Measuring productivity change using alternative input–output concepts: A farm level application using FADN data

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Abstract

Multifactor productivity growth measures can be constructed using different input–output concepts. We estimate three distinct productivity growth measures respectively based on gross output, value added, and cash flow and discuss their economic interpretation. By making use of an index theory based decomposition model, we deviate from making neo-classical assumptions and acknowledge the role of profits. Applying the productivity growth index framework to farm level Flemish FADN data (1990–2003), we show that the estimated percentage growth of productivity is sensitive to the input–output concept under consideration. The empirical practicability of these complementary productivity growth measures depends on the purpose of measurement.

Key words: Index, input–output, MFP, productivity analysis, profits.

JEL classifications: C43, D24, Q12.

1 Introduction

Productivity growth, generally defined as output quantity change relative to input quantity change, can be estimated in a number of ways. Using different methods can yield different results (Kwon & Lee 2004). In this paper we focus on yet another influential factor, namely the input–output concept that is being used. Aside from the distinction between partial and multifactor productivity (MFP), different concepts can be considered regarding output and input. Following the framework developed by Balk (2010), we consider MFP growth using three output variants, namely gross output, value added and cash flow. The inputs capital, labor, land and intermediate inputs are related to gross output, the three primary factors of production (capital, labor and land) to value added and capital to cash flow. Every input–output concept has its corresponding MFP growth measure with a distinct economic interpretation.

The first objective of this paper is comparing and discussing these alternative measures of MFP growth for the agricultural sector. Although alternative MFP models have been adopted in literature, a discussion and comparison of these alternatives, their use, and interpretation has not been of central focus. The second objective is providing a first micro level data application of the Balk (2010) framework developed in recent years. Applying the framework to the agricultural sector using farm level panel data from the Flemish Farm Accounting Data Network (FADN), a third objective is considering methodological aspects of constructing the various input–output variables based on this rich dataset. Studies using farm level data applied to the concept of MFP are scarce, agricultural productivity growth literature has mostly focused on regional or national MFP measures (see Bureau *et al.* 1995; Ball *et al.* 1997; Ball *et al.* 1999; Coelli & Rao 2005; Ball *et al.* 2010; Esposti 2011) while on the other hand, micro level MFP literature rather tempt to focus on the manufacturing sector (Bartelsman & Doms 2000). However, since "[…] firms are heterogeneous, and […] the representative firm is a myth" (Wagner 2011, p. 390), aggregate estimates mask much variability and differences that occur at the micro level. By using farm level data, we provide empirical evidence of the dispersion of agricultural MFP. To the best of our knowledge, only the study by Coelli *et al.* (2006) provides farm level estimates of MFP growth for Belgium using the FADN dataset; other studies have only reported aggregate estimates (Bureau *et al.* 1995; Ball *et al.* 2001; Coelli & Rao 2005; Ball *et al.* 2010).

2 Methodology

2.1 Productivity growth measurement

Productivity, although conceptually defined in a straightforward fashion, can be empirically estimated in different ways. A rough distinction can be made between the accounting approach—as exemplified in this paper—and the economic theoretical approach which depends on the assumption that the production set can be presented by a (parametrical or non-parametrical) functional form. In this paper we will make use of index numbers theory where MFP growth is simply defined as an output quantity index divided by an input quantity index. Accordingly, in this approach MFP growth is calculated residually, *i.e.*, it constitutes the observed rate of change of output that cannot be explained by the combined inputs' rate of change. This method does not involve the so called neo-classical assumptions such as constant returns to scale, optimizing behavior, perfect foresight and competitive markets (both input and output) that imply that in equilibrium, profit is zero, *i.e.*, costs precisely equal revenues (e.g. Dumagan & Ball 2009). By steering clear of neo-classical assumptions, we thus acknowledge profit in the framework considered.

Coelli et al. (2005) present a general discussion regarding index number construction for the purpose of productivity measurement. Balk (1998) focuses on micro economic theory with an application to micro data, while Balk (2010) and Vancauteren *et al.* (2012) focus on MFP constructs recognizing the role of profit. In short, the index number approach to productivity measurement can be summarized as follows. First, one needs to define/choose what is considered output and input and consequently how each component should be measured (the central theme of this paper), which is often dictated by data availability or quality. Next, by using detailed price and quantity data, the appropriate output and input indices can be constructed. Indices allow the weighed aggregation of the different outputs and inputs into one measure (using factor income shares as weights). A choice needs to be made regarding which index formula to employ. Finally, by dividing the output quantity index and the input quantity index, following its definition, the MFP growth index is obtained. In the next sections we will gradually build up a model based on this approach and apply it to agriculture as a specific case.

