Input-output concepts, profits and productivity growth: An application using Flemish farm level data

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Paper prepared for presentation at the EAAE 2011 Congress
Change and Uncertainty
Challenges for Agriculture,
Food and Natural Resources

August 30 to September 2, 2011
ETH Zurich, Zurich, Switzerland

1. Introduction

Productivity growth, generally defined as output quantity change relative to input quantity change, can be constructed from a number of input-output concepts. Aside from the distinction between partial and multifactor productivity (MFP) measures, different levels of output can also be considered. Following the framework by Balk (2010), we consider productivity at three levels, namely gross output, value added and cash flow. Each of these outputs relate to variant sets of the following input components: capital, labour, land and intermediate inputs. Every input-output concept has its corresponding MFP growth measure with an alternative economic interpretation. The first objective of this paper is comparing these various measures MFP growth. To measure MFP growth, we use index theory because this methodology does not impose any functional behaviour between inputs and outputs. Acknowledging profits, we employ a simple framework that decomposes the evolution of profitability into productivity change and price recovery—the ratio of the output and the input price index. We apply the framework to the agricultural sector using data from the Flemish Farm Accounting Data Network (FADN). The second objective of this paper focuses on the methodological aspects using data at the level of the farm. We focus on data measurement, the construction of various input-output variables (e.g., the user cost of capital, farmers' self-income) and report these results using a unique database of farm-level data applied to the Flemish agriculture. In addition, we also discuss the specific productivity measurement challenges for this sector. The use of farm-level data applied to the concept of MFP is not popular. Indeed, agricultural productivity growth literature has mostly focused on national MFP measures (see Bureau *et al*., 1995; Coelli and Rao, 2005) while on the other hand, micro-level MFP literature rather tempt to focus on the manufacturing sector (Bartelsman and Doms, 2000).

This paper is organized as follows: Section 2 introduces the productivity growth decomposition framework and discusses the different MFP growth measures. Section 3 applies this framework to the case of agriculture and describes the data. Section 4 presents and discusses the results while Section 5 concludes.

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 parametric and non-parametric methods. The former depends on the functional behaviour of relating inputs to output from a production or a cost function which are than econometrically estimated, the latter constructs empirical MFP measures from data without any specification of an economic behaviour. In this paper we will make use of productivity indices using simply index numbers 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. Our method does not involve the so-called neo-classical assumptions such as constant returns to scale, optimizing behaviour, perfect foresight, perfect competitive markets (both input and output), *etc*. The competitive markets assumption implies that in equilibrium, profits are zero, i.e. costs precisely equal revenues. By staying clear from neo-classical assumptions, we thus acknowledge profits in our framework.

Valuable references regarding index number construction for the purpose of productivity analysis are Coelli et al. (2005) for a general discussion of the topic; Balk (1998) focuses on micro data, Balk (2010) and Vancauteren *et al.* (2009) focus on MFP constructs recognizing the role of profits, and specifically for agriculture, we refer to Ball and Norton (2002). In short, the index number approach to productivity measurement can be explained as follows. First, one needs to define/choose what is considered output and input and consequently how each component should be measured (which is often dictated by data availability or quality). Next, by using 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 around 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). We start by introducing some notation for the productive 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:

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

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

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

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

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

As a performance measure, profitability growth is dependent both on price changes and quantity changes. To measure pure productive performance, profitability change should be stripped of price changes. The resulting *real* profitability change is MFP growth. 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 (the so called "tests" have been developed in the index number theory to help decide between different index number formulae). This test simply states that the product of a price index and a quantity index equals the value ratio, or mathematically that $\frac{V^t}{V^{t-1}} = \frac{p^t.y^t}{p^{t-1}.y^{t-1}} = P(p^t, y^t, p^{t-1}, y^{t-1})Q(p^t, y^t, p^{t-1}, y^{t-1})$ where *V* represents value and *P(t, t-1)* and *Q(t,t-1)* price and quantity indices for period *t* relative to period *t-1* respectively. Following Balk and van den Bergen (2006) and van den Bergen *et al.* (2008) Laspeyres indices are used throughout the paper because of their computational easiness and zero-value robustness (in the first form).

