ORGANIC FARMING IN DENMARK – PRODUCTIVITY, TECHNICAL CHANGE AND MARKET EXIT

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Abstract

This paper attempts to quantitatively measure the change in the productivity of Danish organic farming in recent years. Based on a translog production frontier framework the technical and scale efficiency on farm level is analysed by following a time trends as well as a general index model specification. We further try to analyse the significance of subsidies for promoting long term growth in organic production by estimating a bootstrapped bivariate probit model with respect to factors influencing the probability of organic market exit. The results revealed significant differencies in the organic farms' technical efficiencies, no significant total factor productivity growth and even a slightly negative rate of technical change in the period investigated. We found evidence for a positive relationship between subsidy payments and an increase in farm efficiency, technology improvements and a decreasing probability of organic market exit which was also confirmed for off farm income.

Keywords

Organic Farming, Total Factor Productivity, Market Exit

1 Introduction

The promotion of organic farming has become an essential element of supranational and national food policy throughout Europe as well as other continents to promote safe and environmentally friendly food production. However, the finding that organic farming technology has developed with relatively little input from scientific oriented research still holds (see Oude Lansink et al. 2002). Empirical evidence on the dynamic development of organic farming with respect to the underlying production structure is still rare and mostly based on partial measures of economic performance (see e.g. Jacobsen et al. 2005). So far, the issue of technical change and productivity development over time seems to be poorly investigated mainly because of a lack of adequate data at the farm level (most recently Sipilaeinen/Oude Lansink 2005). Denmark is currently one of the top-ten countries in Europe with regard to the share of organically cultivated area. However, in the last three to five years Denmark experienced a kind of stagnation with respect to the further development of the organic farming sector described as a 'natural weakening' by sectoral policy advisors (see e.g. Norfelt 2005): While the export of organic products could not been expanded also the domestic consumption stagnated resulting in a total surplus of organic production. After continuing growth the total number of organic farms declined in this period from 3714 in 2002 to 3166 in the year 2004. Experts expect an enduring recession of organic farming in Denmark. This paper attempts to quantitatively measure the change in productivity for Danish organic farming in recent years by using panel data on 56 organic farms mainly engaged in milk production for the period 2002 to 2004. Section 2 gives a brief overview of recent

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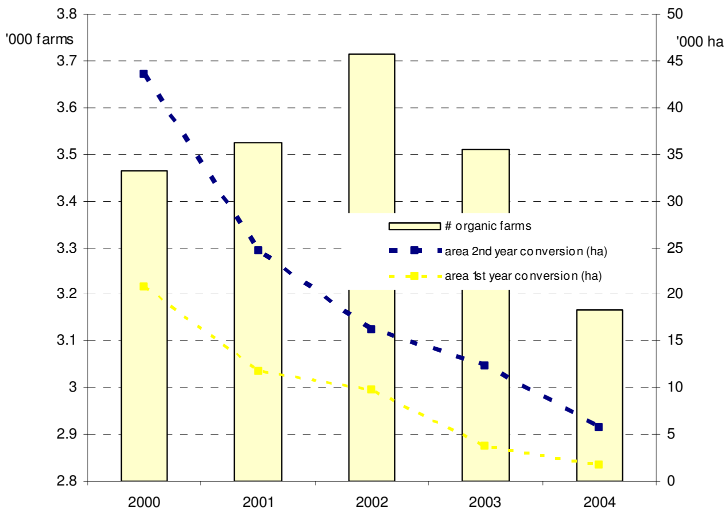
developments in the organic farming sector in Denmark, section 3 summarises the modelling approaches as well as the main findings of most relevant economic studies on organic farming. Section 4 gives a brief theoretical review of the concepts of total factor productivity and market exit as well as outlines the underlying research hypotheses and the different models applied. Section 5 describes the data set and estimation procedures used followed by the exposition and discussion of the estimation results in section 6. Section 7 finally concludes.

2 Organic Farming in Denmark – Sectoral Developments

In the last 10 to 15 years the total organic production in Europe nearly tripled (Hæring et al. 2004) whereas approximately 4-5% of the total agricultural area is organically cultivated. The organically cultivated total area in Denmark increased dramatically until the late 1990s whereas in the period from 1998 to 2000 the largest amount of farms under conversion to organic farming was experienced. These growth rates led to ambitious expectations with respect to the future development of organic farming in Denmark: in 1999 the Organic Council forecasted an organic share of 11% of the total agricultural area for 2003 and a long-term share of even up to 30% (The Organic Council 1999). During this period of growth the highest increase in area cultivated was reached by large dairy farms mainly situated in the southern part of Jutland (see Jacobsen et al. 2005). However, since the year 2000 the rate of farms under conversion to organic farming is dramatically declining (see figure 1).

Figure 1: Organic Farms and Area Under Conversion in Denmark 2000 - 2004



In the year 2003 only 62 new applicants were registered whereas 266 organic farms left the market – either by cessation of production or by converting back to conventional production. During the year 2004 the net number of organic farms exiting the market even increased by 69% to 344. Preliminary estimates for 2005 assume an ongoing decline in the total agricultural area organically cultivated mainly driven by the exit of dairy farms (DAAS 2005). At the same time (November 2003) the overall political approach to the subsector of organic agriculture switched from an inflexible, more environmentally oriented to a flexible, more market oriented approach (Norfelt 2005). The current support scheme aims at linking subsidy payments and environmental benefits. Experts, however, doubt the effectiveness and logic of this approach and expect an enduring recession of organic farming in Denmark. This pronounced decline in organic farming in recent years is more or less unique throughout Europe (Nieberg et al. 2005, Jacobsen et al. 2005). Market observers name as the main factors for this decline falling product prices stemming from decreasing consumption and export demand as well as reduced support measures. Part time farming already plays an important role for organic production in Denmark and the majority of farms converting to organic production in the future is expected to mainly belong to this subsector (Jacobsen et al. 2005). Such part time farmers earn a large amount of their total income outside organic farming which makes the dependence on subsidy payments less pronounced. The succes of the latter is on the other hand crucially determined by the actual labor productivity and consequently the rate of technical change realized in the future to reduce the workload by farming activities. Large organic milk production accounts for the main part of current organic agriculture in Denmark, its ongoing importance is assumed by different sector observers. Because of this relative importance the following empirical analysis focuses organic milk farms all over Denmark. Explanations for the recent decline in organic production found in the relevant literature are solely oriented towards a demand side argumentation stressing the implications of declining or stagnating consumption and hence product price decreases (see most recently Jacobsen et al 2005). However, also supply side factors have to be stressed in order to fully understand the driving forces for the observed recession in Danish organic farming: significant organic overproduction reinforces ceteris paribus farm competition based on relative farm efficiency and the relative total factor productivity development over time. The individual organic farmer is concerned with relative profits and for the latter the relative efficiency of the agricultural operations is crucial. In addition, the mid to long term success of policy efforts to promote organic farming is crucially based on an adequate level of the individual farms' efficiencies (see also Tzouvelekas et al 2001a, b). So far, the efficiency as well as the productivity developments in organic farming have not been investigated for Denmark and only rarely for other European countries (see section 3). The previously described developments in the sector suggest significant differences in farms' total factor productivities and their development over the last years.

