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Components of Productivity Growth in Finnish Agriculture

Doctoral Dissertation

Timo Sipiläinen

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Components of Productivity Growth in Finnish Agriculture

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Abstract

The objective of this study was to measure productivity growth and its components in Finnish agriculture, especially in dairy farming. This is of importance when searching for the correct measures – both political and otherwise – to support productivity growth on farms. The objective was also to compare different methods and models – both parametric and non-parametric – in estimating productivity components and the sensitivity of results with respect to different approaches. The parametric approach was also applied in the investigation of various aspects of heterogeneity.

A common feature of the first three articles is that they concentrate, mainly empirically, on technical change, technical efficiency change and the scale effect. The last two articles explore an intermediate route between the Fisher and Malmquist productivity indices and develop a detailed but meaningful decomposition for the Fisher index, including also empirical applications.

Three panel data sets from 1990s have been applied in the study. The data of 138 farms from the extension service describe grass silage production on cattle farms. MTT's bookkeeping farm data set consists of 72 specialized dairy farms. In addition, a separate data set of 459 bookkeeping farms has been applied. The common feature of all data used in the analyses is that they include the periods before and after Finnish EU accession. The second common feature is that the analysis mainly concentrates on dairy farms or their roughage production systems.

Productivity growth on Finnish dairy farms was relatively slow in the 1990s: approximately one percent per year, independent of the method used. Despite considerable annual variation, productivity growth seems to have accelerated towards the end of the period. There was a slowdown in the mid-1990s at the time of EU accession. No clear immediate effects of EU accession with respect to technical efficiency could be observed. However, average technical efficiency often showed a declining trend, meaning that the deviations from the best practice frontier are increasing over time. This suggests different paths of adjustment at the farm level. Technical change has been the main contributor to productivity growth on dairy farms. However, different methods to some extent provide different results, especially for the subcomponents of productivity growth.

In most analyses on dairy farms the scale effect on productivity growth was minor. A positive scale effect would be important for improving the competitiveness of Finnish agriculture through increasing farm size. This small effect may also be related to the structure of agriculture and to the allocation of investments to specific groups of farms. The result may also indicate that the utilization of scale economies faces special constraints in Finnish conditions. However, the analysis of a sample of all types of farms has suggested a more considerable scale effect than the analysis on dairy farms.

Index words: technical change, efficiency, scale effect, Malmquist, Fisher, TFP, index

Tuottavuuskasvun osatekijät Suomen maataloudessa

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Tiivistelmä

Tutkimuksen tavoitteena oli mitata tuottavuuskasvua ja sen osatekijöitä Suomen maataloudessa, erityisesti maidontuotannossa. Tämä on tärkeää, kun etsitään oikeita keinoja tukea tuottavuuden kasvua tiloilla. Tavoitteena oli myös verrata eri menetelmiä ja malleja – sekä parametrisia että ei-parametrisia – tuottavuuden osatekijöiden määrittämisessä. Parametrista lähestymistapaa sovellettiin myös tutkittaessa heterogeenisuutta aiheuttavia tekijöitä.

Yhteisenä piirteenä kolmelle ensimmäiselle artikkelille on, että ne keskittyvät, enimmäkseen empiirisesti, tekniseen muutokseen, teknisen tehokkuuden muutokseen ja skaalavaikutukseen – kolmeen laajasti käytössä olevaan tuottavuuden muutoksen osatekijään. Kahdessa viimeisessä artikkelissa tutkitaan Fisher- ja Malmquist-tuottavuusindeksien keskinäistä yhteyttä sekä kehitetään yksityiskohtainen mutta tulkittavissa oleva dekomponointi Fisher-indeksille. Artikkeleihin sisältyy myös empiirinen sovellus.

Tutkimuksessa käytetään kolmea aineistoa 1990-luvulta. Maatalousneuvonnan tuottama 138 tilan paneeliaineisto kuvaa säilörehuntuotantoa kotieläintiloilla. 72 maitotilan MTT:n kirjanpitoaineistoa sovelletaan kahdessa artikkelissa. Lisäksi viimeisessä artikkelissa käytetään erillistä kaikkia tuotantosuuntia edustavaa 459 kirjanpitotilan aineistoa. Aineistojen yhteisenä piirteenä on, että ne sisältävät ajanjakson ennen Suomen EU-jäseneksi liittymistä ja sen jälkeen. Lisäksi analyysi keskittyy pääasiassa maitotiloihin ja niiden karkearehun tuotantoon.

Tuottavuuden kasvu on ollut suomalaisilla maitotiloilla melko hidasta 1990-luvulla: noin prosentin vuodessa kaikilla käytetyillä menetelmillä. Huomattavasta vuotuisesta vaihtelusta huolimatta, tuottavuuden kasvu näyttää kiihtyneen tutkimusjakson loppua kohti. Tuottavuuskasvu hidastui 1990-luvun puolivälissä EU:in liittymisen aikoihin. EU-jäsenyydellä ei kuitenkaan havaittu olevan välitöntä vaikutusta tekniseen tehokkuuteen. Kuitenkin keskimääräinen tekninen tehokkuus on hienoisessa trendinomaisessa laskussa ajan myötä. Tämän perusteellakin tilatasolla on noudatettu erilaisia sopeutumispolkuja. Tekninen muutos on ollut keskeinen tuottavuuskasvuun vaikuttava tekijä maitotiloilla. On kuitenkin huomattava, että eri menetelmät tuottavat jossain määrin erilaisia tuloksia erityisesti tuottavuuskasvun osatekijöiden suhteen.

Useimmissa analyyseissa skaalavaikutus tuottavuuskasvun osatekijänä on maitotiloilla vähäinen. Positiivinen skaalavaikutus olisi tärkeä, kun suomalaisen maatalouden kilpailukykyä pyritään parantamaan tilakoon kasvattamisen kautta. Vähäinen skaalavaikutus lienee kytköksissä vallitsevaan tilarakenteeseen ja investointien allokoitumiseen tiettyihin tilaryhmiin. Tulos merkinnee myös sitä, että mittakaavaetujen hyödyntämiselle on erityisiä esteitä Suomen olosuhteissa. Toisaalta eri tuotantosuuntia edustavien tilojen tulosten perusteella skaalavaikutus tuottavuuskasvun osatekijänä näyttää olevan suurempi kuin yksinomaan maitotiloja tarkasteltaessa.

Asiasanat: tekninen muutos, tehokkuus, skaalavaikutus, Malmquist-indeksi, Fisher-indeksi, kokonaistuottavuus

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The empirical research would not have been possible without the data. Two of the articles of the dissertation are based on the data from Association of Rural Advisory Centres, currently ProAgria. PhD Mikko Siitonen never stopped asking the tricky question about completing the thesis. Three of the articles rely on the bookkeeping farm data from MTT Economic Research, for which I am grateful to the former head of the bookkeeping office Mr. Juhani Ikonen and to the current research manager of business accounting, Lic.Sc. Arto Latukka.