The Laspeyres quantity index formula for year *t* relative to year *t-1* is defined as:

$$Q_{(t,t-1)}^{Laspeyres} \equiv \frac{\sum_i p_i^{t-1} q_i^t}{\sum_i p_i^{t-1} q_i^{t-1}} = \sum_i s_i^{t-1} \frac{q_i^t}{q_i^{t-1}}$$

with $s_i^t = \frac{p_i^t q_i^t}{\sum_i p_i^t q_i^t}$ where p_i^t represents unit price, q_i^t quantity, $p_i^t q_i^t$ value at current prices, $p_i^{t-1} q_i^t$ value at previous period's prices and s_i^t represents an output or cost share in period *t*. The Laspeyres quantity index is thus equal to value in the current period *t* expressed at previous period *t-1* prices, divided by value in the previous period. The second part of the equation derives the second form of the Laspeyres quantity index, which shows that it can also be interpreted as a share-weighted sum of quantity ratios. The formula for the Laspeyres price index is analogously given by:

$$P_{(t,t-1)}^{Laspeyres} \equiv \frac{\sum_i p_i^t q_i^{t-1}}{\sum_i p_i^{t-1} q_i^{t-1}}.$$

For the ease of notation we will drop the *Laspeyres* scripts in the remainder of the paper. With the product test defined and the index formula decided, we obtain

$\frac{R^t}{R^{t-1}} = P_R(t,t-1)Q_R(t,t-1)$ and (4)

$\frac{C^t}{C^{t-1}} = P_C(t,t-1)Q_C(t,t-1)$. (5)

Combining the equations (3), (4) and (5), we thus decompose profitability change as follows

$$\frac{\Pi^t}{\Pi^{t-1}} = \frac{P_R(t,t-1)}{P_C(t,t-1)}\frac{Q_R(t,t-1)}{Q_C(t,t-1)}. \quad (6)$$

The MFP growth index for period *t* relative to period *t-1* is now *defined* as the right-hand factor of equation (6), i.e. the output quantity index divided by the input quantity index:

$$MFP(t,t-1) = \frac{Q_R(t,t-1)}{Q_C(t,t-1)}. \quad (7)$$

The decomposition in equation (6) 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-profits (i.e. profitability change = 1), following equation (6), MFP growth will be equal to the inverse of the price recovery index. The model developed above allows us to analyze the profitability and productivity growth 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

Before deriving the different MFP growth models, we will first characterize the outputs and inputs of production using a slightly adapted KLEMS notation for agriculture. In regular KLEMS notation, output is denoted with Y and inputs with KLEMS; the former we will denote with GO, the latter we will adjust to KLL*EMS for agriculture. In this notation, K represents capital input cost; the letter L denotes labour costs (wages) and L* land costs (rent). Given its chief role in agricultural production, we consider land as a separate factor of production here and not as part of capital, as is frequently done in literature. These three inputs constitute the three traditional primary inputs to the agricultural productive process. The letters E, M and S represent energy, material and services costs respectively and together symbolize the intermediate inputs used.

Using our adapted KLL*EMS notation, the input-output framework developed in the previous section can be denoted as KLL*EMS-GO and sees gross output as its output (revenue) concept and KLL*EMS as its inputs (costs). The corresponding accounting identity reads: *GO = KLL*EMS + profit*. As already noted, by not relying on the neo-classical assumption that revenues should equal costs, this model explicitly allows for positive profits. Note that the concept of "profit" is rather vague in agricultural economics with no single definition being used. The main problem with profit calculation in agricultural accounts is the sensitivity to imputations that need to be made regarding unpaid family labour and the usage of privately owned land; see also section 4.2. The resulting GO-based productivity measure was defined as $MFP_{GO}(t,t-1) = \frac{Q_{GO}(t,t-1)}{Q_{\mathrm{KLL^*EMS}}(t,t-1)}$. In this definition, the GO quantity index is calculated as $Q_{GO} = \frac{GO^{t*}}{GO^{t-1}}$, where GO^{t*} denotes GO of period *t* valued at period *t-1* prices. Two approaches are available for this deflation: (i) by using detailed price and quantity information of the different GO components or alternatively when these are not available (ii) using a global producer price index (PPI). Using an aggregate deflator has the disadvantage that quality improvements that are not captured by the deflator, will bias the productivity measures (downwards). Usually, data availability dictates the approach chosen. The KLL*EMS quantity index is calculated analogously as $Q_{KLLEMS} = \frac{KLL^*EMS^{t*}}{KLL^*EMS^{t-1}}$, where once again both deflation methods are applicable. 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 Section 2.4).

