

**International comparison of product supply chains in the agri-food sector:**  
determinants of their competitiveness and performance on EU and international markets



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WORKING PAPER

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## Productivity and Efficiency of European Food Processing Industry

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### Abstract

The aims of research were to conduct a comparative analysis among different EU countries (including Serbia) as well as industries and to measure the productivity level of individual countries, sectors, and companies. Based on a joint estimation of country-specific input distance functions and a meta-frontier analysis for four sectors, we were able to identify the various sources of factor productivity and their developments over time as well as the level and development of the technical efficiency of companies in four food processing industries. The research is based on data drawn from the Amadeus database. We discovered that intra- and intersectoral differences are important characteristics in EU food processing. Efficiency and TFP differences among food processors are significant reasons for variation in all sectors. High TFP was found in Germany, France, Italy, and the Netherlands in all sectors. TFP has a positive trend in the majority of EU member countries; only Bulgaria and Serbia are exceptions.

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# Productivity and Efficiency of European Food Processing Industry

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## 1 Introduction

The food processing industry is an important part of the agri-food chain, which creates the demand for agricultural raw materials. Moreover, the food processing industry in separate EU countries can be regarded as the pivotal players in the substitution of incentives implemented by agricultural policy by incentives resulting from the demand for food. However, at least two requirements have to be met so that the processors can incur this function. First, market power must not be a crucial factor in the exchange transactions of raw materials, so that processors are not able to extract rents from farmers. Second, food processors must be highly productive, and thus competitive, so that they can create a high demand which can be met by the domestic agricultural sector.

In this Working Paper, we focus on the second requirement and analyse productivity in the EU food processing industry. Our aim is to conduct a comparative analysis among the different EU countries (including Serbia) and different industries, and identify the productive and less productive countries, sectors and companies. Based on (1), a joint estimation of country-specific input distance functions and (2), a metafrontier analysis for four sectors using the efficient outputs from (1), we will focus on the various sources of factor productivity and their developments over time, as well as on the level and development of the technical efficiency of companies in four food processing industries. Thus, we will conduct an analysis of the intra- and inter-country differences in technology, efficiency and total factor productivity in the 24 EU member countries (only Croatia, Cyprus, Luxembourg and Malta are missing) and Serbia.

Productivity is generally defined as the relation of output to inputs, and thus gives information about the efficacy of factor input. Productivity is not only determined by the ability to efficiently use inputs in the production of outputs, but also by the technology in use, quality of input use and economies of scale. Given this perception, it is obvious that productivity is often used as an indicator of competitiveness. Moreover, the European Commission regards it as the most reliable indicator of competitiveness over the long term. Productivity can be measured at different levels. The simplest are rather disaggregated and include yield per hectare, or milk per cow. Partial productivity measures, where the total output of a firm, sector or economy is related to one input, are more aggregated. Prominent examples include labour and land productivity. The most comprehensive measure is total factor productivity (TFP), which is a ratio of aggregated outputs and inputs. Thus, TFP and its changes are important indicators of firm or sector performance and will play a central role in our analysis. Moreover, technical efficiency, as an integral part of overall economic efficiency, provides information on the extent to which companies could increase the productivity of their

inputs by catching up to the best-performing companies in a sector, and thereby improve the competitiveness of the whole value chain.

Productivity and efficiency, as important factors determining the overall competitiveness of food processors, have received special attention in the research over the last two decades (e.g. Ohlan (2013), Fu et al. (2011), Ali et al. (2009), Kumar and Basu (2009), Azzam et al. (2004), Xia and Buccola (2003), Doucouliagos and Hone (2000), Hennessey (2005), Buccola et al. (2000), Elyasiani and Mehdian (1993), and Setiawan et al. (2012)). However, only a few papers can be found in the research on the European food industry (e.g. Dios-Palomares and Martínez-Paz (2011), Dimara et al. (2008), Skuras et al. (2006), Keramidou et al. (2011), Kalas and Lambarra (2010), Barros and Santos (2007), Čechura and Hockmann (2010), and Čechura et al. (2011)).

We would like to complement this research by conducting a metafrontier analysis of the comparative assessment of TFP differences among EU member countries. In particular, this Working Paper addresses the following research questions:

- (i) The first relates to the impacts of TCH and TE. The aim is to assess whether there is an indication that the countries are following a sustainable development path, characterised by the development and adoption of innovation and reduced waste of resources due to inefficient input use.
- (ii) The second question concerns productivity levels and developments. In particular, we investigate country differences in terms of total factor productivity and identify whether the development is stable and driven by strong competitive firms, or if leapfrogging occurs.
- (iii) The third question concerns country-specific developments, especially whether the challenges and adjustments are systemic, or whether idiosyncratic developments occurred.

The Working Paper is organized as follows: Chapter 2 contains the theoretical framework and presents the estimation strategy; Chapter 3 describes the data set; Chapter 4 presents (a), results of the country-specific input distance function estimates, compares the estimated technology and technological change and analyses the estimated technical efficiency, and then presents (b), results of the metafrontier analysis, which is used for the comparison of technical efficiency and total factor productivity among the analysed countries. Chapter 5 contains a discussion and concluding remarks, including policy recommendations.