2.2 Productivity and profitability change decomposition model

This section is largely based on the model developed by Balk (2010); a related model was developed by Lawrence et al. (2006), see also O'Donnell (2010) for an extended decomposition of productivity into its constituents. We start by introducing some notation for the production unit under consideration, the farm. All outputs and inputs can be represented by a value, price and quantity vector (value always equals price times quantity). The input side comprises *N* items with a price vector w^t and quantity vector x^t and t represents one accounting year. At the output side we have *M* items and price vector p^t and quantity vector y^t. All the prices and quantities are assumed to be positive and obtained using the *ex post* accounting view. The unit's revenue R^t, *i.e.*, the value of its gross output, is defined as:

$$R^t \equiv p^t . y^t \equiv \sum_{m=1}^{M} p_m^t y_m^t, \tag{1}$$

and the unit's total production cost C^t as:

$$C^t \equiv w^t . x^t \equiv \sum_{n=1}^{N} w_n^t x_n^t. \tag{2}$$

Profitability during period *t,* denoted as Π^t, is defined as revenue divided by total cost, *i.e.*, $\Pi^t \equiv R^t/C^t$. Note that profitability differs from profit, the latter being defined as revenue *minus* costs. Profitability measures the monetary return of aggregate output to aggregate input. It is an important financial measure to monitor a farm's performance trough time. Profitability change between two adjacent periods *t–1* and *t* is given by:

$$\frac{\Pi^t}{\Pi^{t-1}} = \frac{R^t/C^t}{R^{t-1}/C^{t-1}} = \frac{R^t/R^{t-1}}{C^t/C^{t-1}}. \tag{3}$$

As a performance measure, profitability change is dependent both on price changes and quantity changes. To measure pure productive performance, profitability change should be stripped of price changes. As apparent from the previous equation, decomposing profitability change in a price and quantity component comes down to decomposing the revenue changes R^t/R^{t-1} and cost changes C^t/C^{t-1}. This decomposition can be realized by using price and quantity indices that satisfy the product test. This test simply states that the product of a price index and a quantity index equals the value ratio, or mathematically that:

$$\frac{p^t.y^t}{p^{t-1}.y^{t-1}} = P(p^t, y^t, p^{t-1}, y^{t-1})Q(p^t, y^t, p^{t-1}, y^{t-1}) \ , \tag{4}$$

where $P(t,t\text{–}1) \equiv P(p^t, y^t, p^{t-1}, y^{t-1})$ and $Q(t,t\text{–}1) \equiv Q(p^t, y^t, p^{t-1}, y^{t-1})$ represent price and quantity indices for period *t* relative to period *t–1* respectively. Following van den Bergen et al. (2008) Laspeyres quantity indices (and hence Paasche price indices) are used throughout the paper because of computational easiness and zero value robustness.

With the product test defined and the index formula decided upon, we obtain:

$$\frac{R^t}{R^{t-1}} = P_R(t, t-1)Q_R(t, t-1) \text{ and} \tag{5}$$

$$\frac{C^t}{C^{t-1}} = P_C(t, t-1)Q_C(t, t-1). \tag{6}$$

Combining the equations (3), (5) and (6), we thus decompose profitability change as follows

$$\frac{\Pi^{t}}{\Pi^{t-1}} = \frac{P_R(t,t-1)}{P_C(t,t-1)} \frac{Q_R(t,t-1)}{Q_C(t,t-1)} \,. \tag{7}$$

The MFP growth index for period *t* relative to period *t–1* is now *defined* as the right hand factor of equation (7), *i.e.*, the output quantity index divided by the input quantity index:

$$MFP(t, t-1) = \frac{Q_R(t,t-1)}{Q_C(t,t-1)}. \tag{8}$$

The decomposition in equation (7) thus states that profitability changes can be decomposed in its price component, called price recovery, times its quantity component, MFP growth. Price recovery represents the factor by which output prices have changed on average relative to the factor by which input prices have changed. Under the neo-classical assumption of zero profit (*i.e.*, profitability change = 1), following equation (7), MFP growth will be equal to the inverse of the price recovery index. The model developed above allows us to analyze the profitability change, productivity growth and price recovery over time of a farm. In the next section we will further expand this basic model to obtain three distinct measures of productivity growth.

2.3 Alternative productivity growth models

To characterize the inputs and outputs of agricultural production, we will slightly modify the traditional KLEMS notation to KLL'EMS, where L' represents the input category (owned) land. Given its important role in agricultural production, we thus consider land as a separate factor of production and not as part of capital, as is frequently done in literature (see also section 3.2). The other two traditional production factors are represented by K (owned capital) and L (labor input) respectively. The letters E, M and S represent energy, material and services respectively and together symbolize the intermediate inputs used.

Using our adapted KLL'EMS notation, the basic input–output framework (developed in the previous section) can be denoted as KLL'EMS–GO and sees gross output (GO) as its output concept and KLL'EMS as its inputs. The corresponding accounting identity reads: *GO* = *KLL'EMS* + *profit*. As previously noted, by not relying on the neo-classical assumption that revenue should equal cost, this model explicitly allows for negative, positive or zero profit. Using the abovementioned notation, the GO–based productivity measure in equation (8) reads:

$$MFP_{GO}(t,t-1) = \frac{Q_{GO}(t,t-1)}{Q_{KLL'EMS}(t,t-1)} \quad (9)$$

In this definition, the GO quantity index is calculated as $Q_{GO} = GO^{t*}/GO^{t-1}$, where GO^{t*} denotes GO of period *t* valued at period *t–1* prices. The KLL'EMS quantity index is calculated analogously as $Q_{KLL'EMS} = \frac{KLL'EMS^{t*}}{KLL'EMS^{t-1}}$. By changing this basic input–output concept, different models can be constructed, each with its own productivity measure that has an alternative economic interpretation (see the next section).