The first alternative model sees value added (VA) as its output concept, which is defined as gross output minus the costs 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, labour 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 $MFP_{VA}(t,t-1) = \frac{Q_{VA}(t,t-1)}{Q_{KLL^*}(t,t-1)}$. Here, the VA quantity index is calculated using double deflation, which is considered better with regards to single deflation methods (Cassing, 1996). In this method, VA^{t^*} is calculated as: $VA^{t*} = GO^{t*} - EMS^{t*}$ (where gross output and intermediate inputs are deflated using their respective PPI's).

The second alternative model employs cash flow (CF) as its output concept, which is defined as gross output minus the non-capital costs, i.e. $CF = GO\text{-}L\text{-}L^{*}\text{-}EMS$. Note that following this definition, in this analysis the term cash flow does not refer to liquidity concept of the movement of cash into or out of a farm (as derived from a cash flow statement). 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 $MFP_{CF}(t,t-1) = \frac{Q_{CF}(t,t-1)}{Q_K(t,t-1)}$. The deflation approach for the CF quantity index is analogous to the VA approach, using $CF^{t*} = GO^{t*} - KLL^{*}EMS^{t*}$. 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. Capital input measurement, however, specifically entails additional measurement issues. These issues will be briefly dealt with in Section 2.5.

Table 1 Summary table of the different MFP growth models

Model name	Output	Input	MFP measure
KLL*EMS -GO	GO	KLL*EMS	$MFP_{GO} = \frac{\left[\frac{GO^{t*}}{GO^{t-1}}\right]}{\left[\frac{K^{t*} + L^{t*} + L^{*(t*)} + EMS^{t*}}{K^{t-1} + L^{t-1} + L^{*(t-1)} + EMS^{t-1}}\right]}$
KLL*-VA	VA = GO – EMS	KLL*	$MFP_{GVA} = \frac{\left[\frac{GO^{t*} - EMS^{t*}}{\mathrm{GVA}^{t-1}}\right]}{\left[\frac{K^{t*} + L^{t*} + L^{*(t*)}}{K^{t-1} + L^{t-1} + L^{*(t-1)}}\right]}$
K-CF	CF = GO – KLL* = VA – LL*	K	$MFP_{CF} = \frac{\left[\frac{GO^{t*} - LL^{*}EMS^{t*}}{\mathrm{CF}^{t-1}}\right]}{\left[\frac{K^{t*}}{K^{t-1}}\right]}$

Notes: K, L, L*and EMS represent Capital, Labour, Land and Intermediate Inputs respectively and Gross Output, Value Added and Cash Flow are represented by GO, VA and CF respectively.

2.4 Interpretation of the different productivity concepts

The interpretation of MFP is usually addressed as a compositional issue. Under the neoclassical assumptions of perfect competition and constant returns to scale, MFP change is just equal to technical change. However, relaxing these assumptions, MFP change includes factors such as technical change (due to input and output innovation, management skills, *etc.*), technical efficiency change, scale effects, input- and/or output-mix change (due to higher production capacities, deviations from perfect competition, *etc.*), other external factors like the weather and measurement errors.

Changing focus to the first of the three different MFP models, the GO-based MFP model presents the most intuitive or complete production concept by explicitly accounting for all combined inputs used (including EMS) to produce gross output. Overall, it is the most favoured 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, using a new production scheme, *etc.*) 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 (labour, land and capital) to produce value added. Because intermediate inputs are netted out, technical change and improvements in the efficient usage of them are not explicitly considered in this measure and thus this model is conceptually not an accurate measure of technological change or a measure of efficiency improvements (use the GO-based measure instead). 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. Cobbold (2003) and the OECD (2001) interpret this measure—at the industry level—as an industry's capacity to contribute to economy-wide growth of income per unit of primary input. 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 mix of the three primary factors of production a farmer uses 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; Balk, 2009). Criticism 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).