3 Relevant Analyses and Research Desiderata

Economic research with respect to organic farming on the farm level has been started in the mid 1990s and can be basically divided into two strands: empirically oriented analyses mainly applying a multivariate framework and more consultancy oriented partial economic analyses. Partial analyses using single productivity and cost measures have been conducted with respect to organic crop farms in France (Rainelli/Vermersch 2000) and organic farming in the Czech Republic (Jánský et al. 2003). Multivariate studies revealed the following insights so far: Tzouvelekas et al (2001a) found relatively high efficiency scores for conventional and organic cotton farms in Greece and a high inefficiency explaining power for the age and education of the farmers. Both types of farming exhibited a high allocative efficiency, however, organic farms in the sample were found to be less technically and consequently less overall efficient. The findings on the olive and durum wheat farms more or less confirmed these findings (Tzouvelekas et al. 2001b, 2002). Oude Landsink et al (2002) compared the efficiency of organic and conventional crop and livestock producers in Finland and concluded on a higher relative efficiency of organic farms with respect to the organic frontier, but lower with respect to the overall frontier considering also conventional farms. Madau (2005) confirmed earlier studies on a higher average efficiency of conventional farms with respect to cereal farms in Italy for 2000 as well as 2001. Flaten and Lien (2005) concluded on a higher significance of production and institutional constraints than the degree of risk aversion for organic farming decisions in Norway. So far, the only contribution tackling the development of organic fams' efficiency over time was done by Sipilainen and Lansink (2005) by applying a stochastic distance frontier in a translog specification on a sample of conventional and organic dairy farms in Finland for the period 1995 – 2002. The results confirmed again a lower technical efficiency of organic farms and revealed that after an initial drop in farms' efficiencies in the period of conversion to organic farming, approximately 6 years after conversion farms' efficiencies start to increase again. The authors conclude on significant learning effects with respect to organic farming refering to the evidence found by innovation adoption studies. With respect to market entry and exit behaviour of organic farms Pietola and Lansink (2002) analysed factors determining the choice between standard and organic farming technology in Finland by applying a switching-type Probit model. Their findings suggest that decreasing conventional product prices as well as increasing subsidy payments are significant factors for initiating the switch to organic farming which is more likely for farms cultivating a larger area and achieving relatively low yields. This implies an adverse selection problem for policy actions.[1] Whereas the studies on organic farming in Finland have investigated market entry as well as post entry behaviour of organic farms no study so far has attempted to shed empirical light on factors and developments leading to farms exiting the organic farming sector. However, a growing body of literature examines the main factors determining the likelihood of business dissolution by modelling a measure of firm exit as a function of several variables designed to reflect structural incentives and barriers to market exit as well as individual firm characteristics. Here e.g. economies of scale, overall industry growth, profitability, market concentration, capital requirements, sunk costs, R&D, firm size as well as the firm's leverage ratio and its age are used as potential explanatory variables (see e.g. Audretsch 1994, 1995, 2000). Most recently several studies relate also a firm's relative level of technical inefficiency to the probability of exiting the market (Wheelock/Wilson 1995, Dimara et al. 2003, Tsionas/Papadogonas 2005).

The following analysis aims to contribute empirically as well as methodologically to the previously conducted studies by using panel data on 56 milk farms for the period 2002 to 2004. The estimation of a stochastic production frontier aims at filling the gap with respect to multivariate performance measures for the Danish organic sector. The development of total productivity, technical change as well as technical and scale efficiency is further analysed by applying a time trends model specification as well as a general index specification by also considering the current discussion on functional consistency (see Barnett 2005 or Sauer 2006). We investigate the significance of different explanatory factors for the variance in technical change as well as efficiency change over time and try to conclude on the relative significance of policy support measures. We finally attempt to make inferences on the likelihood of organic market exit by using proxies for a potential farm exit. We account for small sample bias by using bias corrected resampling methods and link them to developments in policy relevant farm characteristics over the relevant period. Given the prevailing overproduction in the organic dairy sector and the long term policy goal of stimulating growth in organic production, beside setting incentives for farm conversion feasible policy measures could also be targeted on giving support for farms found to be likely 're-converters' to conventional production. This, of course, only if a future strengthening in the demand for organic dairy products can be reasonabily expected.

4 Total Factor Productivity and Probability of Market Exit – Hypotheses and Modelling

This lead us to the following research hyoptheses:

***Hypothesis 1*:** Significant differences in the organic farms' technical efficiencies and total factor productivities can be expected predominantly as a consequence of differing management abilities and states of technology conversion.

***Hypothesis 2*:** A significant increase in the average total factor productivity has not taken place for organic milk production over the last years. However, because of learning effects among organic farmers a positive average technical change can be assumed for the sector.

***Hypothesis 3*:** Because of the increased ability to afford technology improvements subsidy payments are expected to have a positive influence on the development of technical efficiency as well as technical change on organic farm level. Mixed evidence can be expected for the influence of off farm income as positive efficiency effects because of a softer budget constraint might be outweighed by negative efficiency effects because of a tighter labor constraint. However, a tighter labor constraint could on the other hand also imply positive efficiency effects because of incentives to work more

[1] The study by Klonsky and Smith (2002) investigated the entry/exit behaviour for California's organic farming sector more from a sectoral point of view.

productive and a softer budget constraint could also lead to negative efficiency effects because of disincentives to effective investments.

***Hypothesis 4*:** The probability of organic market exit is expected to be negatively affected by an increase in subsidy payments received as well as an increase in total off farm income earned.