The first alternative model sees value added (VA) as its output concept, which is defined as gross output minus the cost of intermediate inputs, *i.e.*, *VA* ≡ *GO* – *EMS*. By subtracting the intermediate input costs, the farm is considered as a unit that converts the three primary inputs (capital, labor and land) into value added. This model will be denoted as the KLL'–VA model. The corresponding accounting identity is *VA* = *KLL'* + *profit*. The decomposition of the ratio of VA to the primary input costs is analogously to the GO model. The resulting VA–based productivity measure is defined as:

$$MFP_{VA}(t,t-1) = \frac{Q_{VA}(t,t-1)}{Q_{KLL'}(t,t-1)}. \quad (10)$$

The second alternative model employs cash flow (CF) as its output concept, which is *ex post* defined as gross output minus all non-capital costs, *i.e.*, *CF* ≡ *GO* – *L* – *L'* – *EMS*. This model thus sees cash flow as a return for capital usage. The accounting identity is *CF* = *K* + *profit*. The CF–based productivity measure is defined as:

$$MFP_{CF}(t, t-1) = \frac{Q_{CF}(t,t-1)}{Q_K(t,t-1)}. \quad (11)$$

A summary table of the different MFP concepts introduced in this section is presented in Table 1. The practical components for calculation, applied to agriculture, will be elaborated in section 3.2. The list of possible MFP models does not end with the three alternative models discussed in this section, however, by rearranging inputs and outputs even more models can be constructed. The presented models, however, were chosen given their wide application in literature (e.g. OECD 2001) and valuable interpretation (as elaborated in the next section).

< INSERT TABLE 1 HERE >

2.4 Interpretation of the different productivity concepts

In general, MFP growth is defined as the change in outputs that cannot be accounted for by the change in combined inputs, e.g. an MFP index of 1.05 means that by increasing combined input quantity with 1%, output quantity will grow with 5% (*i.e.*, more than 1%) due to productivity growth. The interpretation of MFP is usually addressed as a compositional issue and assumptions enter the picture here (Balk 2010). Under the neo-classical assumptions of perfect competition and constant returns to scale, MFP change is just equal to technological change. However, relaxing these assumptions, MFP change includes factors such as technological change (due to for example input and output innovation and management skills), scale effects, input and/or output mix change (due to for example higher production capacities and deviations from perfect competition), other external factors like the weather and measurement errors. An index based framework that decomposes MFP growth further into these constituents was developed by O'Donnell and applied to Australian (2010) and U.S. agriculture (2012).

Note that all the MFP models considered in this paper are equally complete representations of the production process, *i.e.*, they use the same but differently arranged data. This rearrangement implies that different levels of MFP growth are obtained for each measure, with alternative interpretations and empirical uses. Next we will discuss the interpretation and potential usage of each measure.

The GO–based MFP model presents the most intuitive concept that is closest to production by explicitly accounting for all combined inputs used (including EMS) to produce gross output. Overall, it is the most favored MFP growth measure in literature and the most useful measure to analyze the different sources of MFP growth. By focusing on production, it is the appropriate measure to quantify the effect of changes in the production process (e.g. adopting different technologies or using a new production scheme) and to review growth patterns and assessing the future productive capacity of a farm.

The VA–based MFP measure focuses on the productivity of the three primary factors of production (labor, land and capital) to produce value added. Because intermediate inputs are not considered as inputs, technological change and improvements in the efficient usage of these inputs are not explicitly reflected in this measure and thus this model presents a conceptual alternative measure of technological change or efficiency. Intermediate inputs do have an indirect influence because by changing the required intermediate input usage, real value added in the numerator changes. This effect is indirect, compared to the GO–based MFP measure where the denominator changes directly in response to EMS changes. Where the GO–based measure focuses on production, the VA–based MFP growth complements it by relating to an income concept. At the farm level, this measure is informative because by netting out intermediate inputs (which are transformed or used up in the production process) focus is put on the capacity of the three primary factors of production to produce income, *i.e.*, value added. The VA approach to MFP is also preferred for analyzing the relationship between individual and aggregate measures of productivity change because of the easiness of aggregation (see OECD 2001). Criticism in literature regarding VA–based measures includes conceptual issues (value added is an abstract concept for the real world), biased estimates of industry growth rates and misleading estimates of the contributions to MFP growth (Cobbold 2003). These issues are mere misunderstandings, however, because as argued in this paper there simply is not a single measure of MFP -, technological - or efficiency change, but multiple complementary measures.

The CF–based MFP measure can be interpreted as a capital productivity measure since it measures the change in output (CF) quantity relative to the capital input quantity change. A capital productivity measure can be particularly interesting provided that some agricultural sectors are becoming increasingly capital intensive (e.g. specialized dairy farms) and labor input is frequently substituted for capital. The productivity of capital is furthermore closer related to financial risk, which makes this the preferred productivity indicator to use in financial analysis. Using capital inefficiently and having low capital productivity entails risk. Not having a sufficient return from the capital employed means on the one hand that this capital could have been better invested in other assets with a comparable risk factor. On the other hand this could mean that not sufficient cash flow is generated to fulfill short term liabilities.