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 farm's CF is an important indicator for a farmer regarding his investment. It indicates the extent to which a farm may be able to repay its financial obligations as well as its strategies in funding its capital needs. Capital is an important factor of production for agriculture because in general it is becoming more and more capital intensive. A general trend is the substitution of labour for capital, thus in capital intensive agricultural sectors, capital can be a more important input as opposed to labour. The productivity of capital is furthermore closer related to financial risk, which makes this the preferred productivity indicator to use in such 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 investments (with a comparable risk factor). On the other hand this could mean that not sufficient cash flow is generated to fulfil short term liabilities.

2.5 Capital input measurement

The capital input into the productive process can be expressed in many different terms. An important reference for the topic of capital measurement is the manual by the OECD (2009). As proposed in the manual, we make use of capital services as the capital input. Capital services—representing a quantity concept—embody the flow of productive services (e.g. stables provide housing while tractors facilitate heavy work) from the cumulative stock of past investments. The price component of capital services is called the unit user cost of capital, and can be interpreted as the implicit rental price that capital goods owners "charge" themselves for using their privately owned capital goods. Basically, three components should be taken into account: (i) depreciation, i.e. the value loss due to ageing; (ii) the financial cost of the capital that is tied up in the capital good, i.e. the opportunity cost and (iii) revaluation, i.e. the expected price change of the capital good over time. Practically this translates into the following respective components of the user costs of capital: (i) a rate of depreciation; (ii) an interest rate and (iii) a rate of capital good price change.

The calculation of the capital input constitutes one of the major differences between productivity measurement with and without neo-classical assumptions. Specifically, the zero-profit assumption (costs equal revenues) is realized by ensuring that using an endogenous rate of return in the user cost formula.
To avoid making this neoclassical assumption, the cost of capital input can also be constructed using an exogenous rate, i.e. a rate based on external information (e.g. financial market data).

The practical construction of the user costs of capital and subsequently the volume index of capital services is beyond scope of this paper. Here we simply note that the framework used was an adapted version of the framework for the Dutch National Accounts by Balk and van den Bergen (2006) and van den Bergen et al. (2008). In a more elaborate version of this paper (which will be made available), we formally derive the model. The necessary components will be discussed in the next section however.

3. Farm level MFP growth using index theory: Empirical application

3.1 FADN dataset

The dataset used in this study is the 1989-2003 Belgian Farm Accounting Data Network (FADN) data (see Eurostat, 2000), collected by the former Centre for Agricultural Economics (CAE, now part of the Institute for Agricultural and Fisheries Research (ILVO)). The FADN data collection is stratified to ensure representativeness regarding profitability of all agricultural regions and farm sizes within Flanders. Most farms stay 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 16,410 observations, over a 15 year period. However, some observations were excluded for analysis. Because starting from 2002, the FADN dataset only covers the Flemish region (due to a change of federal data collection to regional data collection), we restrict our analysis to the Flemish region of Belgium (57% of the data). Because of the problematic usage of negative numbers when constructing a ratio, all observations with a negative value of value added or cash flow were removed from analysis (38% of the Flemish data, see also Section 4.2). Finally, given the yearly comparison nature of the MFP index methodology, we deleted any observations not belonging to a two-consecutive year sequence (these 498 observations represented 5% of the Flemish data). After this data management, we were left with 5,225 observations over a 15 year period. This means an average of 348 observations per year, ranging from 456 observations in 1989 to 196 observations in 2003. About one third (31.5%) of the farms stayed in the sample for 5 years or less, where about the same percentage (34%) stayed in the sample for 10 years or more.

3.2 Empirical choices of input-output measurement

At the input side, detailed price and quantity information was available to calculate the respective indices.

The *capital* goods considered in this study are land capital (soil in property, improvements made to soil, standing crops), buildings capital (buildings in property, improvements to buildings), quota capital (milk and sugar beet quota) and dead capital (tractors, machines, small materials). For capital input measurement, the required elements are the opening stock of capital goods (net capital stock), an interest rate, a depreciation rate and price indices. The net capital stock (valued at the previous period’s prices) is provided directly by the FADN data. To stay clear from neoclassical assumption, we do not use an endogenous interest rate. Instead, we make use of a year and farm-specific interest rate calculated as the ratio of the yearly interest 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 ever 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. The depreciation rates were calculated farm, year and asset specific as the ratio of yearly depreciation to the opening stock of that specific asset. Finally, price changes were modelled 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).