4.1. Time Varying Technical Efficiency

Following basically Farrell (1957), technical efficiency (TE) denotes a production unit's ability to achieve maximum output given its set of inputs and considering its production restrictions, i.e. exogenous determinants. An organic milk production frontier provides the upper boundary of all organic milk production possibilities, i.e. every organic milk producer in the sample is located with his input/output combination on or beneath this frontier. Hence, the determination of relative technical efficiency with respect to organic milk production in Denmark is concerned with measuring the distance of each farmer from this production frontier. As the stochastic frontier approach is capable of capturing measurement error and other statistical noise influencing the shape and position of the production frontier we consider it as superior in an agricultural production context largely influenced by randomly exogenous shocks as e.g. climatic influences. However, the stochastic approach to efficiency measurement is subject to prior decisions on the distributional form of the inefficiency component of the error term as well as the modelling of the underlying technology. Because of a lack of significantly varying output and input prices Danish organic milk farming seems to be adequately modelled by the behavioural assumption of output maximisation and hence a production function framework. Hence, an output orientation of the frontier was chosen here. We model technical efficiency of organic milk production by applying a time varying stochastic error components approach (see Kumbhakar et al. 1991, Kumbhakar/Lovell 2000) using the flexible functional form of a translog production function. The single stage production frontier model avoiding inconsistency problems with respect to the econometric specification is formulated as

$$\ln y_{it} = \beta_{ot} + \sum_n \beta_n \ln x_{nit} + \sum_n \sum_k \beta_{nk} \ln x_{nit} \ln x_{kit} + \varsigma_t \ln c_{it} + v_{it} - (\gamma' z_{it} + \varepsilon_{it}) \qquad [1]$$

with y_{it} as the organic milk output of farm i at time t (t = 2002, 2003, 2004), x_{nit} as the variable input n (n = land, labor, materials, cows) of farm i at time t, c_{it} as the quasi-fixed input capital of farm i at time t and where random noise in the production process is introduced through the error component $v_{it} \sim iid\ N(0,\sigma_v^2)$ and the technical inefficiency component u_{it} including a systematic component $\gamma' z_{it}$ associated with the (1xM) vector of exogenous variables z_{lit} (z = investments in capital and machinery, investments in milk quota, organic subsidies, veterinary expenses, external finance, external income, regional location) and γ as an (Mx1) vector of unknown scalar parameters to be estimated as well as a random component ε_{it} . The nonnegativity requirement $u_{it} = (\gamma' z_{it} + \varepsilon_{it}) \geq 0$ is modelled as $\varepsilon_{it} \sim N(0,\sigma_\varepsilon^2)$ where the distribution of ε_{it} being bounded below by the variable truncation point $-\gamma' z_{it}$ (Battese/Coelli 1995 based on Huang/Liu 1994). The technical efficiency of the i-th producer at time t is given by

$$teff_{it} = \exp\{-u_{it}\} = \exp\{-\gamma' z_{it} + \varepsilon_{it}\} \qquad [2]$$

where the predictor function is given in Battese/Coelli 1995. We impose symmetry in inputs by $\beta_{nk} = \beta_{kn}$, homotheticity as well as homogeneity of degree 1 by $\sum_n \beta_n = 1, \sum_n \sum_k \beta_{nk} = 0$. Hence we estimate the translog frontier model in a variable as well as a constant returns to scale specification which enables us to reveal also evidence on the scale efficiency of farm i at time t

$$seff_{it} = teff_{it}^{vrs} / teff_{it}^{crs} \qquad [3]$$

4.2 Technical Change and Total Factor Productivity 1 – Time Trend Specification

By linking the stochastic frontier approach to a time trend specification we are hence able to disentangle the effect of technical change from that of technical efficiency change (Kumbhakar 1990, Battese/Coelli 1992). By following a non-neutral or biased technical change model specification we include beside first and second order time related terms also terms involving the interactions of the variable inputs and time. The technical change index per farm and period is then obtained directly from the estimated parameters by simple calculations

$$tch_{it,t+1}^{tt} = \left\{ \left[1 + \frac{\partial \ln y_{it}}{\partial t_i} \right] * \left[1 + \frac{\partial \ln y_{it+1}}{\partial t_{i+1}} \right] \right\}^{½} \qquad [4]$$

following basically Nishimuzu and Page (1982) as well as Coelli et al. (1998) and using the geometric mean to estimate the technical change index between adjacent periods t and t+1. Technical change is neutral if $\delta_{nt} = 0$ for all inputs n and can be decomposed into pure ($\chi_t + \chi_{tt} t$) and non-neutral technical change $\delta_{nt} \sum_n \ln x_{nit}$. In the case of non-neutral technical change the measure of the bias in technical change is simply

$$b_n^{tt} = \frac{\partial \ln X_{int}}{\partial t} = \frac{\delta_{nt}}{\theta_{int}} + \theta_{int} \qquad [5]$$

where θ_{int} is the factor or input elasticity of input n. Technical change is biased towards input n as $b_n > 0$ and input n saving if $b_n < 0$. θ_{int} and b_n are both farm and time varying. By observing that $d_i^t\left(x_{it}, y_{it}\right) = teff_{it} \neq d_i^{t+1}\left(x_{it+1}, y_{it+1}\right) = teff_{it+1}$ where **x** and **y** are the input and output vectors and d as the distance from the period t observation to the period t technology, the change in technical efficiency per farm and period is obtained by

$$effch_{it,t+1}^{tt} = teff_{it+1} / teff_{it} = \exp\left\{-\gamma' z_{it+1} + \varepsilon_{it+1}\right\} / \exp\left\{-\gamma' z_{it} + \varepsilon_{it}\right\} \qquad [6]$$

and correspondingly change in scale efficiency per farm and period is obtained. Both indices - technical efficiency change by [6] and technical change by [4] - are then multiplied to obtain the Malmquist total factor productivity indezes (tfp) per farm and period as defined in distance notation

$$tfp_{it,t+1}^{tt}\left(y_{it}, x_{it}, y_{it+1}, x_{it+1}\right) = \frac{d_i^{t+1}\left(y_{it+1}, x_{it+1}\right)}{d_i^t\left(y_{it}, x_{it}\right)} \left[\frac{d_i^t\left(y_{it+1}, x_{it+1}\right)}{d_i^{t+1}\left(y_{it+1}, x_{it+1}\right)} * \frac{d_i^t\left(y_{it}, x_{it}\right)}{d_i^{t+1}\left(y_{it}, x_{it}\right)} \right]^{½} = effch_{it,t+1}^{tt} * tch_{it,t+1}^{tt} \qquad [7]$$

and following Faere et al. (1994). Different likelihood ratio (LR) tests are applied using the common LR test statistic to test for (i) the appropriatness of the flexible translog specification, (ii) homotheticity of the production function, (iii) homogeneity of degree 1, (iv) constant versus variable returns to scale specification, and (v) no technical change. With respect to the underlying regression assumptions we further test for heteroscedasticity as well as serial correlation by a F-test formula following Wooldridge (2002). Nevertheless, there are other competing specifications with respect to the measurement of technical change and total factor productivity available in the literature.

