Capalbo *et al*. (1990) note that prices used in the index number approach to calculating TFP are distorted by government policies. They advise that observed prices should be adjusted by implicit and explicit subsidies which should be calculated per commodity. Another solution proposed by the authors is to quantify the inefficiency that is implied by government policy, *i.e.* to estimate technical efficiency alongside the calculation of TFP with the index number approach, since the latter relies on the assumption of full technical efficiency for all observations in the sample. Some authors even assess competitiveness by calculating the extent of government protection, for example using the nominal protection coefficient (NPC). Calculated as the ratio of the domestic price to the reference price of the commodity considered, the NPC compares private revenue to social revenue, and thus shows whether government intervention prevents equality between domestic price and border price (Kavcic *et al*., 2003). An NPC greater than 1 indicates that domestic production is subsidised, while a lower NPC indicates lower protection and thus higher competitiveness. Rakotoarisoa and Gulati (2006) use the NPC to evaluate the competitiveness of the dairy industry in India during 1975-2001, and conclude that India increased its competitiveness over these years, as the NPC decreased consistently.

Non consideration of non-price competitiveness

All measures focus on price (or cost) competitiveness, whereas there are also non-price aspects of competitiveness, as mentioned in Section 1. Most importantly, quality is a key component of competitiveness. Not considering the quality of products when comparing competitiveness between countries is in particular a crucial shortcoming when comparing countries where standards are different, *e.g.* the EU15 *vs*. the CEECs or new member states. For example, Gorton and Davidova (2001) show that CEECs' agriculture was internationally competitive with the EU during 1992-98, but underline that this may not be the case if quality was taken into consideration. Only Thorne (2005) and Toming (2007) attempt to capture some quality aspects in their competitiveness analysis. Bojnec (2003) mentions the export-to-import price ratio that may capture quality differentials between countries, but it is rarely used. According to Harrison and Kennedy (1997), the strategic management school stresses that a firm can improve its competitiveness by developing products of superior quality, as this would enable the firms to gain customers and thus market shares. The authors give the example of the coffee industry, where a quality-enhancing technology such as a packaging system that allows coffee to hold its aroma until reaching the consumer, implies that consumers are willing to pay a higher price. As the authors stress, such technology, albeit enabling the firms to gain market shares, increases their production costs, and therefore competitiveness should not be reduced to economic performance indicators which may indicate a loss of competitiveness. The strategic management framework therefore indicates that there are two types of *ex ante* (potential) competitiveness for a firm: cost leadership and product differentiation. Without referring to competitiveness, Morrison Paul (2000) notes that future studies dealing with productivity in the agri-food sector should take into account the value of product differentiation, and that output measures should reflect quality changes. Ahearn *et al*. (1990), Brinkman (1987) and Toming (2007) also underline that quality is a crucial part of competitiveness. Toming argues in addition that design, after-sales services and degree of novelty are all components of competitiveness, which are however not measured. Kennedy *et al*. (1997) confirm that what matters for agri-food firms' competitiveness is the ability to generate customer value, that is to say perceived benefits to customers divided by price paid by consumers. In this sense, it is value-added competitiveness that is important, rather than commodity competitiveness.

5.3. Different levels for assessing competitiveness

The studies mentioned above are carried out either at the microeconomic level, that is to say at the single farm level (for the agricultural sector), or at the single firm level (for the agri-food sector), at the mesoeconomic level, that is to say at a commodity or sector level, or at the macroeconomic level, that is to say aggregated data at the region or country level.

The choice of data may depend on the competitiveness measures used. Some measures, such as those relying on trade, can be calculated only with aggregated data (meso- or macroeconomic level). For other measures, every type of data may be used depending on the objective of the analysis. Productivity, for instance, may be measured at the firm level, at the commodity level, at the sector level, or at the national level. In general, using microeconomic data allows accounting for variations across firms that would not be captured with the use of aggregated data. For example, in the case of the calculation of technological change, using aggregated data enables calculating the progress for the whole sector, while using firm-level data allows investigating the different rates at which firms adopt new technological innovations. Also, variation across firms may be smoothed when aggregated data are used in the case of investigating the determinants of competitiveness (this may for example explain why a non-significant impact of agricultural support on productivity is more often found in analyses based on aggregated data than on single farm data). Moreover, using firm-level data allows considering factors that may not be visible at the aggregated level, *e.g.* location. By contrast, using aggregated data enables to account for macroeconomic determinants such as public expenditure in infrastructures, whose effect cannot be investigated at the firm-level.

Regarding the use of aggregated data, Capalbo *et al*. (1990) explain that competitiveness should be measured at the commodity level rather than at the sector level, in order to get more homogenous conditions (in particular in terms of policies). However, some competitiveness components are difficult to measure at this level. For example, cost measures are problematic as it is not easy to obtain data (in particular input costs) for a specific activity in a farm or firm. Goldin (1990) stresses that the comparison of countries, in particular when developing countries are considered, can be delicate as comparable data are not always available. Some assumptions must then be made.