The elaborated differences between the three MFP measures illustrate that it is interesting to report MFP growth under each of the presented input–output concepts. The alternative measures allow testing the sensitivity of the MFP growth levels and provide insights into different aspects of the productive process. For a deeper discussion of the sources and constraints of MFP growth specifically for agriculture we refer to Ruttan (2002).

3 Farm level MFP growth using index theory: Empirical application

3.1 FADN dataset

The dataset used in this study is the 1989–2003 Flemish Farm Accounting Data Network (FADN) data, collected by the former Centre for Agricultural Economics (CAE, now part of the Institute for Agricultural and Fisheries Research (ILVO)). This period was chosen because a new system of data collection and reporting was set up in 2004 that presented fundamental differences compared the old system, making it not possible to merge datasets. Hence we opted to use the older FADN series given the longer series of data available and higher level of detail. The FADN data collection is stratified to ensure representativeness regarding profitability of all agricultural regions and farm sizes within Flanders. Most farms take part in the survey for the entire period; when a farm was unable or unwilling to participate, it was replaced with a similar farm.

The original dataset involves 9,403 observations, over a 15 year period. However, because in a productivity framework outputs are assumed non negative, all observations of farms with a negative value added or cash flow in a particular year were excluded for analysis (38% of the observations). Even though these entries are economically plausible—a negative return during certain periods is not uncommon in agriculture—they do not fit into a productivity framework and had to be removed. Given the yearly comparison nature of the MFP index methodology, MFP growth could only be calculated for observations belonging to an at least two year consecutive sequence; in total we calculated MFP growth for 3,327 observations.

Because of the amount of data the analysis of our study produces, we choose to present annual and sectoral averages in the results section. The different farming types are defined using the 2003/369(EC) EU typology. Farms specializing in field crops, grazing livestock and granivores represent 11%, 39% and 16% of the data respectively; mixed farms with livestock combinations and farms with crops and livestock activities represent 19% and 12% respectively. Overall averages further include 3% unclassified farms.

The construction of the quantity index of capital services requires price information of two periods prior to the period under consideration (see section 3.2). Because price information was only available starting from 1989, capital quantity indices and MFP measures could only be calculated starting from 1991. As a result, we will only report indices from 1991 onwards.

The aforementioned attrition of negative cash flow entries results in a left censored cash flow distribution and consequently a left censored quantity index of cash flow and CF–based MFP growth measure. Hence, the mean might be biased upwards as a measure of central tendency for these variables. Therefore, alongside the mean and standard deviation, the median will also be reported in the results section and used instead as a more robust measure of central tendency. To further account for extreme values in the data, the 1%–trimmed mean is used to characterize indices in this study. Practically this means that the 1% smallest and 1% greatest values are omitted in calculating the mean. This rule is common in investment studies to account for highly elevated growth rates (e.g. Benjamin & Phimister 2002).

Summary statistics can be found in Table 2. The empirical construction of all input and output variables will be discussed in the next section.

< INSERT TABLE 2 HERE >

3.2 Empirical choices of input–output measurement

The *capital* goods considered in this study are buildings capital (buildings in property, improvements to buildings), quota capital (milk and sugar beet quota), machinery related capital (tractors, machines, small materials) and land related capital (improvements made to soil, standing crops). Capital input will be represented by capital services—the flow of productive services from the cumulative stock of past investments (OECD 2009). The quantity component of capital services is the opening stock of capital goods (net capital stock) and investments in new capital goods, provided directly by the FADN data. The price component of capital services—the unit user cost of capital—is constructed using a rate of depreciation, an interest rate and a rate of capital good price change. The detailed derivation of the formula of the user cost of capital and the quantity index of capital services using FADN data is beyond scope of this paper, but can be obtain from the authors upon request. This section only discusses the empirical sources of the required components. The depreciation rates were calculated farm, year and asset specific as the ratio of yearly depreciation to the opening stock of that specific asset. We use a year and farm specific interest rate calculated as the ratio of the yearly interest on loans paid to the average inventory of loans. This interest rate more closely reflects the financial situation at farm level, as opposed to using a general exogenous interest rate which is the same for every farm. For farms without loans in a specific year, the mean interest rate of that year was used. Furthermore, as an outlier rule, the minimum and maximum interest rates were imposed by 2 standard deviations from the mean. Price changes were modeled using the CAE Agricultural investment price index. All producer price indices used in this study are for the aggregate Belgian agricultural level and were constructed by the CAE.

Labor quantity is measured by the number of hours worked and the labor price corresponds to hourly wages paid (calculated implicitly by dividing total wages paid by the number of hours worked). The imputed hours of work by the farmer and family members (determined conjointly by the farmer and surveyor) are added to the hours of employees, with imputed hourly wage as prices (determined on a national level by the joint committee).

Land is considered as a separate factor of production. In some studies, land is simply not considered as a variable factor of production, but thought of as fixed, *i.e.*, unchanging across time (e.g. in the manual by the OECD (2001)). However, the amount of land a farm uses can certainly change over time and land prices can change even more considerable. In other words, excluding land from production measurement can bias MFP measures. If land is considered a factor of production, one has the choice between treating it as a separate factor of production and including it under capital. Given land's important role in agriculture, we choose to treat it as a separate factor of production. Land quantity is measured by the amount of hectares used for production (including cropped surface and fallow land); land prices by the leasing cost paid per hectare (calculated implicitly by dividing total leasing cost by the number of hectares). Note that both the actual paid leasing charges and the imputed rental cost for land under property of the farmer are included (determined conjointly by the farmer and surveyor).