4.3 Technical Change and Total Factor Productivity 2 – General Index Specification

Baltagi and Griffin (1988) proposed an econometric procedure for estimating a general index (gi) of technical change which has been most recently extended by Kumbhakar (2004) by adding the definition of tfp growth as an additional equation to be simultaneously estimated with the production or dual cost system. The translog production function incorporating the general index can be written as

$$\ln y_{it} = \beta_{ot} + \sum_n \beta_n \ln x_{nit} + \chi_t a(t) + \sum_n \sum_k \beta_{nk} \ln x_{nit} \ln x_{kit} + \chi_{tt} a(t)^2 + \sum_n \delta_{nt} \ln x_{nit} a(t) + \varsigma_t \ln c_{it} + \sum_l \gamma_l \ln z_{lit} + \varepsilon_{it} \quad [8]$$

with variables' and indezes definitions as above and a(t) as the index of technical change

$$a(t) = a \sum_t \phi_t d_t \quad [9]$$

where d are the year dummies. Technical change in the general index model is defined by

$$tch^{gi}_{it,t+1} = -\left\{a(t+1) - a(t)\right\}\left\{\chi_t + \chi_{tt}\left\{a(t+1) + a(t)\right\}\right\} - \left\{a(t+1) - a(t)\right\}\left(\sum_n \delta_{nt+1} \ln x_{int+1}\right) \quad [10]$$

and is consequently both farm and time specific. Total factor productivity growth is obtained by

$$tfp^{gi}_{it,t+1} = tch^{gi}_{it,t+1} + (1 - \theta^{gi}_{it+1})\dot{y}_{it+1} \quad [11]$$

where θ^{gi}_{it+1} denotes the scale elasticity for observation i at time t+1 corresponding to the sum of the individual input elasticities

$$\theta^{gi}_{it} = \sum_n \left(\partial \ln y_{it} / \partial \ln x_{int}\right) = \sum_n \left(\beta_n + \sum_k \beta_{nk} \ln x_{kit} + \delta_{nt} a(t)\right) \quad [12]$$

and $\dot{y}_{it+1}$ as the estimated organic milk output for farm i at time t+1. In the gi specification efficiency changes are not explicitly estimated but can be recovered by following

$$effch^{gi}_{it,t+1} = tfp^{gi}_{it,t+1} / tch^{gi}_{it,t+1} \quad [13]$$

by simply using the results obtained above. These time trend as well as general index model specifications as well as earlier applications lead us to
Hypothesis 5: *It is assumed that the gi model specification performs significantly better than the tt specification with respect to tracking the observed tfp growth in the organic milk sector.*

4.4 Curvature Correctness

Different recent publications point to the importance of correct curvature of the estimated function in order to infer theoretically consistent policy recommendations (see Barnett 2005, Sauer 2006). With respect to the translog production function curvature depends on the specific input bundle X_n, which can be easily verified by the corresponding bordered Hessian containing beside estimated parameters also observed input quantities. Consequently, for some input bundles quasi-concavity may be satisfied but for others not and what can be expected is that the condition of negative semi-definiteness of the bordered Hessian is met only locally or with respect to a range of input bundles. With respect to our translog production models in [1] and [8] it has to be checked a posteriori for every input bundle that monotonicity and quasi-concavity hold. Quasi-concavity can be imposed at a reference point following Jorgenson and Fraumeni (1981) by replacing the negative product of a lower triangular matrix **Δ** times its transpose **Δ'** (see in detail also Sauer 2006). Imposing curvature at the sample mean is then attained by redefining the parameters in [1] and [8] respectively to

$$\beta_{nk} = -\eta_{nk} + \beta_n \lambda_{nk} + \beta_n \beta_k \quad [14]$$

where $\lambda_{nk} = 1$ if n = k and 0 otherwise and $\eta_{nk} = (\Delta\Delta')_{nk}$ as the nk-th element of $\Delta\Delta'$ with Δ a lower triangular matrix. As our point of approximation is the sample mean all data points are divided by their mean transferring the approximation point to an (n + 1)-dimensional vector of ones. At this point the elements of the Hessian do not depend on the specific input bundle.

4.5 Factors for Total Productivity Change – Multiple Equations Systems

However, the models described so far do not focus on the factors for the development in total factor productivity and its components over time we try to stochastically model such relationships by applying a multi equations linear regression procedure using the development in technical change, the development in technical efficiency as well as the development in scale efficiency as dependent variables:

$$tch_{it}^{s} = \sum_{u} \kappa_{tch} x_{uit} + \varepsilon_{itch} \;\; ; \;\; effch_{it}^{s} = \sum_{u} \kappa_{effch} x_{uit} + \varepsilon_{ieffch} \;\; ; \;\; sceff_{it}^{s} = \sum_{u} \kappa_{sceff} x_{uit} + \varepsilon_{isceff} \qquad [15]$$

where s denotes the specific model used: time trends (tt) or general index (gi) specification, and u is an index for the relative development of the following explanatory variables X during the specific time period(s): investments in capital and machinery, investments in organic milk quota, organic subsidies received, veterinary expenses, external finance, external income farmer, external income other family members, total external income including rents and other transfer payments received. A simultaneous equation approach seems adequate as the total productivity components are assumed to be affected by the same farm specific factors as well as stochastic residuals at the same point in time. Consequently, the variations in the unexplained error term are somehow linked over the different single regressions. A Breusch-Pagan test is applied to test for the significance of this underlying modelling hypothesis. As the dependent variables by definition take values greater than zero we further check for the consistency of our approach by also estimating a censored Tobit model for every productivity component and model specification and test for its significance compared to the model outlined in [15]. To test finally for the robustness of our estimates we further apply a simple stochastic resampling procedure based on bias-corrected bootstrapping techniques (see e.g Efron/Tibshirani 1993 or Horowitz, 2001). By using a bias corrected boostrap we aim to reduce the likely small sample bias in the initial estimates. Our forth modelling stage deals with the determination of policy relevant factors for an increasing likelihood of organic market exit.

4.6 Probability of Market Exit – Bivariate Probit Model

There is a significant amount of work on exit and survival of firms originating from the influential papers by Audretsch (1995) and Audretsch and Mahmood (1994, 1995). It is widely assumed that inefficient producers cannot survive in the long run provided the forces of competition in the relevant sector are reasonably strong (see e.g Wheelock/Wilson 1995 or Dimara et al. 2003). With respect to the empirical investigation of this phenomenon different proxies for the likelihood of market exit were found to be significant in the relevant literature (see e.g. Dunne/Roberts 1991, Mayer/Chappel 1992, Wagner 1994, Mahmood 2000, Fotopoulos/Louri 2000 and Segarra/Callejón 2002). Tsionas/Papadogonas (2005) were the first to explicitly link stochastic measures of technical efficiency to the likelihood of market exit whereas the results of many previous studies suggested that high profits and correspondingly low costs as well as high firm productivity have a negative impact on exit behaviour (see Dunne/Roberts 1991, Mayer/Chappel 1999, Doi 1999, and Audretsch et al. 2000). By using the more comprehensive measures of farms' total factor productivity we try to contribute to this line of empirical research by constructing a binary proxy - *exittfp* - for the likelihood of organic market exit based on a relatively low and steady declining tfp score estimated by the models in [1] and [8] for the total period. On the other hand a high level of debt - i.e. a high leverage ratio - requires high interest payments, thus increasing firm risk and reducing the likelihood of survival (Fotopoulos/Louri 2000). Hence, we use as a second proxy for the probability of organic market exit the binary variable *exitlev* reflecting a relatively high and steady increasing leverage ratio calculated by using observed data. We regress these market exit proxies on potentially explaining factors X by applying a bivariate probit model (Kiefer 1982, Greene 1996) described by