Finally, some authors claim that measuring a nation's or a sector's competitiveness is meaningless and what matters is individual (firms or farms) competitiveness (*e.g.* Brinkman, 1987; Krugman, 1994; Harrison and Kennedy, 1997). The strongest voice by far against the concept of competitiveness applied to a nation is Krugman's (1994), who argues that using the concept in reference to a country's level is a dangerous obsession. He explains that nations are not similar to firms, in the sense that the latter may go out of business if they are not competitive while nations remain, and that most of the production of a country is sold inside it while a firm's production is always sold outside the firm. According to him, the competitiveness concept applied to a nation is only a political device which politicians hide behind when facing deteriorating conditions for their nation's economy or when planning to apply yet another tax policy.

6. Conclusion

This review of the concept of competitiveness in the agricultural and agri-food sectors, which does not claim to be exhaustive, has highlighted several points that should be taken into account when carrying out research on competitiveness.

First, competitiveness should be measured with respect to a benchmark as it is a relative concept. Firms must be compared with each other, or nations with each other. Producing absolute figures for a country or an industry is meaningless. Also, Harrison and Kennedy (1997) explain that if, for example, two firms incur a decrease in production costs, neither of them increases its competitiveness; an increase in competitiveness happens when a firm lowers its costs relative to those incurred by rival firms. Krugman (1994) stresses that it is not because the competitiveness of a nation increases that the competitiveness of another nation will decrease: for example, country B may benefit from higher quality imports from country A, in which case both countries are winners.

Second, competitiveness has a broad and changing definition depending on the school of thought and on the level of investigation. There is, however, a widely held view that it is a complex concept, that incorporates a multitude of aspects. Assessment of competitiveness should therefore be undertaken based on several components. However, it is not rare to find studies that calculate only one measure (*e.g.* export indices only, costs of production alone, productivity growth alone) despite evidence that competitiveness rankings may differ depending on the component measured (*e.g.* Masters and Winter-Nelson, 1995; Wijnands *et al*., 2008). It would be better to measure several components and aggregate them into a single measure of competitiveness or cluster observations in groups on the basis of all components (as in, for example, Fischer and Schornberg, 2007; Carrarese and Banterle, 2008; Wijnands *et al*., 2008), in order to get a more complete overview of competitiveness. However, in this case a delicate issue is how to weight each component of competitiveness for the aggregation.

Third, in the specific case of the agricultural sector, particular attention should be taken of the issue of unpaid inputs, such as family labour. Some studies highlight that competitiveness measurements may vary if the value of own factors are included or excluded, in particular unpaid labour (*e.g.* Goldin, 1990; Bureau and Butault, 1992; Bureau *et al*., 1992; Davidova *et al*., 2003; Thorne, 2005; Cesaro *et al*., 2008).

Finally, the issue of measurement distortion due to government intervention should be considered carefully. Several authors stress that competitiveness components are measured under the assumption of an ideal word of no government intervention. For example, the concept of comparative advantage is based on the assumption of free trade. According to some authors, this is what distinguishes it from competitive advantage; that is to say, from competitiveness. Competitive advantage is measured with market (*i.e.* existing) prices, while comparative advantage should be measured with equilibrium (*i.e*. unobserved) prices (*e.g.* Siggel, 2006). According to Brinkman (1987), government intervention may change competitiveness superficially without increasing real competitiveness. The author explains that in cases where competitiveness is “bought” by public subsidies, it may be a false competitiveness.

This review has also identified some gaps in existing empirical research. Several suggestions for further research can be put forward.

First, the competitiveness of the agricultural sector (in terms of farm or commodity competitiveness) has so far been investigated more frequently than that of the agri-food sector. This is true for quantitative measures of competitiveness, but even more so for the analysis of the determinants of competitiveness. The sources of competitiveness for the agri-food sector have not attracted a great deal of research. One reason may be the difficulty to compare countries when the sector considered includes firms with a multinational character. Moreover, within the agricultural sector, there is a plethora of studies on the specific competitiveness component of productivity and, even more, of efficiency, even though most do not refer explicitly to competitiveness. Studies analysing other components of farm competitiveness (*e.g.* cost measures) are rare. Finally, there is a research gap regarding the assessment of competitiveness of food-chains, that is to say taking into account both the agricultural and the agri-food sectors.

Second, the existing literature has focused mostly on price or cost competitiveness. The non-price component of firms’ or farms’ competitiveness is usually forgotten, although several authors stress it is an important aspect in gaining market shares and sustaining profits. Product differentiation, product and service quality and variety, design, novelty, reputation and reliability, are all competitiveness aspects that need to get more interest from researchers. In the case of product quality in particular, specific care should be given to international comparison: product quality may vary between countries due to differences in consumers’ preferences and requirements.

Finally, the issue of government intervention could be given more attention in the context of trade negotiations and agricultural policy reforms. The main question is whether government funds used to protect a country's agriculture or agri-food sector and to support its competitiveness could generate greater social welfare if they were used differently, either in other policies or in other sectors of the economy. Some studies highlight the fact that public expenditure in R&D, extension and infrastructures may have a larger impact on farm productivity than commodity programs or direct subsidies (*e.g.* Makki *et al*., 1999). Krugman (1994) also stresses that the obsession with competitiveness may result in a misallocation of resources due to wrong government interventions. Instead of comparing competitiveness measures as such, research should focus on the past or potential effect of policies in order to evaluate whether an alternative use of public resources could increase a nation's welfare. Infrastructure and public expenditures may for example be more crucial in developing countries in particular to enhance competitiveness. In addition, the influence of other types of government intervention such as labour or fiscal policies has not been assessed so far, and may be an area for further research.

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