Labour quantity is measured by number of hours worked and the labour price corresponds to hourly wages paid (calculated implicitly by dividing total wages paid by the number of hours worked). The imputed wages for unpaid work by the farmer and family members are included in the analysis; Section 4 will further elaborate on this point.

Given its chief role in agricultural production, *land* is considered as a separate factor of production and not as part of capital, as is frequently done in literature. Land quantity is measured by the amount of hectares used for production; land prices by the leasing costs paid per hectare (calculated implicitly by dividing total leasing costs by the number of hectares). Note that both the actual paid leasing charges and the imputed rental costs for land under property of the farmer are included (see also Section 4).

Intermediate inputs include costs such as seed, water, fertilizer, feed, veterinary costs, *etc*. 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, no detailed price and quantity information could be discerned; hence global indices were used for deflation. As mentioned in Section 2.3, 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. *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 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 2.3 using gross output and the land, labour and intermediate input costs as defined above.

Summary statistics can be found in Table 2. Because of the amount of data the analysis of our study produces (all measures discussed above for each farm and between two adjacent time periods), we choose to present overall averages of the results according to different time periods and agricultural sectors. The time periods were chosen symmetrically and the production types include arable farms, dairy farms (specialized), pig farms (specialized) and mixed farms (animals and crops). These 4 sectors represent 10%, 23%, 20% and 12% of the sample respectively and thus in total cover 66% of the entire sample. The remaining 34% farms were not reported as a separate category (because of the meaningless comparison given the heterogeneity in this group), but were included in all overall average figures (denoted with 'overall average').

The construction of the volume index of capital services requires price information of two periods prior to the period under consideration. Because price information was only available starting from 1989, capital quantity indices could thus only be calculated from 1991. As a result, we will only report indices from 1990 onwards.

To account for unusual, extreme changes in the data, the 1%-trimmed average is used to characterize indices in this study. Practically this means that the 1% smallest and 1% greatest values are omitted in calculating the average and for consistency reasons this outlier rule is applied to all indices calculated. This rule is common in investment studies to account for highly elevated growth rates (e.g. Benjamin and Phimister, 2002).

Table 2 Summary statistics

	Variable	Unit	Obs.	Mean	Median	Std. Dev.
Output	Gross Output	1990 prices	5,225	249,518	205,983	160,695
	Value Added	1990 prices	5,225	128,918	108,905	79,422
	Cash Flow	1990 prices	5,221	72,579	52,853	68,336
Input	Capital	1990 prices	4,721	35,552	31,460	22,192
	Labour	1990 prices	5,225	50,227	49,141	17,684
	Land	1990 prices	5,225	6,169	4,717	7,509
	Intermediate Inputs	1990 prices	5,225	120,600	91,546	94,307
MFP growth	Gross output-based	Index	3,081	1.03	1.02	0.12
(average annual changes)	Value added-based	Index	3,060	1.07	1.05	0.26
	Cash flow-based	Index	3,501	1.62	1.14	1.68

4. Results and discussion

4.1 Results

In this section we will discuss our empirical results of measuring Flemish agricultural MFP growth using FADN data. Table 3 reports the average annual MFP growth rates for the different input-output concepts across different time periods and sectors. This table is based on the median values of annual MFP growth, not the averages; this choice will be further elaborated in Section 4.2. First focussing on the overall averages, median annual growth rates were 2%, 5% and 14% respectively for the GO, VA and CF-based models; cumulatively speaking over the 15-year period considered, MFP grew respectively with 41%, 96% and 510%. In general, Table 3 shows that MFP index numbers are very sensitive to the underlying definitions of the input and output concepts. Looking at the different MFP-measures across sectors, we observe no unambiguous findings; i.e. the different measures yield different results. The MFP change percentages systematically increase in absolute value when one moves from the GO-based concept to the CF-based concept (see also OECD, 2001, pp. 26). Just as the MFP growth rates increase, on average, when one moves from the GO-based concept to the CF-based concept, the variability (standard deviation) of these measures also increases. By looking at subsectors, one notably result is that the higher variability of average annual MFP growth rates for pig farms.