$$\begin{aligned} exittfp_i &= \sum_v \zeta_{tfp} x_{vi} + \varepsilon_{itfp}, \quad exittfp_i = 1 \text{ if } exittfp_i > 0, 0 \text{ otherwise} \\ exitlev_i &= \sum_v \zeta_{lev} x_{vi} + \varepsilon_{ilev}, \quad exitlev_i = 1 \text{ if } exitlev_i > 0, 0 \text{ otherwise} \end{aligned} \qquad [16]$$

where X denotes potentially explanatory factors measured by their relative development over the study period. The model in [16] allows for a simultaneous estimation of the two probit models based on the assumption that the disturbances are correlated in the same spirit as outlined for the seemingly unrelated regression model in [15]. The log-likelihood function and its marginal derivatives are described in Greene (2000). We apply a likelihood ratio testing procedure to investigate the statistical relevance of the underlying assumption of non-zero correlation of the disturbances. To test finally for the robustness of our estimates obtained by [16] we again apply a simple bootstrap.

5 Data and Estimation

We use data on a panel of 56 organic milk farms in Denmark for the years 2002 to 2004 (see KVL, 2005). The organic farms were selected by a stratified random sampling procedure out of a total population of approximately 480 organic milk farms all over Denmark. Basic characteristics of the average organic farm in the total sample as well as for the individual years is shown by table 1:

Table 1: The Average Sample Farm

Farm Characteristics – Statistical Mean	Total Sample (n = 168)	Year 2002 (n = 56)	Year 2003 (n = 56)	Year 2004 (n = 56)
Total Revenue (‘000 DKK)	2,807.490	2,717.717	2,749.137	2,955.617
Total Milk Revenue (‘000 DKK)	2,083.749	2,043.989	2,089.619	2,117.638
Labor (hours per year)	4,991.06	4,973.25	4,988.857	5,011.071
Cows (n)	103.762	100.554	104.554	106.179
Material (DKK)	521,898.6	527,529.9	516,482.4	521,683.5
Land (ha)	137.711	135.762	133.697	143.675
Capital (DKK)	1.29e+07	1.21e+07	1.27e+07	1.40e+07
Investments (DKK)	1,279,805	824,001.6	974,209.6	2,041,203
Investment in Milk Quota (DKK)	177,538.8	109,561.8	208,806.5	214,248.1
Organic Subsidies (DKK)	84,860.21	87,697	80,181.05	86,702.57
Veterinary Expenses (DKK)	54,636.72	50,746.18	56,142.55	57,021.43
External Finance (DKK)	1,126,260	631,147.2	1,072,400	1,675,232
Total External Income (DKK)	102,039	102,371	96,800.45	106,946.9
Leverage Ratio (Debt/Total Assets in %)	65.15	63.77	65.11	66.56
Farm Location (1: Jutland, 0: Sealand, Fynen)	0.946	0.946	0.946	0.946
Age of Farmer (years)	46.268	45.268	46.268	47.268
Years Farmer is Operating the Farm (n)	20.375	19.375	20.375	21.375

1: base year 2002, 2: 1 DKK = 0.135 Euro (31.12.2002), 3: producer price index for agricultural materials p.a. 2003: 102.48, 2004: 109.64; general inflation % p.a. 2003: 2.1, 2004: 1.2; price index for milk and dairy products p.a. 2003: 104.95, 2004: 105.29; price index for machinery p.a. 2003: 96.39, 2004: 92.42 (sources: OECD, Danmark Statistic).

All monetary values have been adjusted with respect to the relevant base year prices of 2002. The average farm in the sample shows a total revenue of about 2.8 Mio DKK where about 74% are due to milk production. The average organic farm used in total nearly 5000 labor hours per year, had a herd size of about 104 cows over the year and cultivated about 138 ha land. Materials, as the sum of the expenses for seed, fertilizer, chemicals, fodder as well as organic nutrients purchased, were about 520 000 DKK per year. For the capital input over the year we use the yearly average of total agricultural assets (as a sum of real property, livestock, equipment and stocks in store) per farm in prices of the base year 2002.[2] Hence, the average farm in the total sample showed a quasi-fixed capital input (or capital stock) of about 12.9 Mio DKK p.a. Total investments over the year were nearly 1.28 Mio DKK per farm whereas about 14% of the total sum had been invested in milk quota. The average amount of organic subsidies were about 85 000 DKK, veterinary expenses about 55 000 DKK, and the total amount of income earned outside of agricultural operations were about 100 000 DKK per year and farm. The average farm in the total sample showed further a leverage ratio (the ratio of debt to total assets) of more than 65% implying a total external finance of about 1.13 Mio DKK per year. The average leverage ratio in the sample increased over the sample years (from 63.8% in 2002 to nearly 66.6% in 2004). The average organic milk farm was finally located on Jutland, the farmer's age was about 46 and the latter run the farm for more than 20 years. The econometric estimations have been pursued as follows: In a first step we estimate the time varying error components approach in the time trends specification as well as the general index production function model. The technical efficiency estimates obtained from the error components model are simultaneously regressed on potentially inefficiency variance explaining factors. To reveal evidence on the driving forces for developments in total factor productivity subsequently the multiple equations system is estimated by a bootstrapped iterative seemingly unrelated linear least square regression procedure using the relative changes in the estimated variables. Finally we estimate the bivariate probit model by a bootstrapped but linear least square iterative seemingly unrelated procedure to get quantitative evidence on the driving forces for an increased probability of organic market exit by defining the two binary dependent variables *exittfp* and *exitlev* as

$$exittfp_i = \begin{cases} 1 \text{ if } \mathrm{tfp}_{i,0203} < \mathrm{tfp}'_{0203} \wedge \mathrm{tfp}_{i,0304} < \mathrm{tfp}_{i,0203} \\ 0 \text{ otherwise} \end{cases}; \quad exitlev_i = \begin{cases} 1 \text{ if } \mathrm{lev}_{i,02} > \mathrm{lev}'_{02} \wedge \mathrm{lev}_{i,04} > \mathrm{lev}_{i,02} \\ 0 \text{ otherwise} \end{cases} \qquad [17]$$

where e.g. tfp'_{0203} denotes the average total factor productivity change (over both model specifications) for the period 2002 to 2003 in the sample and lev'_{02} the average leverage ratio for the year 2002 in the sample. All models were estimated by using STATA or Premium Solver.