Intermediate inputs include costs such as seed, water, fertilizer, feed and veterinary cost. Intermediate inputs are only available in total value hence an implicit quantity index was obtained using the CAE Intermediate consumption price index.

At the output side, detailed price and quantity information was difficult to discern. Hence, global indices were used for deflation. This is not the preferred method of deflation; however, given the unavailability of more detailed price indices at product level, this approach is considered a reasonable alternative. Note that the usage of aggregate price deflators means that quantity change is confounded with differential price change (not necessarily related to quantity). The resulting productivity concept is what in some literature is called "revenue productivity". *Gross output* includes net receipts from agricultural activity, net additions to inventory and the quantities consumed by the farm household. Products that are used as an input in the production process (e.g. foraging crops) are excluded. All products are valued at farm gate prices and reflect the value of the output to the producer; *i.e.*, subsidies are added and taxes subtracted. Gross output was deflated using the CAE Global price index of agricultural and horticultural production. *Gross value added* and *cash flow* were calculated following their definition in section 2 using gross output and land, labor and intermediate input costs as defined above. The components of both measures were deflated using double deflation, which is considered better than single deflation methods (Cassing 1996).

4 Results and discussion

In this section, the empirical results of measuring agricultural MFP growth using Flemish FADN data are presented and discussed. Note that given our micro level focus, care should be taken when interpreting our results, using them for prediction purposes or comparing them with macro level estimates. Table 3 reports the average annual MFP index numbers with respect to the previous year for the alternative input–output concepts across time and typology. The median annual growth rates were 2%, 4.3% and 11.2% respectively for the GO, VA and CF–based models. Cumulatively, MFP grew respectively with 35%, 81% and 336% during the period 1990–2003 for the GO, VA and CF–based models (see Figure 1). The MFP change percentages, on average, increase in absolute value when one moves from the GO–based concept to the CF–based concept. Just as the MFP growth rates increase, on average, the variability of these measures also increases with coefficients of variation of 12%, 26% and 141% respectively. Looking at the different MFP measures across time periods and typologies, we observe that MFP index numbers are sensitive to the underlying definitions of the input and output concepts. The overall trends are similar across measures, but the relationships between yearly MFP growth levels differ from year to year (see Figure 1). Using different measures can lead to different results, which can be illustrated comparing the median measures across typology. We observe that the specialist granivore farming type—which in Belgium is mainly represented by pig farms— is ranked as one of the top productive types at the VA level; at the GO level it is considered of average productivity and conversely, at the CF level it is the least productive typology.

< INSERT TABLE 3 HERE >

< INSERT FIGURE 1 HERE >

In general, the GO–based and VA–based MFP figures are slightly higher than macro level estimates found in literature (e.g. Ball *et al.* 1997; Martin & Mitra 2001; Headey *et al.* 2010), but are in accordance with micro level estimates which are found to vary much more in literature (e.g. Mullen & Cox 1996; Brümmer *et al.* 2002; Mullen 2007; Alvarez & del Corral 2010; Emvalomatis 2012). To the best of knowledge, comparable CF–based MFP measures for agriculture are only provided by Vancauteren *et al.* (2012), but at macro level. Focusing on Belgium, the available macro estimates of average annual GO–based MFP index are also slightly lower than our estimates, ranging from 1.010 estimated by (Coelli & Rao 2005) using a Törnqvist index approach for the period 1980–2000, to 1.014 provided by (Bureau *et al.* 1995) using a Fisher index approach for the period 1973–1989. Coelli *et al.* (2006) provide the single available estimate based on Belgian micro data to our knowledge; using a Malmquist index approach they obtain an average annual GO–based MFP index of 1.010. VA– and CF–based estimates are to the best of our knowledge not available for Belgium (not at macro level, nor at micro level).

The observed differences between the 3 alternative MFP growth measures naturally arise from the different contributions of the various input and output components. Table 4 presents the different components influencing MFP growth: (i) the output quantity indices, (ii) the individual input quantity indices, which are aggregated using (iii) input cost shares. In line with literature (Ball *et al.* 1997), output growth is, on average, greater than input growth, leading to an increase in productivity for all three measures. For the GO–based model, $Q_{KLL'EMS}$ is mostly influenced by EMS growth; on the one hand due to the highest cost share in KLL'EMS, on the other hand because of the high Q_{EMS}. Capital and labor are the most influential inputs in the VA–based model and capital is the sole input in the CF–based model. The cost shares in Table 4 also indicate that interpreting partial productivity measures—capital, labor or land productivity—can be misleading because none of these three factors truly dominates the inputs and hence all should be accounted for.

< INSERT TABLE 4 HERE >

The results from this study also provide evidence for the large dispersion of micro level measured productivity reported in literature (Bartelsman & Doms 2000), *i.e.*, large productivity differences across producers even within specific industries. The ratio of GO–based MFP growth between the 90th and 10th percentile farm of our sample is 1.37. This numbers indicates that the farm at the 90th percentile of the GO–based MFP distribution produces almost one and a half times as much output using the same level of inputs as the 10th percentile plant. The differences are even greater for the VA– and CF–based models with respective ratios of 1.94, and 8.48. Analyzing the drivers of these differences is an important research question on its own that merits supplementary research, a starting point is provided by Syverson (2011).