Table 3 Average annual MFP growth for different input-output concepts and different sectors

	GO-based MFP				VA-based MFP				CF-based MFP			
Sector	1990-1994	1995-1999	2000-2003	1990-2003	1990-1994	1995-1999	2000-2003	1990-2003	1990-1994	1995-1999	2000-2003	1990-2003
Arable farms	1.03	1.03	0.99	1.03	1.06	1.06	0.98	1.04	1.28	1.16	1.06	1.16
	(0.11)	(0.13)	(0.14)	(0.13)	(0.22)	(0.26)	(0.29)	(0.26)	(1.15)	(1.86)	(2.45)	(1.81)
Dairy farms	1.04	1.04	0.99	1.02	1.06	1.07	0.98	1.04	1.11	1.22	0.96	1.12
	(0.11)	(0.10)	(0.09)	(0.10)	(0.19)	(0.18)	(0.17)	(0.18)	(1.40)	(1.62)	(1.44)	(1.50)
Pig farms	1.03	1.12	0.97	1.02	1.14	1.33	0.92	1.07	1.22	1.64	0.95	1.19
	(0.13)	(0.17)	(0.08)	(0.14)	(0.31)	(0.40)	(0.22)	(0.33)	(1.89)	(1.84)	(0.94)	(1.68)
Mixed farms	1.03	1.05	1.01	1.03	1.07	1.11	1.02	1.07	1.22	1.20	1.18	1.20
	(0.13)	(0.13)	(0.13)	(0.13)	(0.28)	(0.29)	(0.29)	(0.28)	(1.63)	(2.01)	(1.48)	(1.73)
Overall average	1.03	1.05	0.99	1.02	1.07	1.08	0.97	1.05	1.20	1.28	0.96	1.14
	(0.12)	(0.13)	(0.10)	(0.12)	(0.24)	(0.28)	(0.23)	(0.26)	(1.62)	(1.77)	(1.63)	(1.68)

Notes: The averages reported are based on median values. The overall average includes sectors other than the 4 presented in detail. Standard deviations are shown between brackets.

For the remainder of the results section, we will focus on the GO-based MFP measure where we focus on the contribution of each of the input factors and output to changes in productivity growth. Table 4 presents the different components influencing GO-based MFP growth. Average annual MFP growth (+3%) is mainly influenced by output growth (+4%) and to a lesser extent by input growth (+1%). Input growth is mostly influenced by EMS growth, mainly because EMS has the highest cost share in KLL*EMS. The cost shares also indicate that partial productivity measures—capital, labour or land productivity—are not accurate representations because none of these three factors truly dominates the inputs. Despite the dissimilar cost shares, sectoral differences of GO-based MFP growth are limited; temporal differences are a bit more pronounced.

Table 4 Components of gross output based MFP growth

	Q_{GO}	Q_K	s_K	Q_{Labour}	s_{Labour}	Q_{Land}	s_{Land}	Q_{EMS}	s_{EMS}	Q_{KLL^*EMS}	MFP_{GO}
Sector											
Arable farms	1.05	0.98	0.16	1.00	0.30	1.02	0.08	1.03	0.46	1.01	1.04
	(0.16)	(0.15)	(0.07)	(0.09)	(0.10)	(0.09)	(0.04)	(0.14)	(0.08)	(0.08)	(0.13)
Dairy farms	1.03	1.00	0.21	0.99	0.36	1.02	0.04	1.03	0.40	1.01	1.03
	(0.11)	(0.17)	(0.08)	(0.07)	(0.09)	(0.08)	(0.01)	(0.11)	(0.07)	(0.07)	(0.10)
Pig farms	1.05	0.98	0.13	1.01	0.18	1.04	0.01	1.04	0.68	1.02	1.02
	(0.18)	(0.17)	(0.05)	(0.09)	(0.06)	(0.12)	(0.01)	(0.12)	(0.09)	(0.08)	(0.14)
Mixed farms	1.06	1.00	0.16	1.00	0.27	1.04	0.05	1.03	0.52	1.02	1.04
	(0.16)	(0.15)	(0.06)	(0.07)	(0.09)	(0.11)	(0.02)	(0.11)	(0.11)	(0.08)	(0.13)
Period											
1990-94	1.05	1.04	0.15	1.00	0.30	1.03	0.03	1.04	0.52	1.02	1.04