## 2 Theoretical framework and estimation strategy

The research questions will be dealt with (1) estimation of country specific input distance function with inter- and intra-sectoral heterogeneity using the Amadeus database and (2) Based on the parameters the efficient output level will be calculated. These will be used in a metafrontier estimate of sectoral input distance functions to determine the TFP level of the analysed sectors (slaughtering, fruits and vegetables, dairy and milling) and TFP development.

In order to produce coherent results, all models (the country-specific models in (1) as well as the metaproduction models in (2)) will make use of the same procedure: The models are formulated as a special case of input distance functions with sector dummies in (1) for capturing the intersectoral differences in technology. Moreover, in all models it is explicitly considered that food processing production possibilities are affected by firm (intrasectoral) heterogeneity, which influences the level as well as shape of the production possibilities.

## 2.1 Theoretical framework

Since we are analysing a food processing industry which is dominated by large companies<sup>1</sup>, often registered on the stock market, we follow Georgescu-Roegen (1951) and assume that companies maximise their return on capital ( $r$ ), instead of making the conventional profits maximisation assumption. In the case of large companies, shareholders (or owners in general) are primarily interested in a high dividend from the exerted capital; profit maximisation can be considered of secondary importance. That is, maximizing returns on capital appears to be a more appropriate decision rule in the case of the manager-operated but shareholder-owned companies which prevail in food processing<sup>2</sup>.

In terms of the transformation function, the technical production possibilities are given by  $f(\mathbf{x}, k, \mathbf{y}^*) = 1$ , where  $\mathbf{y}^*$  and  $\mathbf{x}$  denote vectors of (technically efficient) outputs and inputs, respectively, and  $k$  represents capital. The relation between technically efficient and actual output is given by  $\mathbf{y}^* = \mathbf{y}e^{\mathbf{u}}$ , where  $\mathbf{u} \geq 0$  indicates inefficiency, i.e., the amount by which output can be increased without changing the bounds of the transformation function.

Denoting the prices for inputs and output by  $\mathbf{w}$  and  $\mathbf{p}$  and for capital by  $r$ , the optimisation problem becomes:

$$(1) \quad \max_{\mathbf{y}, \mathbf{x}, k} \left\{ r = \frac{\mathbf{p}\mathbf{y}^* - \mathbf{w}'\mathbf{x}}{k}; f(\mathbf{x}, k, \mathbf{y}^*) = 1 \right\}, \text{ with } \mathbf{y}^* = \mathbf{y}e^{\mathbf{u}}.$$

After small mathematical manipulations, the first-order conditions are:

$$(2) \quad \begin{aligned} \frac{p_j y_j^*}{k} + \lambda f(\mathbf{x}, k, \mathbf{y}^*) \frac{\partial \ln f(\mathbf{x}, k, \mathbf{y}^*)}{\partial \ln y_j^*} &= 0, \text{ for } j = 1, \dots, J \\ -\frac{w_i x_i}{k} + \lambda f(\mathbf{x}, k, \mathbf{y}^*) \frac{\partial \ln f(\mathbf{x}, k, \mathbf{y}^*)}{\partial \ln x_i} &= 0, \text{ for } i = 1, \dots, I \\ -\frac{\mathbf{p}'\mathbf{y}^* - \mathbf{w}'\mathbf{x}}{k} + \lambda f(\mathbf{x}, k, \mathbf{y}^*) \frac{\partial \ln f(\mathbf{x}, k, \mathbf{y}^*)}{\partial \ln k} &= 0 \end{aligned}$$

where  $\lambda$  is the Lagrange multiplier from the maximisation problem.

The first-order conditions in (2) imply:

<sup>1</sup> This is especially true if we use the Amadeus data set in the analysis.

<sup>2</sup> Our decision rule is a modification of the returns for a dollar model (Färe et al., 2002).

$$(3) \quad \sum_j \frac{\partial \ln f(\mathbf{x}, k, \mathbf{y}^*)}{\partial \ln y_j^*} = - \sum_i \frac{\partial \ln f(\mathbf{x}, k, \mathbf{y}^*)}{\partial \ln x_i} - \frac{\partial \ln f(\mathbf{x}, k, \mathbf{y}^*)}{\partial \ln k}.$$

The virtue of (3) is that it allows an investigation of input and output structures that comply with the conditions of economic optimisation using only information on quantities. Since price data are often scarcely available, assuming that returns on capital are maximized instead of profits provides an additional advantage for the empirical analysis.

Before the empirical implementation is presented, a further implication of maximising the returns on capital will be developed. Since the first-order conditions (2) imply:

$$\begin{aligned} \frac{\partial f}{\partial x_i} &= - \frac{w_i}{p_j} \frac{\partial f}{\partial y_j^*} \text{ for all } i \text{ and } j \\ \frac{\partial f}{\partial y_l^*} &= \frac{p_l}{p_j} \frac{\partial f}{\partial y_j^*} \text{ for all } l \text{ and } l \neq j, \text{ and} \\ \frac{\partial f}{\partial k_l^*} &= - \frac{r}{p_j} \frac{\partial f}{\partial y_j^*}, \end{aligned}$$

condition (3) can be expressed as:

$$(4) \quad \mathbf{p}'\mathbf{y}^* = \mathbf{w}'\mathbf{x} + rk.$$

Thus total revenues are distributed for the remuneration of inputs. The only condition under which (4) is fulfilled is that the processors operate at constant returns to scale. Thus, compared to pure profit maximisation, the maximisation of returns on capital implies an additional restriction regarding the scale of production. Moreover, testing (4) provides information on whether the empirical observations are consistent with decision rule (1).