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Helsinki, February 2008

Timo Sipiläinen

List of original articles

The thesis is a summary and discussion of the following articles, which are referred to by their Roman numerals:

I Sipiläinen, T. and Ryhänen, M. 2005. Technical change in Finnish grass silage production. Agricultural and Food Science 14(3): 250–263. (© Copyright of Agricultural and Food Science)

II Sipiläinen, T. 2007. Sources of productivity growth on Finnish dairy farms – Application of an input distance function. Food Economics – Acta Agriculturae Scandinavica, Section C 4(2): 65–76. (© Copyright of Taylor and Francis Group)

III Sipiläinen, T. Sources of productivity growth on Finnish dairy farms – The scale effect in the decomposition of Malmquist productivity index. Submitted manuscript to Food Economics.

IV Kuosmanen, T., Post, T. and Sipiläinen, T. 2004. Shadow price approach to total factor productivity measurement: with an application to grass-silage production. Journal of Productivity Analysis 22: 95–121. (© Copyright of Kluwer Academic Publishers)

V Kuosmanen, T. and Sipiläinen, T. Exact decomposition of the Fisher ideal total factor productivity index: With an application to Finnish farms. Submitted manuscript to Journal of Productivity Analysis.

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Authors contribution

Article I is based on the joint research project concerning the Finnish grass-silage production. The research was carried out at the University of Helsinki, when the authors were working there. The development of the theoretical framework and the empirical approach, the data collection and processing and the analysis have mainly been performed by Mr. Sipiläinen. Both authors have contributed in the writing of the report.

Article IV started as collaboration between Kuosmanen and Post. Mr. Sipiläinen joined the team in a later stage. Thus, the theoretical part of this article was developed together by Kuosmanen and Post. Mr. Sipiläinen conducted the empirical application of the paper, including the data collection and processing, computations, and reporting and interpreting the results.

The theoretical part of article V emerged from the discussions during Mr. Sipiläinen’s visit at the Wageningen University in the Netherlands in 2002. The formal analytical treatment is mainly due to Kuosmanen, but Mr. Sipiläinen also actively contributed to the development of the decomposition. The application to Finnish farms was conducted by Sipiläinen, including the data collection and processing, and all computations. Both authors have contributed in the writing of the report.

Contents

1 Introduction

The demand for productivity growth has become a focus of current political discussion. The competitiveness of firms and even nations has been closely linked to their productivity. The need for productivity improvements drives firms to make their operations more effective, for example by reducing their workforce. The resulting productivity growth helps them to sustain their competitiveness on the market. Rising costs of welfare services are also increasing pressures on the productivity of the public sector as the population is ageing. Even in cases where productivity growth with respect to conventional inputs and outputs coincides with the equal environmental burden of production, productivity growth may enhance environmental sustainability in the sense that fewer resources per unit of output are consumed.

The discussion on productivity and productivity growth in Finnish agriculture has also raised increasing concerns. The integration of Finnish agriculture into the European and global markets means that it is even more difficult to protect primary production from foreign competition. It is also well known that the productivity of Finnish agriculture has been relatively low, mainly because of the natural conditions but also for historical reasons. Therefore, in addition to finding ways to compensate for the natural disadvantages, it is important to search for ways to improve farm performance.

Productivity is a physical measure and can be defined as the ratio of outputs to inputs: how much output we can obtain from one unit of input. When there is only one output (O) and one input (I), calculating this ratio (P) is straightforward: P = O/I. Productivity change is then an increase or a decrease in this ratio. Even when all inputs and outputs change by the same proportion over time, calculating productivity growth is easy. If inputs grow by λ and outputs by γ, productivity changes by γ / λ. However, each input and output often changes non-proportionally over time. From this it follows that we need specific estimation methods for measuring productivity change.

Partial productivities (e.g., kg milk per hour of labour input) are often used instead of total factor productivity, which covers all inputs and outputs of the units under comparison. Total factor productivity is not easy to measure. Therefore, it is tempting to use partial measures such as labour productivity, e.g. kg of milk per hour of labour input. However, we know that it is possible to substitute capital for labour. In the analysis, looking only at partial productivity may result in misleading interpretations. For example, if the output remains unchanged but increasing capital input reduces the demand for labour, our analysis concerning labour input shows increasing labour productivity and decreasing capital productivity. However, the aggregate input usage does not necessarily change at all, and total factor productivity with respect to capital and labour remains unchanged.

Several methods have been suggested and used in the measurement of productivity growth. The most commonly used methods are index numbers and parametric or nonparametric estimation of productivity change (see for example Coelli et al. 1998; Diewert and Nakamura 2003). The most commonly used indices are the Tornquist quantity index (Törnqvist 1936) and the Fisher quantity index (Fisher 1922). These indices also fulfil most of the 20 properties required for ideal indices (Diewert 1992). The above-mentioned index number formulae have been shown to support various functional forms and behavioural assumptions, but their determination does not necessitate any estimation. On the other hand, the indices presume that both price and quantity information are available, setting high demands for the availability of data. The less extensive data requirement with respect to prices is one of the reasons why the Malmquist index (Malmquist 1957; Caves et al. 1982; Färe et al. 1994a,b,c) has become so popular in productivity analysis.

When no firm specific price data are available an assumption that the firms are facing uniform or equal prices is powerful. If this assumption is valid it does not matter whether we are actually measuring, for example, input quantity or input cost at a certain time point. Of course, over time we have to take price changes into account in this specific input cost category in order to also provide a correct proxy for the input quantity over time. This additionally shows that the uniform or equal price assumption has often also been applied although not explicitly announced in the preparation of data for several Malmquist index studies. This means that many applications actually utilize some information about prices even if they claim to apply Malmquist indices because of missing price data. We should also note that the use of prices cannot be avoided in the estimation Malmquist indices, either. However, the prices are not actual but their shadow values.

The Malmquist productivity index and Fisher ideal index are equivalent under fairly restrictive assumptions (see Diewert 1992; Färe and Grosskopf

1992). Diewert refers to a particular flexible functional form, but Färe and Grosskopf refer to a set of assumptions concerning production technology and economic behaviour. These include monotonicity, convexity and constant returns to scale properties of the technology and allocative efficiency with respect to profit-maximizing behaviour. Balk (1993), in turn, has critically noted that it is unrealistic to assume that a firm could be allocatively efficient with respect to the previous period and future prices for the same set of input quantities.

Caves et al. (1982) introduced the Malmquist index approach based on distance functions[1] to production economics, applying a translog function. The approach was further developed and popularized by Färe et al. (1994a,c), who applied a non-parametric mathematical programming approach when estimating distance functions. These functions describe the technology and therefore do not, in principle, depend on price information. The distance functions applied in this study rely on Shephard's (1953, 1970) definition of distance functions (proportional expansion or contraction), which are reciprocals of Farrell's (1957) measures of technical efficiency. Input and output orientations are usually separated, although other directions or definitions, for example non-radial (Färe and Lovell 1978; Russell 1987), hyperbolic (Färe et al. 1994b) or directional (Chambers et al. 1996, 1998) could also be applied.