6 Results and Discussion

We estimated 4 different models (due to space limitations the individual parameter estimates are not reported here but can be obtained from the authors). All model specifications showed to be significant at a satisfying statistical level. For the time trends as well as general index model more than 70% of all estimated parameters are statistically significant. All estimated specifications showed to be theoretically consistent for every observation in the sample. A likelihood ratio test confirmed the chosen functional form of a flexible translog, homotheticity of the underlying production function could not been rejected in a single hypothesis framework, but was significantly rejected by the joint test for linear homogeneity, respectively constant returns to scale. The hypothesis of no technical change in the sample

[2] Because of a lack of data (i.e. replacement costs, depreciation rates) we were not able to use more sophisticated capital measurement techniques as e.g. the perpetual inventory method. However, as we define capital as a quasi-fixed input and incorporate it as a single term along with investments in the estimations we assume that potential measurement errors are relatively insignificant. Such an approximative procedure is followed by several studies in the field.

was rejected at the 1%-level, the same was found for the likelihood ratio test of the underlying modelling assumption of treating capital as a quasi-fixed input. Heteroscedasticity of the error terms was rejected at the 1%-level of significance, the same was found for serial correlation using a F-test formula. With respect to the seemingly unrelated estimation procedure the Breusch Pagan test statistic rejected the independence hypothesis at a significant level for both models. Finally a likelihood ratio test procedure confirmed the applicability of the chosen bivariate probit model frame by rejecting the hypothesis of zero correlation of the disturbances.

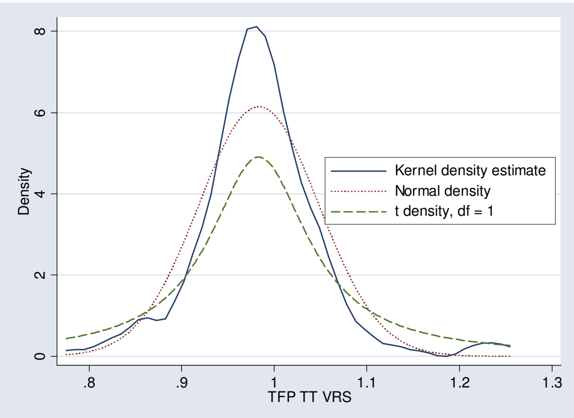
6.1 Total Factor Productivity, Technical Change and Technical Efficiency

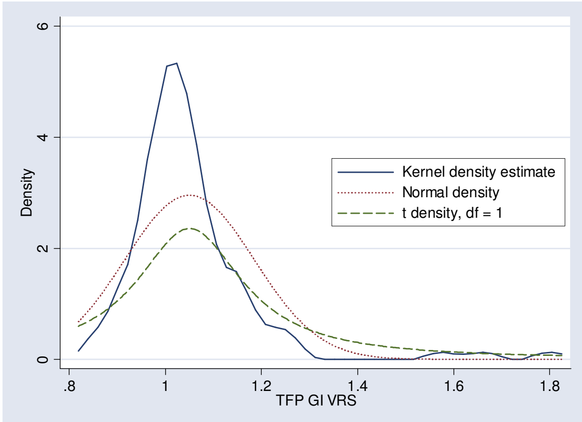
The mean technical efficiency was found to be the lowest in 2003 with a value of about 0.924 for the variable and 0.954 for the constant returns to scale specification. However, it slightly increased for the most current year 2004 up to 0.941 and 0.955 respectively varying between a range of 0.678 and 0.999 and 0.671 and 0.999 respectively. The scale efficiency on farm level consequently increased from a mean value of 0.965 in 2002 to about 0.979 in 2004. With respect to the explanation of the variance in (static) inefficiency for the year 2004 the analysis showed that the amount of total investments by the farm and the amount of externally generated total income including rents and transfer payments have a positive effect on the farm's technical efficiency. This could be due to a softer budget constraint faced by the farm with respect to new technology investments as well as a higher state of technology for organic farms already willing and capable to invest in advanced technology in the past. On the other hand it was found that the amount of externally earned income by the family members – i.e. predominantly wage income - negatively affects farms' relative technical efficiency. One reason for this finding could be that family members heavily engaged in off farm activities supply far less labor hours to on farm activities implying an increased likelihood of labor shortages at times where labor demanding activities are scheduled. Despite the reference to a relatively short time period (3 years)[3] the following results on the development of total factor productivity, technical change, and efficiency change over time deliver valuable insights in the level and structure of organic farms' relative productivity. Table 3 gives a detailed summary of the development of the various tfp components over time measured by the alternative model specifications:
(i) Over all estimated models the change in the mean *efficiency* on farm level was found to range from -0.4% to +2.1% for the period 2002/2003, from +0.4% to +8.9% for the period 2003/2004, and from -0.1% to +5.1% for the total period 2002 to 2004. No clear difference was found with respect to the scale specifications but with respect to the alternative models chosen: the results by the general index model indicate a clear increase in efficiency over the individual as well as the total time period whereas the time trend model delivered mixed evidence. However, taking only the more significant variable scale specifications into account (see LR testing) we can conclude that a considerable improvement in efficiency took place in organic milk production in Denmark over the total period investigated. (ii) The results on the change in the organic farms' *scale efficiency* show positive rates for all periods investigated as well as all models tested. An increase in scale efficiency up to 0.4% was found for 2002/2003, up to 1.2% for 2003/2004, and up to 1% for the total period 2002 to 2004. We can therefore conclude on a slight improvement in the relative efficiency of the scale of organic milk production over the total period. (iii) *Technical change* was found to be in a range from -5.4% to -0.2% for the period 2002/2003, in a range from -0.2% to -1.3% for the period 2003/2004, and in a range from -0.2% to -3.7% for the total period 2002 to 2004 (mean values). No clear difference was found with respect to the scale specifications but again with respect to the alternative models chosen: the results by the time trends model clearly indicate a decline in

[3] No other complete panel data set is currently available for organic farms in Denmark.

the rate of technical change on farm level in the individual as well as in the total time period whereas the results by the general index model were found to be not that pronounced but still significantly negative. To conclude and by refering only to the variable returns specifications it became clear that there has been a significant decline in the rate of technical change in organic milk production in Denmark over the total period investigated. (iv) Based on these individual performance measures the change in *total factor productivity* for the individual as well as total time period investigated was found to vary significantly between the alternative models tested. Whereas the general index model in both scale specifications indicates a clear improvement in the mean total factor productivity for the organic milk farms – of about 1.3% in 2002/2003, 8.7% in 2003/2004, as well as 5% for the total period investigated – the time trends model delivered rather mixed results: here a clear negative change in the mean total factor productivity was found for 2002/2003 (in the range of -5.8% to -4%) and for the total period (in the range of -3.8% to -1.3%) whereas the mean total factor productivity for 2003/2004 more or less showed to be positive (a range of -0.3% to +0.6%). Overall it can be concluded that mixed results were found for the development of the mean total factor productivity in the organic milk sector. Figures 3a and 3b illustrate the distribution of the tfp indezes for the total period 2002 to 2004 obtained by the different estimation models for the more significant variable scale specification.