In Figure 2, the profitability decomposition model developed in section 2.2 is presented. In this figure, we look at the cumulative effect of the yearly changes in productivity, price recovery and profitability, with 1990 as the base. Overall, we observe that productivity increased significantly over the period under consideration; price recovery on the other hand shows a decreasing trend (due to effect of both declining output prices and rising input prices). Profitability, which combines the effect of both, therefore lies somewhere in between showing (although larger than one) only a moderate increase.

< INSERT FIGURE 2 HERE >

5 Conclusion

Productivity growth is an important performance measure that can be used to review past growth patterns and to assess the future productive capacity at farm level. Our results show that by avoiding neo-classical assumptions on the construction of multifactor productivity (MFP) growth, a unique answer to the percentage growth of MFP does not exist; much depends on the input–output concept under consideration. The presented framework relates all inputs—capital, labor, land and intermediate inputs—to gross output, the primary factors of production—capital, labor and land—to value added and capital to cash flow. For our data, the average levels of the MFP measures increase from the gross output to the value added and cash flow based model: Median annual MFP growth rates are 2.0%, 4.3% and 11.2% respectively. Looking at the different MFP measures across sectors, we observe that different measures yield different results because sectors are ranked differently when using alternative measures. The results of our profitability decomposition framework show that the farmers of our sample have been able to continue to increase agricultural output in the face of lower output prices thanks to increasing productivity.

The policy implications of our findings are that care needs to be taken when interpreting and comparing MFP growth measures across studies and that attention should be given to the input–output concept used. The various MFP growth measures discussed have different economic interpretations; the gross output measure focuses on production, the value added measure relates to an income concept and the cash flow measure can be interpreted as a capital productivity measure. Because of these different interpretations, the measures should be seen as complements and the choice of measurement depends on the purpose of analysis.

As motivated in section 2.3, even more MFP models can be constructed by rearranging inputs and outputs. Further research can consider some of these alternative models (such as MFP versions of land and labor productivity analogous to the capital productivity concept in this paper) and look deeper into the differences between these measures and their potential usage. Another interesting venue is looking at the variability or dispersion of the alternative measures, e.g. following the recommendations for empirical research on heterogeneous firms by Wagner (2011), and determining the drivers of these differences (e.g. Syverson 2011). Furthermore, the implications of using alternative micro level MFP growth measures can examined when analyzing the impact of important issues such as policy changes (Mary 2012), R&D spillovers (Bervejillo *et al.* 2012), and climate change (e.g. Salim & Islam 2010).

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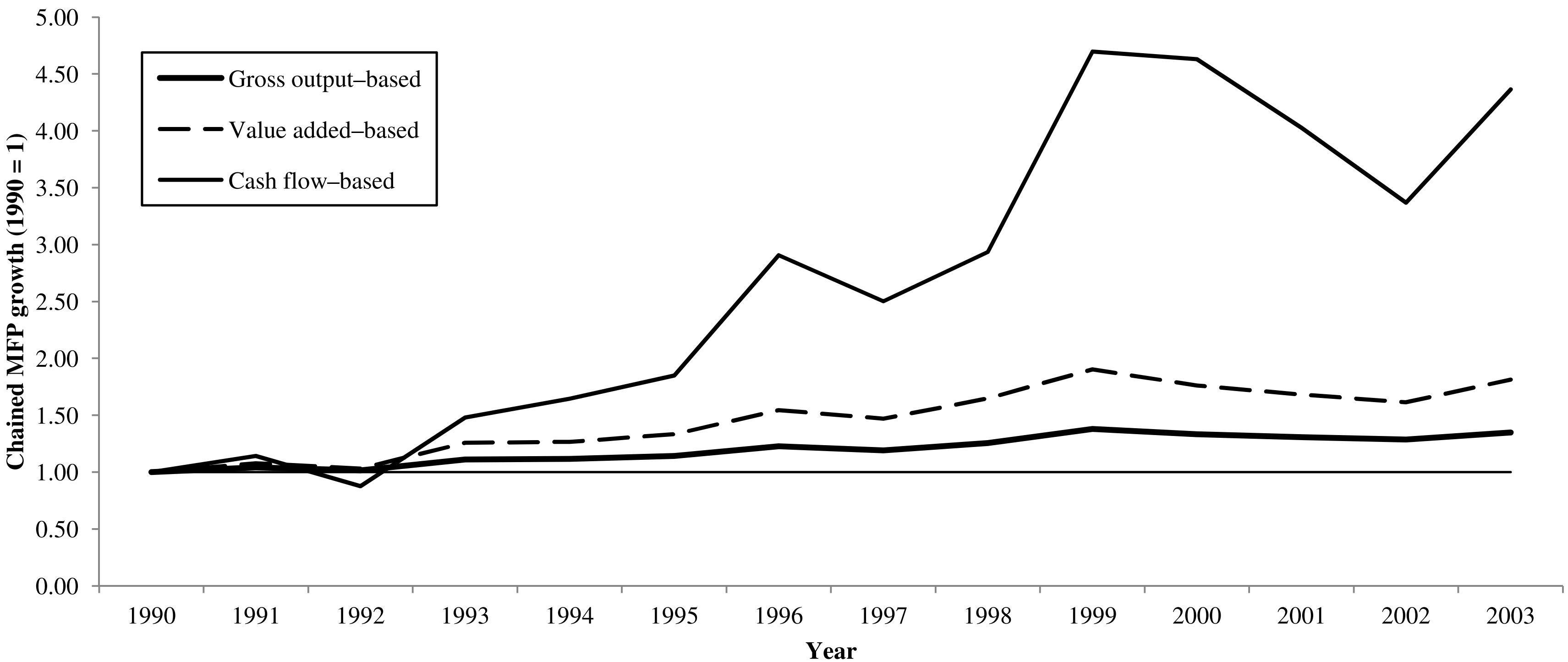