The popularity of the Malmquist index approach is also related to the fact that decompositions of the index have generally been available. At first, productivity growth was seen as equal to technical change, i.e., the shift of the production frontier/function (i.e., the time derivative of the production function; Solow 1957). Nishimizu and Page (1982) were the first to separate technical change (the shift of the frontier) and technical efficiency change (the change in the distance from the frontier) components in productivity growth. The same components were present in the Färe et al. (1994b) non-parametric decomposition of the Malmquist index. The two above-mentioned components of technical change and technical efficiency change are widely recognized and used. More debate has centred on whether benchmark (constant returns to scale) technology or best practice (variable returns to scale) technology should be used, or how to define the scale effect in non-parametric decompositions (Ray and Desli 1997; Färe et al. 1994a,c; Lovell

[1] See in more detail in Articles II and III

2003). These issues are important, since the choices made affect the magnitude of components in the productivity decomposition. Therefore, the analysis of various decompositions played an important role in this study.

As is well known, the concept of inefficiency involves two components: technical and allocative inefficiency. While technical inefficiency is related to the distance from the production frontier (or isoquant), allocative inefficiency is linked to deviation from the optimal input and output mixes. In the discussion of Malmquist indices above, allocative inefficiency has been ignored. However, decompositions of productivity (or output) growth including allocative and price effects have recently also been presented (Karagiannis et al. 2004; Karagiannis and Tzouvelekas 2005; Brümmer et al. 2003; Kumbhakar and Lovell 2000; Bauer 1990). In addition, we should note that productivity growth is naturally not the ultimate goal of a firm as such, but profitability is the driving force behind it. When firms, like farms, are price takers, their options in enhancing profitability mainly lie in their ability to improve their input output relation (productivity) and to allocate their resource (input) and product (output) sets optimally.

1.1 Objectives of the study

The starting point for this study was linked to Finnish EU accession at the beginning of 1995. This caused a drastic change in the economic environment of Finnish farmers. Thus, the starting point for the thesis was mainly empirical, but during the process the work evolved more towards theoretical considerations on how farm productivity and its components can be measured. The study aimed at yielding estimates of productivity change and decompositions for defining the main sources of this change. The grounds for the evaluation of the changes in components lie in three points: Firstly, EU accession exposed Finnish farms and processors to a common market, which increased foreign competition and the demand for improved productivity. Secondly, the small average size of Finnish farms is a competitive disadvantage that could probably be at least partially removed by increasing farm size. This, however, necessitates farms being able to exploit economies of scale. In Finnish natural conditions this may be more difficult than in more favourable regions. Third, at the time of EU accession, direct acreage payments as a proportion of total returns increased considerably. This was expected to affect farmers’ incentives to produce technically efficiently. Therefore, it was also of interest to separate technical efficiency from other productivity components.

More specifically, the objective was to examine the decomposition of productivity growth into its sources on Finnish farms during the 1990s. This is of importance when searching for the correct measures – both political and otherwise – to support productivity growth on farms. The objective was also to use and compare different methods and models – both parametric and non-parametric – in estimating productivity components and the sensitivity of results with respect to different approaches. The parametric approach was also applied in the investigation of various aspects of heterogeneity.

A common feature of the first three articles is that they concentrate, mainly empirically, on technical change, technical efficiency change and the scale effect – the three widely recognized technical components of productivity change. The objectives of the last two articles are more theoretically oriented. The aim of Article IV is to explore an intermediate route between the Fisher and Malmquist productivity indices so as to minimize data requirements and assumptions about the economic behaviour of production units and their production technology. Article V aims at developing a detailed but meaningful decomposition for the Fisher index and also providing an empirical application for the decomposition derived in the study.

1.2 Outline of the thesis

The thesis consists of five articles. In the thesis, both parametric and non-parametric approaches are applied in the determination and decomposition of productivity growth. The applications with the parametric approach utilize stochastic frontier analysis (SFA), where the estimation method is based on maximum likelihood. The error term in the estimation can be divided into two components: technical inefficiency and noise. Technical inefficiency is represented as one-sided deviation from the frontier, while noise is a stochastic two-sided error term. A model variant is applied where the factors explaining technical inefficiency can be estimated simultaneously with the estimation of the frontier function (Battese and Coelli 1995). A detailed description of the method can be found in Coelli (1996), Greene (2003) or Kumbhakar and Lovell (2000). The estimations are performed by the programs Frontier 4.1 and Limdep 8.0.

In the first article, stochastic production frontier analysis is applied in decomposing output growth of grass silage production into technical change, technical efficiency change, the scale effect and input growth. In addition to the decomposition, the effects of technology choice on productivity are clarified. The second article applies a similar stochastic frontier model but in the form of input (output) distance functions. The decompositions are based on the Malmquist productivity index (Orea 2002; Newman and Matthews 2006). In this case, the results of input and output distance functions are compared and the connection between size and technical efficiency is also examined.

The last three articles apply non-parametric methods. In the non-parametric applications, data envelopment analysis (DEA) is utilized (for example Charnes et al. 1978; Banker et al. 1984; Färe et al. 1994b). The DEA approach does not make any distinction between technical inefficiency and noise, but the whole deviation from the frontier is interpreted as inefficiency. On the other hand, in the non-parametric approach there is no need to specify a specific functional form, as in the parametric approach. The DEA approach applied in this study is non-stochastic, although non-parametric stochastic counterparts have also been developed (Kuosmanen 2006). The DEA-based inefficiency scores were estimated by MSExcel, OnFront 2.0 and GAMS.

The third article examines the sources of productivity change on Finnish dairy farms in the 1990s through alternative decompositions, for instance into technical change and technical efficiency change. Special attention is given to defining scale efficiency and the scale effect. The role of the scale effect seems to have been partially neglected in non-parametric productivity analysis, although it has been an important element of parametric analysis. Several methods and decompositions have been suggested for analyzing the sources of productivity change. In this paper, the output-oriented Malmquist productivity index is adopted, and it is decomposed according to Färe, Grosskopf, Norris and Zhang (1994c), Ray and Desli (1997) and Lovell (2003). The approach of Färe et al. starts from changes in the benchmark (constant returns to scale) technology, while the starting point of Ray and Desli is the best practice (variable returns to scale) technology. In the latter approach it is possible to take into account the scale effect in the form of a scale change factor instead of scale efficiency change, in addition to technical change and technical efficiency change. In the multi-input multi-output case, input mix and output mix effects can be determined when analyzing the scale and volume effect (Lovell 2003). From the empirical data, indices are calculated applying DEA-based output distance functions.