Figure 2a & 2b: Kernel Density Distribution TFP - TT VRS / GI VRS





If we look on the frontier of the farms with the highest total factor productivity in the sample it becomes clear that there has been considerable fluctuation over time with respect to the farms on the frontier: the organic milk farms part of the frontier defined by the highest tfp in 2002/2003 fall all back below the 25% tfp frontier in 2003/2004. The farms forming the 25% tfp frontier in 2003/2004 catched up with respect to their status in 2002/2003 far below the frontier. If we further compare the tfp estimates for the total period with the tfp divisia index calculated based on observed values (-0.1% for 2002/2003, +0.6% for 2003/2004, and +0.2% for the total period) we find mixed evidence with respect to the most accurate model specification for the sample of organic farmers: the general index model shows to be more accurate with respect to reflecting the sign (i.e. direction) of the tfp change, the time trends model shows to be more accurate with respect to explaining the absolute difference (regardless the sign of change) in tfp changes. It seems from the results here that the general index model delivers more accurate tfp rankings for both scale specifications compared to the time trends model. These empirical findings in a way confirm the results of previous studies concluding in a better performance of the general index model with respect to the prediction of total factor productivity growth (see Baltagi/Griffin 1988, Baltagi et al. 1995, Kumbhakar/Heshmati 1996, Kumbhakar/Lovell 2000, and Kumbhakar 2004). It can be expected that the gi model is designed to more accurately handle annual fluctuation in the data structure compared to the tt model. The outlined time trends as well as general index models have been built on the assumption that technical change in organic milk farming is non-neutral. Hence, we also estimated time varying and farm specific bias in technical change. The results were found to be consistent over the two models chosen and suggest that an upward and/or downward movement of the production function due to technical change has been biased in favour of the usages of labor and materials with respect to the variable scale specifications and in favour of labor, materials and cows for the constant returns to scale specifications. This holds for both time periods investigated. In other words these results imply that at average technical change on the organic farm level - if a positive rate could be actually achieved – has been labor, materials and cows saving. The estimated output elasticities for the variable inputs show only minor changes over the years observed. Over all different model specifications marginal changes in the input materials lead to the highest output changes, marginal changes in the number of cows lead to the lowest output changes. This suggests that by using additional units of materials the organic milk farms can increase their milk output by a larger amount than by using additional units of cows.

6.2 Factors for Total Factor Productivity Growth

The estimated multiple equations systems delivered empirical evidence on factors potentially explaining the variance in total factor productivity growth of organic milk farms over the total period investigated. The results of the applied bias corrected bootstrap procedure confirmed the robustness of the SURE estimates.[4] Table 3 summarizes the most significant factors with respect to the development of total factor productivity over time for both models. We refer to the variable scale specifications here as the statistically superior ones (see LR-tests).

Table 3: Most Significant Factors for TFP Change – VRS Specifications

Factor[1]	Influence on TFP Components by Factor Increase[2]	
Model	**Time Trend**	**General Index**
Total Investment	positive TCH, increase in EffCH	positive TCH, increase in EffCH
Investment in Quota	positive TCH, increase in EffCH	negative TCH, increase in EffCH
Organic Subsidies	increase in EffCH	positive TCH, increase in EffCH
Veterinary Expenses	increase in EffCH	increase in EffCH
External Finance	negative TCH, decrease in EffCH	positive TCH, decrease in EffCH
Total External Income	positive TCH, increase in EffCH	negative TCH, increase in EffCH

1: complete table of estimates see appendix table A4, 2: TCH – Technical Change, EffCH – Change in Efficiency

The analysis showed that for both models an increase in total investment, an increasing amount of organic subsidies received as well as rising veterinary expenses are significantly linked to a positive rate of technical change and an increase in farms' efficiency over time. Whereas an economically motivated explanation seems to be evident with respect to total investment - i.e. rising technical change and technical efficiency by more current technology as e.g. robotic weeding, band-steaming or automatic milking - such an explanation seems not that evident for the factor organic subsidies as well as veterinary expenses. One argumentation for the effect of the latter could be that an increase in veterinary expenses reflects a higher care of herd health and willingness to conquer diseases leading to an enhanced efficiency of the input cows. However, with respect to an increase in organic subsidies one could argue that this implies a larger farm budget for technology investments and scale enhancements. The different multiple equation systems delivered on the other hand mixed evidence with respect to the effects of increasing quota investments, total external income as well as the amount of external finance by the individual organic farm. Whereas the model evidence tends towards positive technical change effects and an increase in efficiency

[4] The estimation results of the single equation Tobit models showed more or less the same parameter values but with a lower statistical significance.

for the first two, the empirical evidence for the effects of an increase in external finance clearly tends to negative influences on the organic farms' total productivity development in the period investigated. Increasing investments in milk quota lead to the availability of more current technology and the realization of scale effects through an enhancement of production. An increase in the total amount of off farm income (incl. rents and transfer payments) should result in a softer budget constraint and hence an additional increase in technology investments. Finally an increase in external finance over time implies beside increasing investments also rising debt and interest payments as well as risk exposure.

6.3 Probability of Market Exit

The estimated bivariate probit models are finally aimed to give empirical insights in the structural dynamics of the organic farming sector in Denmark over the last years. Table 4 summarizes the effects found for the different policy relevant factors tested for their influence on the probability of organic market exit. The results of the applied bias corrected bootstrap procedure confirmed the robustness of the bivariate probit estimates.

Table 4: Factors for Increased Probability of Organic Market Exit

Dependent Variable	Exit Proxy TFP	Exit Proxy Leverage
Factor[2]	Influence on Probability of Organic Market Exit	
Total Investment	negative	(not significant at 10%-level)
Investment in Quota	positive	(not significant at 10%-level)
Organic Subsidies	negative	negative
Total External Income	negative	negative
Total Period Operated by Current Farmer	negative	negative

1: binary proxies 0 – low likelihood, 1 – high likelihood of exit; 2: complete table of estimates can be requested from authors.