## 2.2 Empirical implementation

In the empirical analysis, we assume that the transformation process can be approximated well by a translog transformation function. However, instead of a vector of outputs we have only one output  $y$ :

$$(5) \quad \begin{aligned} \ln f(\mathbf{x}, y^*, k) &= a_0 + \alpha_y \ln y^* + \frac{1}{2} \alpha_{yy} \ln y^{*2} \\ &+ \sum_i b_i \ln x_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln x_i \ln x_j + \ln y^* \sum_i \delta_{yi} \ln x_i \\ &+ \gamma_k \ln k + \frac{1}{2} \gamma_{kk} \ln k^2 + \ln k \sum_i \delta_{ik} \ln x_i + \delta_{yk} \ln k \ln y^* = 0 \end{aligned}$$

In this case condition (3) becomes:

$$(6) \quad \begin{aligned} \alpha_y + \alpha_{yy} \ln y^* + \sum_i \delta_{yi} \ln x_i + \delta_{yk} \ln k = \\ - \left( \sum_i \beta_i + \gamma_k \right) - \sum_i \ln x_i \left( \sum_j \beta_{ij} + \delta_{ki} \right) - \ln y^* \left( \sum_i \delta_{yi} + \delta_{yk} \right) - \left( \sum_i \delta_{ki} + \gamma_{kk} \right) \ln k \end{aligned}$$

In order to facilitate the empirical analysis, we assume that the technology can be expressed in the form of an input distance function. Since the input distance function is homogeneous of degree 1 in all inputs  $(\mathbf{x}, k)$ , the following restrictions apply to the transformation function:

$$(7) \quad \begin{aligned} \sum_i b_i + \gamma_k &= -1 \\ \sum_j \beta_{ij} + \delta_{ik} &= 0, \text{ for } i=1, \dots, I \\ \sum_i \delta_{ki} + \gamma_{kk} &= 0 \\ \sum_i \delta_{yi} + \delta_{yk} &= 0 \end{aligned}$$

After applying these restrictions and normalising by  $k$ , (6) reduces to:

$$(8) \quad \alpha_y + \alpha_{yy} \ln y^* + \sum_i \delta_{ki} \frac{\ln x_i}{\ln k} = -1,$$

which holds for every  $x$  and  $y$  only when  $\alpha_y = -1$ ,  $\alpha_{yy} = 0$ , and  $\delta_{ki} = 0 \forall i$ .

Using these restrictions, the transformation function gives:

$$(9) \quad \ln \frac{y^*}{k} = \alpha_0 + \sum_i \beta_i \ln \frac{x_i}{k} + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln \frac{x_i}{k} \ln \frac{x_j}{k}.$$

Equation (9) plays a central role in the empirical application.

### 2.3 Efficiency, productivity and heterogeneity

#### A) Efficiency

Given the definition of inefficiency ( $u$ ) and adding a term ( $v$ ) which accounts for random variation (statistical noise), the model estimated in the empirical analysis is given by:

$$(10) \quad \ln \frac{y}{k} = \alpha_0 + \sum_i \beta_i \ln \frac{x_i}{k} + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln \frac{x_i}{k} \ln \frac{x_j}{k} - u + v.$$

Equation (10) can be estimated using standard stochastic frontier techniques. Besides requiring only quantity information and still complying with economic optimization, (10) has the further advantage that it could reduce the endogeneity problem involved in estimating distance functions (Kumbhakar, 2011). Since the endogeneity problem often frustrates estimation (Marschak and Andrews (1944), Olley and Pakes (1996), Levinsohn and Petrin (2003) and others) and can lead to an inconsistent parameter estimate, the derived function can be regarded as a possible way of avoiding the problem in the empirical application.

#### B) Productivity

Productivity finds its expression in the shape of (10), and thus the parameter vector  $(\alpha_0, \beta)$ . However, the coefficients depend on the quality of the individual inputs. Input quality, in turn, is determined by the embedded knowledge, i.e., human capital for labour, technological knowledge for capital, and embedded innovation in materials (Barro and Sala-i-Martin,

1995). Due to technological progress and learning by doing, the technology improves over time. This will not only induce shifts in the transformation function but will also affect the productivity of the individual inputs. Moreover, it can be assumed that the various improvements in quality have rather different direct and indirect effects on the individual inputs. However, due to limitations in data availability, the impacts for the various improvements cannot be estimated separately. Instead, it is commonly assumed that a trend variable ( $t$ ) can be incorporated which captures the joint effects in input quality improvements. We proceed in this way and extend (10) by:

$$(11) \quad \alpha_0 = b_0 + b_t t + \frac{1}{2} \beta_{tt} t^2 \quad \text{and} \quad \alpha_j = b_j + \beta_{jt} t, \forall j.$$

The resulting function

$$(12) \quad \ln \frac{y}{k} = b_0 + b_t t + \frac{1}{2} \beta_{tt} t^2 + \sum_{j \neq 1} b_j \ln \frac{x_j}{k} + \sum_{j \neq 1} \beta_{jt} t \ln \frac{x_j}{k} + \frac{1}{2} \sum_{j \neq 1} \sum_{k \neq 1} \beta_{jk} \ln \frac{x_j}{k} \ln \frac{x_k}{k} - u + v$$

will be used as a benchmark in the empirical application.