The last two articles are more theoretically oriented. The fourth article explores an intermediate route between the Fisher and Malmquist productivity indices so as to minimize data requirements and assumptions about the economic behaviour of production units and their production technology. Assuming quantity data on inputs and outputs and the behavioural hypothesis of allocative efficiency, the exact value of the Fisher ideal productivity index is calculated using implicit shadow prices revealed by the choice of input-output mix. The approach is operationalized by means of a nonparametric data envelopment analysis (DEA) model for empirical farm data on silage production.

The fifth article extends the decompositions of total factor productivity (TFP) to Fisher indices. This paper presents an exact decomposition of the Fisher ideal TFP index that leaves no debatable mixed-period components or residual terms. The article systematically isolates the five effects of 1) technical change, 2) technical efficiency, 3) scale efficiency, 4) allocative efficiency change, and 5) the change in price strength. The three efficiency components 2) to 4) further decompose into input- and output-side effects. The new decomposition is compared with alternative decompositions presented in the literature (Färe et al. 1994c; Ray and Mukherjee 1996; Zofio and Prieto 2006), both theoretically and by means of an empirical application.

Three data sets have been applied in the study. The data from the extension service describes grass silage production on cattle farms. It is a complete panel of 138 farms for 1990 to 2000. The data have formed the basis of the empirical application in Articles I and IV. MTT's bookkeeping farm data for a panel of 72 specialized dairy farms covering the years 1989 to 2000 have been used in Articles II and III. In addition, a separate panel data set of 459 bookkeeping farms has been applied in Article V. This period of the analysis in this case covers the years 1992 to 2000. Thus, the common feature of all data used in the analyses is that they include the periods before and after Finnish EU accession. The second common feature is that the analysis mainly concentrates on dairy farms or their roughage production systems. A more detailed description of the data sets has been presented as a separate data section in each article.

2 Results and discussion

The objective of this study was to provide answers to questions related to the measurement of productivity growth and its components in Finnish agriculture, especially in relation to dairy farming. General research questions were presented in Section 1 and more in detail in each of the five articles. The articles handle the same topic, productivity, but raise different aspects and methods relevant for the measurement of productivity. The articles utilize three data sets, the common feature of which is that they are panel data from the same time period of the 1990s before and after Finnish EU accession.

The purpose of this chapter is to summarize the answers to the research questions, to discuss the results and to provide general conclusions. In addition, topics for future research are suggested.

The contribution of the first three articles of this study lies mainly in their empirical applications. The first two applied the stochastic parametric frontier approach, but to different data sets. The second and third articles utilized the same data but different methods, as non-parametric DEA was applied in article three. Despite the similarities between the articles with respect to the components of productivity, they have been fine-tuned differently. The first article applied a special case of output distance functions, the frontier production function, but the main contribution lay in the analysis of how to take the heterogeneity of production systems into account. An artificial nested test was introduced to the stochastic frontier production function framework when searching for the most appropriate model specification (see Battese and Coelli 1988, 1992, 1995; Coelli 1996 and the model suggested by Coelli et al. in 1999).

The results demonstrated a link between the shape and location of the production frontier and the harvesting technique, the location of the farm and the share of arable land area under grass. The results suggest that differences between harvesting techniques should be interpreted more as indicators of various production conditions and farmers' objectives than as a primary source of technical inefficiency. One should also consider whether it is reasonable to compare all units with the same best practise frontier or whether one should take into account background or production environment related differences, especially those that the decision-maker cannot control. The analysis showed, for example, that precision chopping was generally the most technically efficient harvesting technique, but when the heterogeneity of production frontiers was taken into account, precision-chopping farms actually became less efficient relative to their own frontier than flail-chopping farms. Round baler farms, in turn, were less technically efficient than flail-chopping farms, independently of the model specification. We should, however, take into consideration that the choice of the harvesting technique is not the only difference: farms employing flail chopping have often avoided long-term investments in their harvesting technique. It is also evident that harvesting with the flail chopper produces the highest field yields, since in this technique the losses are the smallest at the time of harvesting. However, the losses are greater in storage and feeding, but this cannot be taken into account in the analysis when no records are available.

The silage area on the sample farms steadily increased during the research period, resulting in a total output growth exceeding 6% per year. Although the input use per hectare decreased, the total input growth was the most important factor explaining the output growth at the farm level. This result is in accordance with Ahmad and Bravo-Ureta (1995), among others. According to the specified models, the annual technical progress was approximately 1.4%. Despite the general trend in technical change, the annual variation was large. Estimated models showed a slight tendency towards declining technical efficiency over time, but the scale effect was negligible.

The second and third articles examined productivity changes on Finnish dairy farms by applying the Malmquist productivity index and its extensions. Over time, several decompositions of the index have been proposed in order to define the sources of productivity growth (*e.g.* Färe et al. 1994a,c, Ray and Desli 1997; Lovell 2003). Many of the applications, as also the application in the third article, have been non-parametric and non-stochastic. In Article III, the components of productivity growth were identified from the stochastic input distance function. The application followed the approaches suggested by Brümmer et al. (2002), Karagiannis et al. (2004), Kumbhakar and Lovell (2000) and Orea (2002).

The specification tests in Article II suggested that the input distance function provides a slightly better fit of the data than the output distance function, being in line with the fact that under the milk quota regime the behavioural hypothesis of cost minimization is consistent with the production environment.

The results showed that productivity growth was relatively modest in the 1990s and mostly related to (neutral) technical change. In the stochastic input distance function the scale effect was also a considerable contributor to productivity change, especially at the end of the research period. This result is understandable when taking into account that the scale elasticity was larger than one and the input use increased over time. Investments in the enlargement of dairy farms started to grow in 1996–1997 because of the introduction of state-sponsored investment subsidies and less restrictive quota policies. Uncertainties related to EU accession in 1995 were also likely to have postponed farmers' development decisions and their implementation in the early 1990s.

EU accession did not seem to have a significant effect on technical efficiency as such, but technical efficiency steadily decreased over time. This may have been related to changes in the income structure (increasing direct payments and lower sales revenue), but it is also likely to be related to changes in investment patterns. The result of increasing technical inefficiency indicates that it may be difficult to maintain technical efficiency in the adjustment process and that variation between farms increases over time. Some of the farms were lagging behind the frontier farms.

Although farm size could explain part of the variation in technical inefficiencies among dairy farms, this result in our sample was dependent on the orientation of the stochastic distance function. While the output-oriented distance function suggested increasing technical efficiency in relation to farm size, the result was the opposite with the input orientation (c.f. Sipiläinen and Heshmati, 2004). The result of the stochastic input distance function also contradicted that in Sipiläinen (2003), which suggested a positive connection between farm size and technical efficiency in a DEA model of constant returns to scale. Thus, even though, for example, Coelli and Perelman (1999, 2000) and Orea et al. (2004) found a strong correspondence between the results of input and output orientations, this is obviously not always the case.