By approximating the likelihood of organic market exit by the two binary variables defined in [16] reflecting the relative level and development of the farms' total factor productivity and the farms' leverage ratio, we found significant evidence for the following relationships: a lower likelihood of market exit for organic milk farms showing a relatively high increase in total investment over the last years, showing an increase in the amount of organic subsidies received, and generating an increasing part of the total income by off farm activities. In addition: the longer the total time period the organic farm is operated by the current owner the lower is the risk of organic market exit found. However, on the other hand we found for the probit model that increasing the investment in additional milk quota could lead to an increase in the risk of exiting the organic milk market. As outlined in section 2 the Danish organic milk sector has been plagued by a structural overproduction in the last years. Following the politically motivated assumption that - despite such short term overproduction - agricultural policy should focus on the long term goal of sustainable growth in organic farming in Europe one can conclude that ongoing monetary support by the state and supranational authorities as well as the promotion of off farm income opportunities would offer most promising starting points for effective policy measures to stimulate long term growth in organic production. Following on the other hand the purely economically motivated assumption that a mid to long term organic market equilibrium should be achieved where organic supply matches organic demand one can conclude that such ongoing monetary production support is a waste of resources and that fiscal policy should focus on an adequate discouraging marginal taxation of off farm earnings.

7 Conclusions

In the preceeding analysis we attempted to measure the total factor productivity growth of organic milk production in Denmark. By using recent panel data we tried to add to the empirical literature on organic farming. By considering theoretical consistency of the estimation model as well as applying different models we tried to add to the more modelling oriented literature on productivity analysis. Furthermore possible factors for explaining the variation in the different productivity components over time were investigated and policy relevant characteristics of farms likely to exit the market were analyzed. We found significant differences in the organic farms' technical efficiencies and total factor productivities on a high level (hypothesis 1). The results, however, only partly confirmed hypothesis 2 assuming no significant total factor productivity growth over the last years and show even a slightly negative rate of technical change for organic milk production in Denmark. However, it seems that these empirical results are not strong enough to support the view of a profound stagnation in organic milk farming. We further found evidence for a positive relationship between subsidy payments and increasing farm efficiency as well as technology improvements (hypothesis 3). This holds also with respect to off farm earnings. Moreover hypothesis 4 has been confirmed, expecting a negative effect of an increase in subsidy payments as well as an increase in off farm income over time on the likelihood of market exit. With respect to the relative superiority of the different modelling approaches evidence was found for a more accurate mapping of total factor productivity growth by the general index model (hypothesis 5). The farm rankings by the different productivity indezes estimated were nevertheless found to be significantly correlated. With respect to future policy measures these findings suggest that if further growth in organic farming should be stimulated, ongoing monetary support is effective to keep farms in the business. In addition policy measures should be also focused on promoting alternative off farm income possibilities. The latter suggestion seems to gain even more importance if one keeps in mind that organic dairy farms in Europe are expected to face reduced prices in the next years as a result of the general EU reform. Needless to say that beside such supply oriented measures also demand oriented measures have to be pursued. Future research should focus on shedding empirical light on the long term developments in the market. However, this requires the availability of a larger panel data set than currently available.

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Table 3: Total Factor Productivity Decomposition – Different Periods and Alternative Models

Time Period	2002 - 2003														
Model	Divisia Index[3]	**Time Trend**							**General Index**						
Specification		Constant Returns to Scale			Variable Returns to Scale				Constant Returns to Scale			Variable Returns to Scale			
Measure		TFP[1]	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH	TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH
Mean	0.999[2] (-0.1%)	0.942 (-5.8%)	0.946 (-5.4%)	0.996 (-0.4%)	0.960 (-4%)	0.961 (-3.9%)	0.999 (-0.1%)	1.003 (+0.3%)	1.014 (+1.4%)	0.993 (-0.7%)	1.021 (+2.1%)	1.013 (+1.3%)	0.998 (-0.2%)	1.014 (+1.4%)	1.004 (+0.4%)
StErr	0.005***	0.006***	0.003***	0.006***	0.008	0.003***	0.008***	0.005***	0.079***	0.001***	0.081***	0.079***	0.001***	0.079***	0.003***
Min	0.986	0.787	0.878	0.831	0.793	0.884	0.833	0.950	0.844	0.992	0.850	0.843	0.993	0.843	0.994
Max	1.014	1.048	1.048	1.127	1.138	1.003	1.199	1.199	1.268	0.994	1.278	1.265	0.999	1.266	1.011
Time Period	**2003 - 2004**														
Model	Divisia Index[1]	**Time Trend**							**General Index**						
Specification		Constant Returns to Scale			Variable Returns to Scale				Constant Returns to Scale			Variable Returns to Scale			
Measure		TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH	TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH
Mean	1.006 (+0.6%)	0.997 (-0.3%)	0.992 (-0.8%)	1.004 (+0.4%)	1.006 (+0.6%)	0.987 (-1.3%)	1.019 (+1.9%)	1.012 (+1.2%)	1.087 (+8.7%)	0.998 (-0.2%)	1.089 (+8.9%)	1.087 (+8.7%)	0.998 (-0.2%)	1.089 (+8.9%)	1.001 (+0.1%)
StErr	0.009***	0.008	0.003***	0.006***	0.009	0.003***	0.007***	0.003***	0.167***	0.001***	0.167***	0.166***	0.001***	0.166***	0.003***
Min	0.990	0.853	0.935	0.866	0.852	0.931	0.860	0.967	0.869	0.998	0.871	0.867	0.998	0.868	0.992
Max	1.041	1.243	1.044	1.205	1.236	1.032	1.221	1.095	1.799	0.999	1.803	1.801	0.999	1.803	1.007
Time Period	**Total Period (2002 – 2004)**														
Model	Divisia Index[1]	**Time Trend**							**General Index**						
Specification		Constant Returns to Scale			Variable Returns to Scale				Constant Returns to Scale			Variable Returns to Scale			
Measure		TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH	TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH
Mean	1.002 (+0.2%)	0.962 (-3.8%)	0.963 (-3.7%)	0.999 (-0.1%)	0.987 (-1.3%)	0.971 (-2.9%)	1.017 (+1.7%)	1.010 (+1.0%)	1.050 (+5%)	0.995 (-0.5%)	1.055 (+5.5%)	1.050 (+5%)	0.998 (-0.2%)	1.051 (+5.1%)	1.002 (+0.2%)
StErr	0.008***	0.056***	0.022***	0.052***	0.061***	0.019***	0.060***	0.037***	0.135***	0.003***	0.135***	0.134***	3.34E-04***	0.135***	0.003***
Min	0.986	0.704	0.903	0.727	0.729	0.903	0.833	0.950	0.844	0.992	0.850	0.843	0.993	0.843	0.992
Max	1.041	1.089	1.017	1.150	1.172	1.008	1.218	1.199	1.799	0.999	1.803	1.801	0.999	1.803	1.011

1: TFP – Total Factor Productivity, TCH – Technical Change, EFFCH – Efficiency Change; 2: *,**,***: significance at 10, 5, and 1 % -level, 3: calculated based on observed values.