Given the panel structure of the data, we assume that the efficiency term  $u$  is allowed to vary among firms, unlike a random effect model (Pitt and Lee, 1981). This implies that the shocks which induce inefficiency have to be the same in each period, and that the firms are unable to adjust to these shocks.

An obvious extension is to allow for time-varying inefficiency. This results in the "true random effect" model discussed in Greene (2004). Within this context, the parameter  $b_0$  is allowed to vary among firms.

### C) Heterogeneity

The specification discussed so far presumes that firms have similar technologies, and the only differences result from the intensity of input use. This implies that firms from different sectors but with the same input-output combination generate the same marginal products. Given the diversity of the food processing sector, this implication can be regarded as rather strong. We therefore assume that heterogeneity exists not only among sectors, but also among the firms within a sector. We consider these two kinds of heterogeneity by expanding the first-order terms in (12):<sup>3</sup>

$$(13) \quad \begin{aligned} b_0 &= \beta_0 + \sum_s d_s \beta_s + \beta_\eta \eta, \\ b_t &= \beta_t + \sum_s d_s \beta_{st} + \beta_{t\eta} \eta, \\ b_j &= \beta_j + \sum_s d_s \beta_{js} + \beta_{j\eta} \eta, \forall j \end{aligned}$$

In (13),  $d$  represents dummy variables which account for intersectoral differences in technologies. In the empirical application, we distinguish between five sectors (slaughtering, fruits and vegetables, dairy, milling and others). The variable  $\eta$  represents an unobservable random variable which is assumed to capture technology differences

<sup>3</sup> The true effect model results from (13) by assuming that  $b_t$  and all  $b_j$  are constants and all  $\beta_s$  are zero.

among firms which are not covered by the dummy variables. In the estimation, we assume that  $\eta$  follows a standard normal distribution, i.e.,  $\eta \sim N(0,1)$ . The specification given by (12) and (13) can be estimated using a random parameter approach. In the context of efficiency analysis, this class of model was introduced by Tsionas (2002) and Greene (2005).

Given the outlined considerations, the estimation technique can be summarized as:

$$\ln \frac{y_{it}}{k_{it}} = g(\mathbf{x}_{it}^*, t, \mathbf{d}, \eta_i) - u_{it} + v_{it}, \text{ with}$$

$$(14) \quad v_{it} \sim N(0, \sigma_v^2), u_{it} \sim N^+(0, \sigma_u^2) \text{ and } \eta_i \sim N(0, 1).$$

The function  $g(\bullet)$  captures all influences discussed using (12) and (13). The vector  $\mathbf{d}$  represents the sector and country dummies, and  $\mathbf{x}^*$  contains the transformed right-hand-side variables in (12). The subscripts  $i$  and  $t$  denote firm and time, respectively. Since we are using an unbalanced panel data set,  $t \in \mathfrak{S}(i)$  and  $\mathfrak{S}(i)$  represent a subset of years  $T_i$  from the whole set of years  $T (1, 2, \dots, T)$ , for which the observations of the  $i$ -th processing firm are in the data set.

Efficiency is estimated using the Jondrow et al. (1982) procedure. This approach computes  $E[u | u + v]$ , i.e., expected inefficiency under the condition that  $u + v$  is given. The density and distribution function of  $u + v$  are used in the calculation; however, these depend on the variances of  $u$  and  $v$ , and so does  $E[u | u + v]$ .

The random parameter model is fitted by the maximum simulated likelihood in the SW NLOGIT 5.0.

## 2.4 Metafrontier analysis

The metafrontier analysis will be conducted using the same model specification as for the individual countries. We will calculate the efficient output based on the parameter estimates of the country multiple input distance function and will use them in the estimation of the stochastic metafrontier multiple output distance function. Moreover, we will employ the Fixed Management model to capture heterogeneity. The estimated metadistance function will allow us a coherent comparison of the level of technical efficiency and TFP among the EU member countries.