In the stochastic input distance function the scale elasticity was considerably larger than one (indicating increasing returns to scale), but the increase in technical inefficiency was also the largest. The result suggests that in the present sample the scale effect and the distribution of technical efficiency were interrelated. The returns to scale result also differed from the output distance function approach applied in Sipiläinen and Heshmati (2004), where RTS was on average decreasing. On the other hand, the RTS of the input distance function was approximately at the same level as in the study of Morrison Paul et al. (2004). Because of the high RTS and increasing input use, the role of the scale effect in productivity growth was considerable at the beginning (negative) and at the end of the research period (positive), but over the whole period it was negative. If the first year was removed from the analysis the scale effect would have been positive for the whole period and in some years even the biggest contributor to productivity growth.

The process of EU accession seems to have affected productivity growth firstly by reducing and postponing investment and then by boosting it. The changes in behaviour are related to both uncertainty and support measures such as investment aids. Increased investment led to growing herd sizes in the latter part of the 1990s. The growth of farms makes it possible to utilise modern technology to improve productivity, but it is too early to determine whether productivity growth will continue to increase or accelerate from the low level of the 1990s. Productivity growth needs to be more rapid in order for Finnish dairy farms to keep up with, or even catch up with, dairy farms in other countries.

Article III utilizes the same data set as Article II but a different method, non-parametric output-oriented DEA, in deriving the Malmquist index and its components. In order to reduce the effect of stochastic variation, three-year moving averages were used. According to the results, productivity growth in this case was also on average slow, as in the applications of Articles I and II, and the variation between farms was large. The same perception also concerns the components of productivity change, and especially the scale effect. The results suggest that although the average values of respective components in different decompositions are close to each other, the components may differ significantly, even in sign, at the farm level. This conclusion is consistent with the observations of Lovell (2003).

In a DEA-based approach, Ray and Desli's and Lovell's decomposition of the Malmquist productivity index seem intuitively appealing, since they separated the scale effect into one specific component, while in Färe et al. (1994c) the decomposition appears through two separate components (technical change and scale efficiency change when the actual technology is not constant returns to scale). Lovell's suggestion for further decomposing this so-called activity or volume effect, where scale efficiency plays no explicit role, into the radial scale effect and input and output mix effects is also more in the spirit of production economics. However, Färe et al. (1994a) suggested the decomposition of technical change into magnitude change (measured along the ray) and input and output biases, which could also take into account the changes in input and output mixes over time. Lovell (2003) also suggested the decomposition of technical change as an alternative to the decomposition of the activity effect. However, the decomposition suggested by Färe and Grosskopf (1996) is problematic, since it is not independent of the choice of the base period in the bias component.

In the present case, the number of observations was relatively small. The differences between various decompositions may be relatively smaller in larger samples, but as Lovell (2003) has shown, even qualitative differences in technical change are still possible in a sample of approximately 100 units. However, the results for technical change under variable- and constant-returns-to-scale reference technology, and for scale efficiency and the scale change factor for the whole study period are almost identical, suggesting that the difference in the average scale effect is small, independent of the definition of the measure.

Table 1 collates the results of the three articles. Altogether, the average annual productivity changes are at the same level in each analysis. The differences are larger in the decompositions, but in every case technical change is the main contributor to productivity growth. The largest differences are related to the stochastic input distance function.

Table 1. Average annual productivity change (%/a) and its components for 1990–2000 reported in Articles 1 to 3.

	A1	A2	A3(F)	A3(RD)	A3(L)
Technical change	1.43	0.88	1.21	1.06	1.06
Technical efficiency change	-0.19	-0.48	0.02	0.02	0.02
Scale effect	-0.01	0.65	-0.28	-0.13	-0.55
Input mix effect					0.42
Productivity change	1.23	1.09	0.94	0.94	0.94

A1: Stochastic parametric frontier production function of silage production
A2: Stochastic input distance function of milk production
A3: Non-parametric output distance function of milk production (three-year averages)
(F: Färe et al. (1994c) decomposition; RD: Ray and Desli (1997) decomposition; L: Lovell (2003) decomposition)

The contribution of the last two articles is more theoretical, departing from the typical Malmquist-type approach and extending the analysis towards the estimation and decomposition of Fisher indices. In earlier decompositions only technical elements of productivity growth have been considered without setting any specific assumptions in the sense of economic behaviour.[2] In the fourth article the conditions of the Malmquist productivity index have been re-examined to coincide with the Fisher ideal TFP index, and these insights have been utilized to calculate Fisher productivity indices from the quantity data, utilizing implicit shadow prices revealed by the observed mix of inputs and outputs. The proposed approach sets both minimal data requirements and minimal assumptions about firm behaviour and production technology. Similarly to the Malmquist approach, our approach only required data on input and output quantities. In contrast to the conventional Malmquist approach, however, we did not make any strong assumptions about the technology, except that all observed input-output combinations were feasible. Instead, we built on economic theory and economic assumptions in the spirit of Afriat (1972) and Varian (1984). Specifically, we assumed that firms chose input-output combinations that were allocatively efficient (at least by approximation) in terms of return-to-the-dollar maximization ('profitability'). This hypothesis enabled us to recover the underlying economic prices (or a range of possible prices) from the observed choices of input-output quantities. Of course, this limits the scope of the method to situations where our economic assumptions hold, at least by reasonable approximation. On the other hand, our method applies to a much more general class of technologies than the usual Malmquist techniques. For example, our approach avoids difficulties with increasing returns or economies of scale, non-convexities, or congestion of production factors.

It is known in theory that the difference between the Fisher and the Malmquist indices should be rather small in practice (Balk 1993). Therefore, the empirical part of the paper compared the results of Fisher and Malmquist productivity indexes in a real-world application to see how well the Malmquist index approximates the shadow-price Fisher index, and vice versa. The application concerned the productivity development of grass-silage production on Finnish dairy farms in the 1990s.[3] We expected some differences in

[2] We should note that the input distance function and cost function as well as the output distance function and revenue function are dual to each other.
[3] The same data set was applied in Article I.

this application because relative prices and the input mix changed quite radically during this decade as result of Finland's accession to the European Union in 1995. The main findings were that 1) the two approaches gave highly uniform results throughout the period considered when averaged over the entire sample of 138 farms; but 2) there are considerable differences in the two indices at the level of individual farms. The circular test was also empirically investigated by comparing the product of annual TFP indices to the directly-calculated TFP index from 1990 to 1999. Major circular gaps were found at the level of individual farms in both indices, but these gaps cancelled out almost perfectly when averaged over the sample of farms. These findings suggest that alternative techniques can yield relatively robust results at the more aggregate level of the sample. However, analyzing productivity developments at the level of individual firms appears rather sensitive to the choice of index formula, the length of the time period, and assumptions concerning firm behaviour and production technology.