Figure 1 Cumulative multifactor productivity (MFP) growth using alternative input–output models

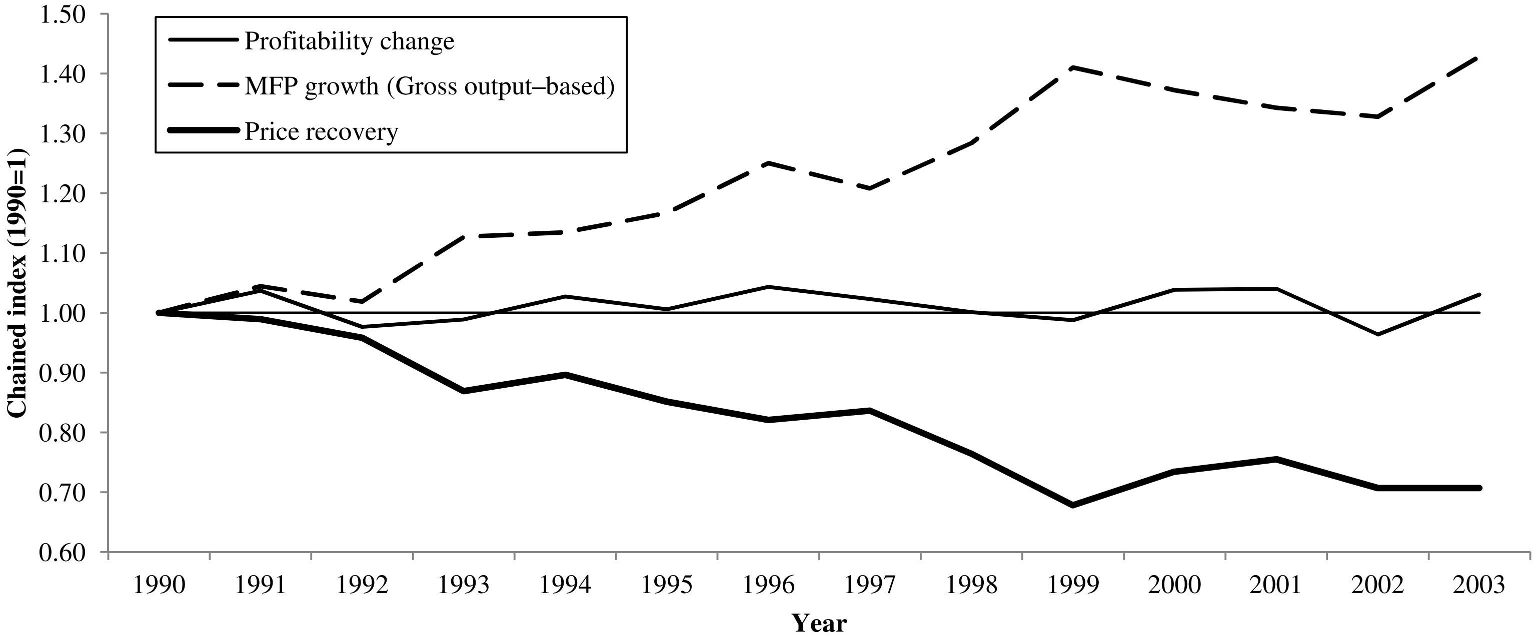

Figure 2 Cumulative decomposition of profitability change in multifactor productivity (MFP) growth and price recovery

Table 1 Summary table of the different multifactor productivity (MFP) growth models

Model name	Output	Input	MFP measure
KLL'EMS–GO	GO	KLL'EMS	$MFP_{GO} = \frac{\frac{GO^{t*}}{GO^{t-1}}}{\frac{K^{t*} + L^{t*} + L'^{t*} + EMS^{t*}}{K^{t-1} + L^{t-1} + L'^{t-1} + EMS^{t-1}}}$
KLL'–VA	VA = GO – EMS	KLL'	$MFP_{VA} = \frac{\frac{GO^{t*} - EMS^{t*}}{VA^{t-1}}}{\frac{K^{t*} + L^{t*} + L'^{t*}}{K^{t-1} + L^{t-1} + L'^{t-1}}}$
K–CF	CF = GO – LL'EMS = VA – LL'	K	$MFP_{CF} = \frac{\frac{GO^{t*} - LL'EMS^{t*}}{CF^{t-1}}}{\frac{K^{t*}}{K^{t-1}}}$

Notes: K, L, L' and EMS represent Capital, Labor, Land and Intermediate Inputs respectively. Gross Output, Value Added and Cash Flow are represented by GO, VA and CF respectively. "*"denotes a variable of period *t* valued at period *t–1* prices.