### Fixed Management model

Álvarez et al. (2003 and 2004) specified the Fixed Management model as a special case of the Random Parameters model in the following form:

$$\ln TE_{it} = \ln f(\mathbf{x}_{it}^*, t, m_i; \mathbf{b}, \boldsymbol{\beta}) - \ln f(\mathbf{x}_{it}^*, t, m_i^*; \mathbf{b}, \boldsymbol{\beta}) \leq 0,$$

$$(15) \quad \ln TE_{it} = -u_{it},$$

and

$$(16) \quad \ln \frac{y_{it}}{k_{it}} = \ln \frac{y_{it}^*}{k_{it}^*} - u_{it} = \ln f(\mathbf{x}_{it}^*, t, m_i^*) = b_0 + \beta_m m_i^* + \frac{1}{2} \beta_{mm} m_i^{*2} + (b_t + \beta_{tm} m_i^*) t + \\ + \frac{1}{2} \beta_{tt} t^2 + (b_x + \beta_{xt} t + \beta_{xm} m_i^*) \ln \mathbf{x}_{it}^* + \frac{1}{2} \ln \mathbf{x}_{it}^* \mathbf{B}_{xx} \ln \mathbf{x}_{it}^* + v_{it} - u_{it}$$

Technical efficiency,  $TE_{it(t)}$ , with  $0 < TE_{it(t)} < 1$ , captures deviations from the maximum achievable output.  $m_i^* \sim \bullet(0,1)$  represents unobservable fixed management. The symbol  $\bullet$  expresses that  $m_i^*$  could possess any distribution with zero mean and unit variance. The difference between the real ( $m_i$ ) and optimal ( $m_i^*$ ) management determines the level of technical efficiency. Technical efficiency is defined by:

$$(17) \quad \ln TE_{it} = \gamma_0 + \gamma_t t + \gamma_x \ln \mathbf{x}_{it}^*,$$

where

$$\gamma_0 = \beta_m (m_i - m_i^*) + \frac{1}{2} \beta_{mm} (m_i^2 - m_i^{*2})$$

$$\gamma_t = \beta_{tm} (m_i - m_i^*)$$

$$\gamma_x = \beta_{xm} (m_i - m_i^*)$$

Thus, technical efficiency consists of three components:

- (i) time invariant firm-specific effect – management –  $\gamma_0$ ,
- (ii) interaction of  $m_i^*$  with time – technological change –  $\gamma_t$ ,
- (iii) interaction of  $m_i^*$  with inputs quantity and quality – scale effect –  $\gamma_x$ .

Álvarez et al. (2004) showed that  $u_{it}$  can be estimated according to Jondrow et al. (1982) as (18), with simulated  $m_i^*$  according to (19).

$$(18) \quad E[u_{it} | \varepsilon_{it}, m_i^*] = \frac{\sigma \lambda}{(1 + \lambda^2)} \left[ \frac{\phi(-(\varepsilon_{it} | m_i^*) \lambda / \sigma)}{\Phi(-(\varepsilon_{it} | m_i^*) \lambda / \sigma)} - \frac{(\varepsilon_{it} | m_i^*) \lambda}{\sigma} \right],$$

where  $\lambda = \frac{\sigma_u}{\sigma_v}$ ,  $\sigma^2 = \sigma_u^2 + \sigma_v^2$  and  $\varepsilon_{it} = v_{it} + u_{it}$ .

$$(19) \quad \hat{E} \left[ m_i^* \left| \frac{y_i}{k_i}, \mathbf{x}_i^*, \mathbf{b}, \boldsymbol{\beta} \right. \right] = \frac{\frac{1}{R} \sum_{r=1}^R m_{i,r}^* \hat{f} \left( \ln \frac{y_i}{k_i} \left| \mathbf{x}_{i,r}^*, t, m_{i,r}^*; \mathbf{b}, \boldsymbol{\beta} \right. \right)}{\frac{1}{R} \sum_{r=1}^R \hat{f} \left( \ln \frac{y_i}{k_i} \left| \mathbf{x}_{i,r}^*, t, m_{i,r}^*; \mathbf{b}, \boldsymbol{\beta} \right. \right)}$$

The Fixed Management model is fitted by maximum simulated likelihood with NLOGIT 5.0.

## 2.5 TFP calculation and decomposition

Total factor productivity is calculated in the form of the Törnqvist-Theil index (TTI) (see, e.g., Čechura, Hockmann, 2010). The Törnqvist-Theil index exactly determines the changes in production resulting from input adjustments if a function has the translog form

(for the proof see Diewert, 1976). Furthermore, Caves et al. (1982) show the TTI extension for multilateral consistent comparisons.

The index is constructed as the deviation from the sample means. The input index for constant returns to scale (CRS) is given by:

$$(20) \quad \ln t_{it}^{CRS} = \frac{1}{2} \sum_{j=1}^K \left[ \left( \frac{\varepsilon_{it,j_0}}{\sum_{i=1}^K \varepsilon_{it,j_0}} + \frac{\bar{\varepsilon}_j}{\sum_{i=1}^K \varepsilon_{j_0}} \right) \left( \ln x_{it,j}^* - \overline{\ln x_j^*} \right) + \frac{\bar{\varepsilon}_j}{\sum_{i=1}^K \varepsilon_{j_0}} \overline{\ln x_j^*} - \frac{\varepsilon_{it,j_0}}{\sum_{i=1}^K \varepsilon_{it,j_0}} \ln x_{it,j}^* \right]$$

with  $\varepsilon_{it,j_0} = \frac{\partial \ln f(\mathbf{x}_{it}^*, t, m_i^*; \mathbf{b}, \boldsymbol{\beta})}{\partial \ln \mathbf{x}_{it,j}^*}$ .