The firth article develops a new decomposition of the Fisher TFP index. This decomposition is compared to the Malmquist decomposition of Färe, Grosskopf, Norris and Zhang (1994) and to Fisher decomposition of Ray and Mukherjee (1996) and Zofio and Prieto (2006). By introducing the maximum return to dollar (profitablility) measure (given prices) and applying input and output distance functions as well as cost and revenue functions we were able to present the Fisher index as the product of technical efficiency, technical change, scale efficiency, allocative efficiency and the price strength components. We should note that even though the names of the components may be similar in different approaches, they have been constructed in a different manner. Thus, they also describe slightly different aspects of production. Despite this, our proposed decomposition is important for many reasons. The decomposition further enhances our general understanding of the Fisher index. For example, we note that changes in allocative efficiency contribute to the Fisher index as separate components, but not to the Malmquist index (compare with Färe and Grosskopf 1992; Balk 1993; and Kuosmanen et al. 2004). Note that allocative component is also included in Ray and Mukherjee's and Zofio and Prieto's decomposition. However, by distinguishing between input- and output-oriented sub-components, and technical and allocative efficiency, and by introducing the new price strength component (the relative change in the input-output price ratio), the present decomposition can provide a detailed picture of the driving forces behind productivity change.

The decomposition is even more detailed than the decompositions suggested in the other two alternative decompositions.

The results suggest a fairly similar productivity growth with respect to the Malmquist and Fisher indices, as expected. The largest differences were observed at the end of the period under investigation. All presented decompositions indicate a decrease in average technical efficiency in the sample. In turn, scale efficiency and allocative efficiency tend to improve over time. Technical change shows mixed results in various decompositions. Even the sign is different, as our suggested decomposition shows a slightly positive trend, while the other two decompositions suggest a slightly negative trend over time. However, the differences in absolute terms were small.

The decomposition enhances our understanding of the sources of productivity growth as well as the position of the Fisher index as a useful index number formula for productivity analysis. The proposed decomposition may also provide useful insights for other decompositions. While the existing Malmquist decompositions usually assume either input or output orientation, our decomposition builds on geometric means of both input and output oriented sub-components. A similar approach might in principle be adapted to the Malmquist decompositions. Our decomposition may inspire debate about the relative merits of different index number formulae used in productivity measurement. We believe there is no single superior index number for all empirical studies, although the Malmquist index dominates in productivity decompositions. Different index formulae may be appropriate depending on the purposes of the analysis and the interpretation of productivity.

3 Conclusions

1) Productivity growth on Finnish cattle farms was relatively slow in the 1990s: approximately one percent per year, independent of the method used. Despite considerable annual variation, productivity growth seems to have accelerated towards the end of the period. There was a slowdown in the mid-1990s at the time of EU accession.

2) No clear immediate effects of EU accession with respect to technical efficiency could be observed. However, average technical efficiency showed a declining trend, meaning that the deviations from the best practice frontier are increasing over time. This suggests different paths of adjustment at the farm level.

3) Technical change has been the main contributor to productivity growth on dairy farms. However, the empirical evidence suggests that the level of efficiency is not independent of the estimation or computation method. Different methods to some extent provide different results, especially for the sub-components of productivity growth. Therefore, the decompositions should be interpreted with care.

4) Farm-level components deviate considerably more than average effects between methods of measurement. This raises some concerns with respect to the use of individual performance measures in farm-level evaluation.

5) Despite this, careful analysis of the decompositions is likely to provide valuable insights for the policy analysis.

6) In most analyses on dairy farms the scale effect was minor. A positive scale effect would be important for improving the competitiveness of Finnish agriculture through increasing farm size. This small effect may also be related to the structure of agriculture and to the allocation of investments to specific groups of farms. The result may also indicate that the utilization of scale economies faces special constraints in Finnish conditions. We have, however, to keep in mind that the data samples in the study are relatively small. The analysis of a sample of all types of farms for 1992 to 2000 has suggested a more considerable scale effect.

7) Many productivity decompositions start from the Malmquist index. We have shown that interpretable decompositions can also be derived for the Fisher index, not only for the Malmquist index. The advantage of the

Fisher index decompositions is that they can also cover allocative effects on productivity change.

8) Productivity growth is typically a small residual compared to the total quantities of inputs and outputs. Thus, relatively small changes in one or both of them can lead to considerable changes in the estimated growth of productivity. This is problematic, especially in agriculture where the annual variation in crop yields is typically high. Therefore, for example, the effect of periods under investigation (e.g. the effect of the first and last year in the sample) should be chosen carefully. Neither should short-term changes be interpreted as long-term policy effects with respect to productivity trends.

This study mainly describes the changes from a historical point of view and concentrates on the policy perspective, where EU accession plays the most important role. However, decisions concerning production activities are made at the farm level, usually by the farm family. Differences in technical efficiency could be observed and also different development paths of productivity over time. Despite this, the present analyses cannot provide specific tools enabling farmers to improve performance in practise. It is even difficult to precisely say how large the actual improvement potential is in the heterogeneous environment. The good news is that there is considerable variation between farms, which can offer at least some improvement potential in the future.

Productivity growth is essential from the perspective of competitiveness. The role of productivity growth increases as international competition grows. When prices have to be taken as given, productivity growth and the optimal allocation of inputs and outputs are the ways farmers are able to improve their economic performance. What are the most suitable ways to promote it? Are they aimed at accelerating technical progress, increasing farm size or reducing technical inefficiency? It seems important to promote both the frontier performance and also the performance of the farms not reaching the frontier. Both options are at least to some extent related to the competence and education as well as the managerial skills of the farmer. Perhaps one of the most important sources of resource heterogeneity is managerial competence, although we have keep in mind that the heterogeneity of resources such as land quality or climate are difficult or even impossible to eliminate. This is also the reason why Finnish farmers cannot reach the high productivity levels of the most favourable production regions.

4 Summary

The objective of the study was to analyse productivity growth on Finnish farms during the 1990s. The period is of interest because of the drastic changes due to Finnish EU accession at the beginning of 1995. The aim was to compare different methods, both parametric and non-parametric, in estimating productivity changes and in decomposing productivity growth into its sources. This is of importance when searching for the correct measures, both political and otherwise, to support productivity growth on farms.

The thesis consists of five articles. In the first article, a stochastic production frontier analysis is applied in decomposing the output growth of grass silage production into technical change, technical efficiency change, the scale effect and input growth. In addition to the decomposition, the effects of technology choice on productivity are clarified. The second article applies a similar stochastic frontier model but in the form of an input (output) distance function. The decompositions are based on the Malmquist productivity index. In this case the results of input and output distance functions are compared and the association between farm size and technical efficiency is also examined.