	(0.15)	(0.18)	(0.07)	(0.08)	(0.11)	(0.09)	(0.02)	(0.13)	(0.14)	(0.08)	(0.12)
1995-99	1.07	0.99	0.18	1.00	0.27	1.03	0.03	1.04	0.52	1.02	1.05
	(0.16)	(0.16)	(0.07)	(0.08)	(0.10)	(0.10)	(0.03)	(0.11)	(0.14)	(0.08)	(0.13)
2000-03	0.99	0.96	0.17	1.00	0.25	1.03	0.04	1.01	0.54	1.00	1.00
	(0.12)	(0.12)	(0.07)	(0.07)	(0.09)	(0.10)	(0.03)	(0.10)	(0.14)	(0.06)	(0.10)
Overall average											
All sectors,	1.04	1.00	0.17	1.00	0.28	1.03	0.03	1.03	0.52	1.01	1.03
1990-2003	(0.15)	(0.16)	(0.07)	(0.08)	(0.11)	(0.09)	(0.03)	(0.12)	(0.14)	(0.08)	(0.12)

Notes: *Q* represents a quantity index and *s* represents a cost share (see Section 2.2). The overall average includes sectors other than the 4 presented in detail. Standard deviations are shown between brackets

In Figure 1, we look at the profit decomposition model developed in Section 2.2. In this figure, we look at the cumulative effect of the yearly changes of productivity, price recovery and profitability, with 1990 as the base. Overall, we observe that productivity increased 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.

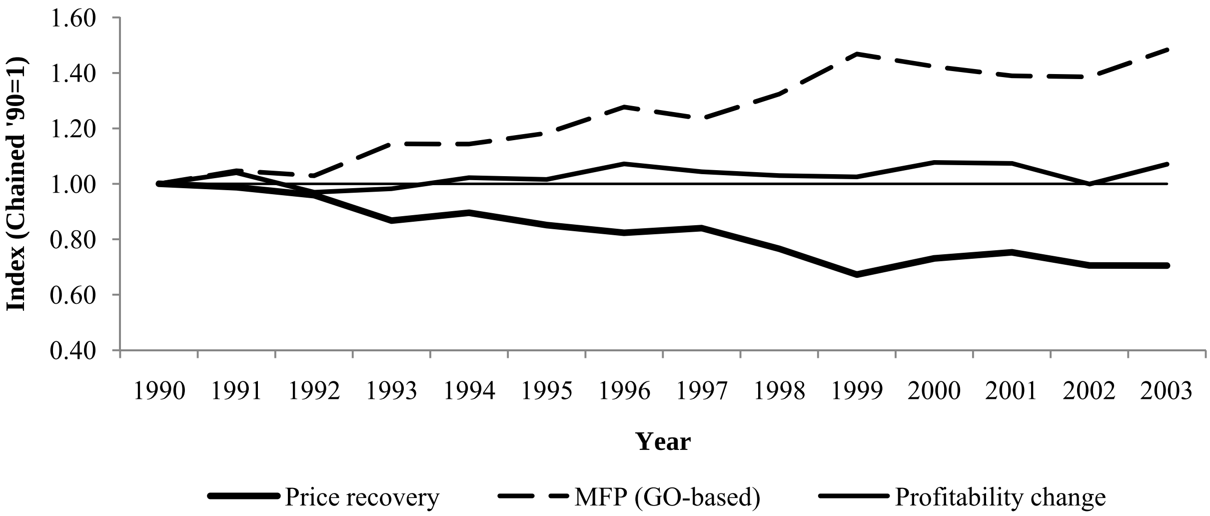

Figure 1 Profit decomposition model

4.2 Additional challenges of measuring agricultural MFP

When measuring productivity growth, different choices need to be made. Most of these choices have been covered (extensively) in literature (e.g. how to measure the different outputs and inputs, how to subsequently deflate them, the choice of interest rate, the methodology for productivity measurement, *etc*.). Here we would like to highlight some points that are of importance specifically for the presented agricultural productivity growth framework: (i) problems regarding negative cash flows, (ii) cash flow variability problems, (iii) accounting for imputed labour and land input and (iv) land as a factor of production.