Table 2 Summary statistics

	Variable	Unit	Obs.	Mean	Std. Dev.	Median
Output	Gross Output	1990 prices (€)	5,835	241,947	158,185	198,052
	Value Added	1990 prices (€)	5,835	125,074	78,244	105,374
	Cash Flow	1990 prices (€)	5,805	69,462	67,064	50,026
Input	Capital	1990 prices (€)	5,037	29,851	18,251	26,933
	Labor	1990 prices (€)	5,835	49,933	17,857	48,827
	Land	1990 prices (€)	5,835	6,043	7,237	4,634
	Intermediate Inputs	1990 prices (€)	5,835	116,873	92,925	87,730
Multifactor	Gross Output–based	Index	3,327	1.028	0.125	1.020
productivity growth	Value Added–based	Index	3,327	1.072	0.279	1.043
	Cash Flow–based	Index	3,327	1.755	2.479	1.112

Table 3 Average annual multifactor productivity (MFP) growth for different input–output concepts and typologies

	Annual MFP growth								
	GO–based			VA–based			CF–based		
Year	**Mean**	**Std. Dev.**	**Median**	**Mean**	**Std. Dev.**	**Median**	**Mean**	**Std. Dev.**	**Median**
1991	1.044	0.102	1.041	1.113	0.233	1.079	1.589	1.949	1.142
1992	0.976	0.133	0.975	0.950	0.265	0.956	1.393	2.640	0.766
1993	1.106	0.105	1.096	1.243	0.249	1.219	2.629	3.179	1.692
1994	1.007	0.106	1.003	1.033	0.238	1.007	1.713	2.468	1.111
1995	1.028	0.111	1.024	1.085	0.272	1.052	1.683	2.646	1.123
1996	1.072	0.128	1.075	1.191	0.301	1.159	2.330	3.024	1.572
1997	0.966	0.127	0.971	0.936	0.264	0.951	1.361	1.846	0.861
1998	1.063	0.137	1.054	1.153	0.294	1.122	1.663	2.086	1.173
1999	1.098	0.142	1.098	1.197	0.336	1.154	2.675	3.203	1.601
2000	0.973	0.083	0.967	0.957	0.191	0.926	1.262	1.242	0.985
2001	0.979	0.096	0.981	0.952	0.206	0.955	1.190	1.721	0.870
2002	0.989	0.102	0.982	0.964	0.211	0.960	1.263	1.859	0.837
2003	1.075	0.133	1.049	1.171	0.303	1.122	2.292	2.994	1.296
Typology									
Specialist field crops	1.039	0.133	1.027	1.091	0.283	1.046	1.765	2.373	1.153
Specialist grazing livestock	1.027	0.109	1.019	1.056	0.210	1.033	1.678	2.176	1.097
Specialist granivore	1.017	0.142	1.017	1.081	0.360	1.056	1.744	2.780	1.090
Mixed livestock	1.022	0.122	1.017	1.063	0.301	1.033	1.764	2.508	1.109
Mixed crops–livestock	1.039	0.133	1.031	1.101	0.298	1.060	1.841	2.594	1.180
Overall average	1.028	0.125	1.020	1.072	0.279	1.043	1.755	2.479	1.112

Notes: GO, VA and CF stand for Gross Output, Value Added and Cash Flow respectively.

Table 4 Components of multifactor productivity (MFP) growth for different input–output concepts

Input–output model	Output	Input									MFP growth
	Q_{Output}	Q_K	s_K	Q_L	s_L	$Q_{L'}$	$s_{L'}$	Q_{EMS}	s_{EMS}	Q_{Input}	Q_{Output}/Q_{Input}
GO–based	1.043 (0.144)	1.004 (0.166)	0.171 (0.072)	1.001 (0.079)	0.282 (0.102)	1.029 (0.094)	0.037 (0.029)	1.029 (0.109)	0.510 (0.132)	1.016 (0.078)	1.028 (0.125)
	1.030	*0.960*	*0.159*	*1.000*	*0.276*	*1.000*	*0.031*	*1.021*	*0.492*	*1.006*	*1.020*
VA–based	1.074 (0.278)	1.004 (0.166)	0.355 (0.119)	1.001 (0.079)	0.572 (0.120)	1.029 (0.094)	0.073 (0.055)			1.005 (0.081)	1.072 (0.279)
	1.039	*0.960*	*0.357*	*1.000*	*0.569*	*1.000*	*0.060*			*0.988*	*1.043*
CF–based	1.732 (2.434)	1.004 (0.166)	1.000 (0.000)							1.004 (0.166)	1.755 (2.479)
	1.099	*0.960*	*1.000*							*0.960*	*1.112*

Notes: Mean values are presented with standard deviations between brackets and medians below in italics. K, L, L' and EMS represent Capital, Labor, Land and Intermediate Inputs respectively. Gross Output, Value Added and Cash Flow are represented by GO, VA and CF respectively. *Q* represents a Laspeyres quantity index and *s* represents a cost share. Average MFP growth is not exactly reproducible using the input–output data presented because all consist of averages of annual data.