The last three articles apply non-parametric methods, utilizing data envelopment analysis (DEA). The DEA approach does not make any distinction between technical inefficiency and noise, but the whole deviation from the frontier is interpreted as inefficiency. On the other hand, no specific assumptions about the functional form are needed. In this sense the approach is non-stochastic. The third article examines the sources of productivity change on Finnish dairy farms in the 1990s through alternative decompositions. Special attention is given to defining scale efficiency and the scale effect. The role of the scale effect seems to have been partially neglected in non-parametric productivity analysis, although it has been an important element of parametric analysis. In the empirical data, indices are calculated applying the DEA-based output distance functions.

The last two articles are more theoretically oriented. The fourth article explores an intermediate route between the Fisher and Malmquist productivity indices so as to minimize data requirements and assumptions about the economic behaviour of production units and their production technology. Assuming quantity data on inputs and outputs and the behavioural hypothesis of allocative efficiency, the exact value of the Fisher ideal productivity index is calculated using implicit shadow prices revealed by the choice of input-output mix. The approach is operationalized by means of the non-parametric data envelopment analysis (DEA) model for empirical farm data on silage production.

The fifth article extends the decompositions of total factor productivity (TFP) to Fisher indices. This paper presents an exact decomposition of the Fisher ideal TFP index that leaves no debatable mixed-period components or residual terms. We systematically isolate five effects of 1) technical change, 2) technical efficiency, 3) scale efficiency, 4) allocative efficiency change, and 5) the change in price strength. The three efficiency components 2) - 4) further decompose into input- and output-side effects. The new decomposition is compared with alternative decompositions presented in the literature both theoretically and by means of an empirical application

Three data sets have been applied in the study. Data from the extension service describes grass silage production on cattle farms. It is a complete panel of 138 farms from 1990 until 2000. The data have formed the basis of the empirical application in Articles I and IV. MTT's book-keeping farm data for a panel of 72 specialized dairy farms covering the years 1989 to 2000 have been used in Articles II and III. In addition, a separate panel data set of 459 book-keeping farms has been applied in Article V. This period of the analysis in this case covers the years 1992 to 2000. Thus, the common feature of all data used in the analyses is that they include the periods before and after Finnish EU accession. The second common feature is that the analysis mainly concentrates on dairy farms or their roughage production systems.

The main results and conclusions can be summarized as follows:

a) Productivity growth on Finnish cattle farms was relatively slow in the 1990s: approximately one percent per year, independently of the method used. Despite the considerable annual variation, productivity growth seems to have accelerated towards the end of the period. There was a slowdown in the mid-1990s at the time of EU accession.

b) No clear immediate effects of EU accession with respect to technical efficiency could be observed. However, average technical efficiency showed a declining trend, meaning that the deviations from the best practice frontier are increasing over time. This suggests different paths of adjustment at the farm level.

c) Technical change has been the main contributor to productivity growth on dairy farms. However, the empirical evidence suggests that the level of efficiency is not independent of the estimation or computation method. Different methods provide to some extent different results, especially for the sub-components of productivity growth. Therefore, the decompositions should be interpreted with care.

d) Farm-level components deviate considerably more than average effects between the methods of measurement. This raises some concerns with respect to the use of individual performance measures in farm-level evaluation.

e) Despite this, a careful analysis of the decompositions is likely to provide valuable insights for policy analysis.

f) In most analyses on dairy farms the scale effect was minor. A positive scale effect would be important for improving the competitiveness of Finnish agriculture through increasing the size of farms. This small effect may also be related to the structure of agriculture and to the allocation of investments to specific groups of farms. The result may also indicate that the utilization of scale economies faces special constraints in Finnish conditions. We have, however, to keep in mind that the data samples in the study are relatively small. The analysis of a sample of all types of farms for 1992 to 2000 has suggested a more considerable scale effect.

g) Many of productivity decompositions start from the Malmquist index. We have shown that interpretable decompositions can also be derived for the Fisher index, not only for the Malmquist index. The advantage of the Fisher index decompositions is that they can also cover allocative effects on productivity change.

h) Productivity growth is typically a small residual compared to total quantities of inputs and outputs. Thus, relatively small changes in one or both of them can lead to considerable changes in estimated productivity growth. This is problematic, especially in agriculture where the annual variation in crop yields is typically high. Therefore, for example, the effect of periods under investigation (e.g. the effect of the first and last year in the sample) should be carefully examined. Neither should short-term changes be interpreted as long-term policy effects with respect to productivity trends.

5 Yhteenveto

Tutkimus koostuu viidestä artikkelista, joiden tavoitteena oli mitata tuottavuuskehitystä ja tutkia tuottavuuskehityksen jaottelua (dekomponointia) eri tekijöihin suomalaisessa maatila-aineistossa 1990-luvulla. Ajanjakso on mielenkiintoinen, koska EU-jäsenyys vuonna 1995 aiheutti voimakkaan muutoksen suomalaisten maatilojen toimintaympäristössä. Tavoitteena oli verrata eri menetelmiä – sekä parametrisia että ei-parametrisia – tuottavuusmuutoksen estimoinnissa sekä tuottavuuskasvun jaottelussa eri lähteisiin. Näiden lähteiden tunnistaminen on tärkeää, jotta poliittisilla ja muilla keinoilla voitaisiin tukea maatilojen tuottavuuskasvua.

Ensimmäisessä artikkelissa sovelletaan stokastista tuotantorintamafunktioanalyysia maatilojen säilörehutuotoksen kasvun dekomponointiin. Tuotoksen kasvu jaoteltiin tekniseen muutokseen, teknisen tehokkuuden muutokseen, skaalavaikutukseen sekä panosten käytön lisäykseen. Dekomponoinnin lisäksi selvitettiin teknologiavalinnan vaikutusta tuottavuuteen. Toisessa artikkelissa sovellettiin samanlaista stokastista rintamamallia, mutta tällöin käytettiin panosetäisyysfunktiota (myös tuotosetäisyysfunktiota). Maitotilojen tuottavuuskasvun dekomponoinnit perustuvat Malmquist-tuottavuusindeksiin. Tässä artikkelissa verrattiin panos- ja tuotosetäisyysfunktioiden tuottamia tuloksia ja tutkittiin yhteyttä tilakoon ja teknisen tehokkuuden välillä.

Kolmessa viimeisessä artikkelissa sovellettiin ei-parametrisia menetelmiä tehokkuuden mittausmenetelmiä. Ei-parametrisissa sovelluksissa käytettiin paloittain lineaarista DEA -rintamamenetelmää. DEA -lähestymistavassa ei tehdä eroa teknisen tehottomuuden ja satunnaisvirhetekijöiden välillä, vaan kaikki poikkeamat tehokkuusrintamasta tulkitaan tehottomuudeksi. Tässä mielessä lähestymistapa on ei-stokastinen, mutta toisaalta menetelmää käytettäessä tuotantoteknologiasta tehtävät oletukset ovat olennaisesti parametrista menetelmää vähäisemmät. Kolmannessa artikkelissa tutkittiin vaihtoehtoisia tuottavuuskehityksen dekomponointeja samalla aineistolla kuin artikkelissa kaksi. Erityishuomiota kiinnitettiin skaalavaikutuksen määrittelyyn ja mittaamiseen. Skaalavaikutuksen rooli näyttää jääneen melko vähäiselle huomiolle ei-parametrisessa analyysissa. Empiirisessä aineistossa komponentit laskettiin DEA:han perustuvien tuotosetäisyysfunktioiden avulla.