A bar over a variable specifies the arithmetic mean over all observations. That is, the output index and the efficiency index are defined as:

$$(21) \quad \ln \psi_{it} = \ln y_{it} - \overline{\ln y_{it}} \quad \text{and} \quad \ln \nu_{it} = \ln TE_{it} - \overline{\ln TE_{it}}.$$

Since TFP is in our case a combination of technical efficiency effect, technological change effect and management effect, the required indices are defined as:

$$(22) \quad \ln \tau_{it} = \frac{1}{2} \left[ (\varepsilon_t + \bar{\varepsilon}_t)(t - \bar{t}) + \bar{\varepsilon}_t \bar{t} - \varepsilon_t t \right], \quad \text{with} \quad \varepsilon_t = \frac{\partial \ln f(\mathbf{x}_{it}^*, t, m_i^*; \mathbf{b}, \boldsymbol{\beta})}{\partial t},$$

$$(23) \quad \ln \mu_{it} = \frac{1}{2} \left[ (\varepsilon_{m_0} + \bar{\varepsilon}_m)(m_i - \bar{m}_i) + \bar{\varepsilon}_m \bar{m}_i - \varepsilon_m m_i \right]$$

with  $\varepsilon_m = \frac{\partial \ln f(\mathbf{x}_{it}^*, t, m_i^*; \mathbf{b}, \boldsymbol{\beta})}{\partial m_i}$ .

Using these definitions, TFP and its breakdown is given by:

$$(24) \quad \ln TFP_{it} = \ln \psi_{it} - \ln t_{it}^{CRS} = \ln \nu_{it} + \ln \tau_{it} + \ln \mu_{it}$$

$TE \quad TCH \quad MAN$

Changes in TFP can be expressed either as a ratio (on the mean) of the output and input index (for CRS) or as a multiplication of TFP components, i.e., technical efficiency effect (TE), technological change effect (TCH) and management effect (MAN).

### 3 Data

The data we use in the analysis is drawn from the Amadeus database, created and produced by Bureau van Dijk. The database contains financial information for public and private companies across Europe. The database provides detailed information about (standardised) annual accounts, financial ratios, sectoral activities and ownership information.<sup>4</sup>

*Table 3.1 Structure of the data set*

EU member country	Slaughtering	Fruit & Vegetable	Dairy	Milling	Other Food Processing	Total
Austria	69	31	39	1	140	280
Belgium	539	318	276	167	1591	2891
Bulgaria	200	64	83	32	384	763
Czech Republic	381	68	282	110	1036	1877
Germany	375	186	414	115	1066	2156
Denmark	41	31	15	38	252	377
Estonia	58	10	43	9	104	224
Spain	2031	835	570	329	3822	7587
Finland	159	52	84	32	339	666
France	1887	462	623	351	2775	6098
United Kingdom	837	546	450	266	3053	5152
Greece	223	468	206	118	656	1671
Hungary	226	111	79	60	318	794
Ireland	72	0	17	19	159	267
Italy	2211	1321	1666	868	3981	10047
Lithuania	125	19	99	31	250	524
Latvia	58	19	70	18	216	381
Netherlands	55	71	64	20	328	538
Poland	1189	521	754	207	1279	3950
Portugal	279	97	75	106	700	1257
Romania	676	126	317	219	769	2107
Sweden	393	143	27	110	597	1270
Slovenia	66	18	27	9	68	188
Slovakia	89	24	87	36	264	500
Serbia	112	75	45	173	395	800

Source: Amadeus database and our own calculations.

The panel data set that we use in our analysis contains companies whose main activity is food processing according to the NACE classification (NACE 10 – manufacture of food products – groups from 10.1 to 10.9). It is an unbalanced panel data set, which represents the period from 2003 to 2012 and contains 9,885 food processing companies from 27 EU countries. Since not all companies in the database have complete information, we exclude those companies with negative and zero values of the variables of interest. Thus, we were constrained to using an unbalanced panel data set containing 8,110 companies with 52,682

<sup>4</sup> More information on the Amadeus database is provided at: <http://www.bvdinfo.com>.

observations, i.e., on average 6.5 observations per company in the period from 2003 to 2012. Table 1 presents the structure of the data set.

The following variables were used in the analysis: output ( $y_{it}$ ), labour ( $L_{it}$ ), capital ( $C_{it}$ ) and inputs (materials) ( $M_{it}$ ). Output represents operating revenue (Turnover) of the company. Labour input is the total number of employees. Capital represents the book value of fixed assets. Finally, variable inputs (materials) were used in the form of the total costs of materials and energy consumption per company. Output was deflated by the sectoral index of food processing prices (EU level – 27 countries or country level if it was disposable, respectively; 2010 = 100) and capital, and inputs were deflated by the index of producer prices in the industry (country level; 2010 = 100).

Moreover, we rejected producers with fewer than three observations (on average) to decrease the problem associated with the entry and exit of producers from the database.