In some cases, negative cash flows might be present during certain periods, certainly for the agricultural sector where margins are frequently small. This is a known problem in agricultural economics that relates to using imputed costs to account for the usage of unpaid family labour and privately owned land. These negative entries prove a difficulty for the productivity measurement framework because of the problematic interpretation of an index when negative entries occur (i.e. an index makes no sense when a variable changes sign). Different approaches are possible to resolve these problems. On the one hand one can replace the negative CF's with 1 or any other small number (introducing zero values is also not a valid option because of the related zero-value problems for certain index formula). This approach was tested for our data, but did not yield satisfactory results (i.e. highly elevated growth levels). An alternative would be replacing the negative CF's with a missing value. This approach solves the problem, but results in unequal sample sizes of the different MFP measures considered, which does not allow an equal comparison. Another approach is dropping the observations with a negative CF. A downside of this method is that it truncates the data, which has an influence on the representativeness. However, because this is not the focus of this paper and to be able to correctly compare the three MFP concepts this approach was employed in this paper.

We observed high cash flow changes in the dataset. These changes are not extraordinary outlier values, but are simply the result of CF being smaller than GO and VA (by definition), thus closer to zero in some cases, producing small changes in absolute terms but great changes in relative terms. These high changes have a pronounced influence on the average CF growth and in turn on the average CF-based MFP growth. This raises the question whether these elevated changes should be included in the analysis or not? These values are not outliers per se because these changes are plausible, yet they do not fit in the general (i.e. average) picture. The underlying reason of this variability is that we have quite heterogeneous farms from the perspective of the input-output market size (large rather industrial farms to self employed, family owned farms). For this paper we choose to use the median to characterize the three different MFP growth measures (because of its resistance to extreme values) because our focus is not a representative picture for Flemish agriculture. We do would like to note that in analysis where this is important, high CF changes should be dealt with.

The third point raised is how to account for privately owned land and unpaid family labour in agricultural productivity measurement. On the one hand, statistics regarding these inputs are frequently not a very accurate reflection of the actual input to the production process and therefore they may bias the productivity indicator. On the other hand, excluding imputed measures might be a serious underestimation of the land and labour components. Specifically in our case, about one thirds of Flemish agricultural land is privately owned by the farmer. Imputations for this land are based on the amount of privately owned hectares used in a certain year, times the region specific leasing costs. This is an underestimation of the actual value of the land because usually land is worth much more than what these average prices indicate (i.e. the land quality is not reflected in the rental prices. Regarding labour, our farms mostly use unpaid family labour. External labour is only used in 20% of the panel observations and on average only presents a fraction of total labour costs. For unpaid labour imputations are based on the amount of annual working units (AWU's), national average hours worked per AWU and average hourly wage rates for agricultural work (determined at national level). No detailed statistics regarding unpaid hours worked are collected. This approach mainly represents an underestimation of the actual amount of hours worked by farmers and family members. Despite these reported underestimations, we included the imputed measures because no more detailed records were available and excluding them would present a serious underestimation of input. In relation to previous point, we do note that when excluding imputed costs for analysis, less negative CF observations need to be excluded.

The final point we briefly would like to raise here is the treatment of land in productivity measurement. In some cases, 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, thus excluding it 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. For a discussion on this topic, we refer to Gaffney (1994).

5. Conclusion

Our results show that by avoiding any 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 data shows that the average levels and variability of the MFP measures systematically increase from the gross output to the cash flow based model: Annual MFP growth rates were 2% (±12%), 5% (±26%) and 14% (±68%) respectively for the gross output, value added and cash flow-based models. Looking at the different MFP-measures across sectors, we observe that different measures yield different results. In our sample, MFP growth is furthermore mainly influenced by output growth and to a lesser extent by input growth. 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 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 thus be seen as complements and the choice of measurement depends on the purpose of the analysis.

Challenges for the presented agricultural productivity growth framework include problems regarding negative and variable cash flows, accounting for imputed labour and land inputs and the treatment of land as a factor of production.

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