Kaksi viimeistä artikkelia ovat edellisiä teoreettisempia. Neljännessä artikkelissa tutkittiin yhteyttä Fisher- ja Malmquist-tuottavuusindeksien välillä niin, että voitaisiin minimoida aineistovaatimukset ja taloudelliset käyttäytymisoletukset sekä oletukset tuotantoteknologiasta. Olettaen, että käytössä on tiedot panosten ja tuotosten määristä sekä että tuotanto on allokatiivisesti tehokasta, laskettiin Fisher-tuottavuusindeksien arvot panos-tuotossuhteiden paljastamien varjohintojen avulla. Menettelytapaa sovellettiin DEA -menetelmää käyttäen maatilojen säilörehuaineistoon.

Viides artikkeli laajensi kokonaistuottavuusindeksin dekomponointia Fisher-indekseihin. Tämä artikkeli esitteli jaottelun, jossa ei jäänyt jäljelle periodien välisiä termejä eikä jäännöstermejä. Artikkelissa erotettiin systemaattisesti viisi tuottavuusvaikutusta: tekninen muutos, teknisen, skaala- ja allokatiivisen tehokkuuden muutos, sekä hintasuhteiden muutos. Tehokkuuden muutoskomponentit voitiin edelleen jaotella panos- ja tuotosvaikutuksiksi. Uutta jaottelua verrattiin vaihtoehtoisiin, aiemmin kirjallisuudessa esitettyihin dekomponointeihin sekä teoreettisesti että empiirisen sovelluksen avulla.

Tutkimuksessa käytettiin kolmea aineistoa. Neuvontajärjestöltä saatu aineisto kuvasi säilörehuntuotantoa kotieläintiloilla. Se on täydellinen paneeli 138 tilalta vuosilta 1990–2000. Aineistoa käytettiin artikkelien I ja IV empiirisissä sovelluksissa. MTT:n kirjanpitotilojen paneeliaineistoa 72:lta maidontuotantoon erikoistuneelta tilalta vuosilta 1989–2000 käytettiin artikkeleissa II ja III. Lisäksi erillistä 459 tilan paneeliaineistoa vuosilta 1992–2000 käytettiin artikkelissa V. Siten aineistojen yhteisenä piirteenä oli, että ne kattoivat ajanjakson ennen ja jälkeen Suomen EU:hun liittymistä. Toinen yhteinen piirre oli, että analyysi keskittyi pääasiassa maitotiloihin ja niiden karkearehun tuotantoon.

Keskeiset tulokset ja johtopäätökset voidaan vetää yhteen seuraavasti:

a) Tuottavuuden kasvu suomalaisilla kotieläin-/maitotiloilla oli suhteellisen hidasta 1990-luvulla – noin prosentin vuodessa menetelmästä riippumatta. Huolimatta huomattavasta vuotuisesta vaihtelusta, tuottavuuden kasvu näyttää kiihtyneen tarkastelujakson loppua kohti. Tuottavuuskasvu oli hidasta EU:hun liittymisen aikoihin 1990-luvun puolivälissä.

b) EU-jäsenyydellä ei ollut erityistä välitöntä vaikutusta tekniseen tehokkuuteen. Kuitenkin, keskimääräinen tehokkuus heikkeni trendinomaisesti, joten poikkeamat parhaista käytännöistä kasvoivat ajan myötä. Siten tilojen sopeutumispolut näyttävät erkaantuneen toisistaan ajan myötä. Empiiriset tulokset osoittivat, että teknisen tehokkuuden taso ei ollut riippumaton estimointimenetelmästä.

c) Tekninen muutos on ollut keskeinen tuottavuuden kasvua edistävä tekijä. Erilaiset estimointimenetelmät tuottivat kuitenkin jossain määrin erilaisia tuloksia erityisesti tuottavuuskasvun osatekijöiden osalta. Sen vuoksi yksittäisen dekomponoinnin tuloksia on syytä tulkita varovasti.

d) Tilatason komponentit poikkeavat toisistaan merkittävästi enemmän kuin keskimääräiset vaikutukset menetelmien välillä. Tämä osoittaa, että tilakohtaisten komponenttien käyttöön jatkoanalyyseissa liittyy epävarmuutta.

e) Tästä huolimatta, huolellinen komponenttien analysointi tuottaa todennäköisesti arvokasta tietoa poliittisen päätöksenteon tueksi.

f) Useimmissa tapauksissa skaalavaikutus oli vähäinen suomalaisilla maitotiloilla. Positiivinen skaalavaikutus olisi tärkeä, jotta suomalaisten tilojen kilpailukykyä voitaisiin edistää tilakoon kasvun kautta. Vähäinen skaalavaikutus saattaa kuitenkin olla kytköksissä maatalouden nykyiseen rakenteeseen ja investointien allokoitumiseen tiettyihin tilaryhmiin. Tulos antaa siten viitteitä siitä, että mittakaavaetujen hyödyntämiselle on erityisiä rajoitteita Suomen olosuhteissa. On kuitenkin huomattava, että käytetyt aineistot ovat suhteellisen pieniä. Analyysi, jossa käytettiin kaikentyyppisiä tiloja vuosilta 1992–2000, osoitti huomattavasti suurempien mittakaavaetujen olemassa oloa.

g) Useat tuottavuuden dekomponoinnit perustuvat Malmquist-indekseihin. Olemme kuitenkin osoittaneet, että myös Fisher-indeksille on mahdollista johtaa tulkittavissa oleva dekomponointi. Fisher-indeksin dekomponoinnin etuna on, että siinä voidaan ottaa huomioon myös allokatiiviset vaikutukset tuottavuuden muutokseen.

h) Tuottavuuskasvu on tyypillisesti pieni jäännöserä verrattuna panosten ja tuotosten käytön kokonaismääriin. Siten suhteellisen pienet muutokset yhdessä tai molemmissa niistä saattavat johtaa huomattaviin muutoksiin tuottavuuden kasvussa. Tämä on ongelmallista erityisesti maataloudessa, jossa vuotuiset satovaihtelut ovat tyypillisesti suuria. Sen vuoksi, esimerkiksi tutkimusajanjakson alku- ja loppuajankohdan vaikutusta ajanjakson tuottavuuskasvuun tulisi arvioida huolellisesti. Vastaavasti lyhyen aikavälin muutoksia ei pitäisi tulkita politiikkamuutosten pitkän ajan tuottavuusvaikutuksiksi.

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