In the estimation, we normalized all variables in logarithm by their sample mean. This has the advantage that the first-order parameters can be interpreted as cost shares at the mean. We used this procedure since it significantly simplifies the discussion of the estimates.

## 4 Results

### 4.1 Country input distance function estimates and TFP calculations

In this chapter we first focus on parameter estimates and make a technology comparison among the countries, as well as an evaluation of economies of scale. Then, the questions related to technological change are addressed. A comparison of trends in TE and TFP is carried out in the third and fourth parts of this chapter. In these sections, we also address the question concerning catching-up and falling-behind processes. The chapters present the results separately for the slaughtering, fruits and vegetables, dairy and milling sectors, except for the second chapter, which is devoted to all food processing sectors.

#### 4.1.1 Parameter estimates

##### 4.1.1.1 Slaughtering

Table 4.1 provides parameter estimates of the derived input distance function (14) for slaughtering and 24 EU member countries, as well as Serbia. Instead of discussing each country estimate separately, we will evaluate and compare the results of a given sector (in this case slaughtering) for all countries together. This strategy helps us to better understand the common and individual specifics of the slaughtering sector in EU member countries, including Serbia, as far as technology, efficiency and productivity are concerned. This strategy also holds for other analysed sectors (i.e. fruits and vegetables, dairy and milling).

We start with a discussion of the first-order parameters, economies of scale and the significance of heterogeneity in the production structure. In particular, we evaluate the significance of inter- and intrasectoral heterogeneity.

Table 4.1 provides the estimated first-order parameters on inputs of the input distance function. Most of the estimated parameters are highly significant, even at a 1 % significance level. This not only concerns those conventionally discussed in production function estimates, but it also holds for the coefficients which capture inter- and intrasectoral heterogeneity. Thus, we can already conclude that heterogeneity among firms as well as among sectors (in this case slaughtering and other food processing sectors, except for fruits and vegetables and dairy and milling, which are also a subject of the sector effect estimate) is an important characteristic in EU food processing, and has to be considered when conducting a reliable analysis of the sector.

As far as the theoretical consistency of production technology is concerned, specification (6) and the restrictions in (7) imply the estimation of an input distance function. Thus, even though we use a further restriction, the functional form in (12 or 14, respectively) should inherit the properties of an input distance function. Färe and Primont (1995) show that this representation of production technology should be non-increasing in outputs, as well as non-decreasing and concave in inputs. The monotonicity requirements for inputs results in  $\beta_L > 0$ ,  $\beta_M > 0$  and  $\beta_L + \beta_M < 1$ . Table 4.1 shows that these conditions are met, even if (in the majority of cases) intersectoral heterogeneity is considered. Diminishing marginal returns (concavity) in inputs requires  $\beta_{qq} + \beta_q^2 - \beta_q < 0$  for  $q = L, M$ . This condition holds for all inputs<sup>5</sup>. The monotonicity requirement for output is also fulfilled, because restriction (7) was directly applied. Since the theoretical assumptions hold, we can conclude that the derived model specifications approximate well the real transformation process. This also holds for the assumption of constant returns to scale.

<sup>5</sup> Here we restrict our attention to the first principle minors of the second derivative of the input distance function. Reason: too time-consuming to test everything and, in addition, we do not need convex technologies (which imply diminishing returns to scale), but only diminishing returns to scale (which does not imply convex technologies).

Table 4.1 First-order parameters – slaughtering

Country		Constant			Labour			Materials		
		$\beta_0$	$\beta_{0\_Slaughter}$	$\beta_{0\eta}$	$\beta_L$	$\beta_{L\_Slaughter}$	$\beta_{L\eta}$	$\beta_M$	$\beta_{M\_Slaughter}$	$\beta_{M\eta}$
Austria	Coeff.	0.0819	-0.1668	0.0799	0.2155	-0.0959	0.0391	0.6527	0.2043	0.1123
		***	***	***	***	***	***	***	***	***
Belgium	Coeff.	0.0553	-0.0980	0.0372	0.2139	0.0519	0.0078	0.5930	0.0801	0.2241
		***	***	***	***	***	***	***	***	***
Bulgaria	Coeff.	0.4220	-0.2240	0.6360	0.3734	0.2218	0.6343	0.3808	-0.1233	0.2831
		***	***	***	***	***	***	***	***	***
Czech Republic	Coeff.	0.1817	-0.1656	0.0807	0.1206	0.0395	0.1071	0.8381	-0.0101	0.1459
		***	***	***	***	***	***	***		***
Germany	Coeff.	0.0214	-0.0576	0.1501	0.2315	-0.0695	0.1783	0.7101	0.0640	0.1078
		***	***	***	***	***	***	***	***	***
Denmark	Coeff.	0.0016	-0.0626	0.0903	0.1105	-0.0222	0.0393	0.8179	0.0459	0.0759
			**	***	***		***	***	**	***
Estonia	Coeff.	0.0657	-0.0467	0.0815	0.0911	-0.0124	0.0918	0.7700	0.0687	0.1120
		***	**	***	***		***	***		***
Spain	Coeff.	0.0671	-0.0284	0.1968	0.2284	-0.0374	0.0751	0.7530	-0.0004	0.1259
		***	***	***	***	***	***	***		***
Finland	Coeff.	0.1356	-0.0027	0.0380	0.1440	0.0377	0.0938	0.5466	0.0450	0.1082
					***		***	***		***
France	Coeff.	0.0876	0.1446	0.0966	0.1791	0.1446	0.0567	0.6647	0.0499	0.0998
		***	***	***	***	***	***	***	***	***
United Kingdom	Coeff.	0.0944	-0.1208	0.1090	0.1098	-0.0443	0.0850	0.8745	0.0496	0.1709
		***	***	***	***	***	***	***	***	***
Greece	Coeff.	0.0882	-0.1277	0.0747	0.1119	-0.0746	0.0601	0.8164	0.1294	0.1275
		***	***	***	***	***	***	***	***	***
Hungary	Coeff.	-0.0344	-0.0792	0.2329	0.1903	0.1963	0.0283	0.6018	-0.0126	0.2054
		**	***	***	***	***	***	***		***
Ireland	Coeff.	-0.0174	-0.0460	0.1060	0.0640	0.0024	0.0272	0.9104	-0.0443	0.0479
			***	***	***		***	***	**	***
Italy	Coeff.	0.2359	-0.1674	0.1333	0.2726	-0.0418	0.1352	0.7009	-0.0177	0.2693
		***	***	***	***	***	***	***	***	***
Lithuania	Coeff.	0.0125	-0.0919	0.1079	0.0987	0.0064	0.0548	0.8704	0.0175	0.0673
			***	***	***		***	***		***
Latvia	Coeff.	0.1149	-0.0673	0.0486	0.0128	0.1289	0.1650	0.9040	-0.0054	0.1539
		***	***	***	**	***	***	***		***
Netherlands	Coeff.	0.0955	-0.0965	0.2348	0.0912	-0.0331	0.0014	0.8539	0.0161	0.0766
		***	***	***	***	***		***	*	***
Poland	Coeff.	0.2813	-0.1930	0.2117	0.1842	-0.0166	0.1050	0.7583	0.0378	0.2001
		***	***	***	***	***	***	***	***	***
Portugal	Coeff.	0.0781	0.0590	0.0191	0.1677	0.0590	0.0038	0.6750	0.0740	0.1971
		***	***	***	***	***		***	***	***
Romania	Coeff.	0.2151	-0.0341	0.1601	0.2110	0.0906	0.0607	0.7116	-0.0080	0.1862
		***	**	***	***	***	***	***	***	***
Sweden	Coeff.	0.0378	-0.0321	0.1500	0.1704	-0.0245	0.0508	0.6994	0.1633	0.1264
		***	***	***	***	***	***	***	***	***
Slovenia	Coeff.	-0.0328	-0.0723	0.0318	0.2968	-0.1830	0.0282	0.6156	0.0556	0.0173
			***	***	***	*	***	***	**	*
Slovakia	Coeff.	0.1149	-0.0453	0.1338	0.1061	-0.0712	0.0643	0.8516	-0.0414	0.1482
		***	***	***	***	***	***	***	**	***
Serbia	Coeff.	0.1333	-0.2239	0.1435	0.0931	0.0184	0.1316	0.8759	0.0069	0.0654
		***	***	***	***		***	***		***

Source: own calculations

The estimated cost shares correspond to the information we have in the data set. The most significant part of company expenditures is for materials. This was expected, since the procurement of agricultural raw materials usually constitutes the majority of the cost in the food processing industry. However, the materials cost share differs significantly among

the countries. The lowest materials cost share is in Bulgaria (0.381) and the highest in Ireland (0.910). However, these values do not take sectoral differences into account. Since the heterogeneity among sectors was revealed by the estimate, the corresponding value of the materials cost share for slaughtering is the sum of  $\beta_M$  and  $\beta_{M\_Slaughter}$ .<sup>6</sup> The sector-specific effect is significant in 16 of 25 countries, and is positive in the majority of cases. That is, the corresponding value of the materials cost share for slaughtering is generally higher than in other food processing sectors not controlled for sectoral effects. Moreover, the estimates revealed highly significant intrasectoral heterogeneity. The parameter  $\beta_{M\eta}$  is significant in all analysed countries, even at a 1 % significance level (except for Slovenia, which is significant at a 5 % level of significance).

The labour cost shares also differ to a large extent among the countries. The lowest labour cost share is in Latvia (0.013) and the highest in Bulgaria (0.373). In general, some countries are characterised by materials-using and labour-saving technology, while for others the opposite is true. Heterogeneity among sectors is also pronounced for the labour cost share. It is significant in 19 of 25 cases. Whereas for materials inputs the sector-specific effect is generally higher, for the labour cost share it is generally lower. That is, the slaughtering sector has, in general, a higher materials cost share and lower labour cost share as compared to other food processing sectors. If we take intersectoral heterogeneity into consideration, then the labour cost share is, in the majority of cases, in the interval 0.1 to 0.25. Since the materials cost share is, in the majority of cases, in the interval 0.65 to 0.9, and constant returns to scale are assumed, the addition to one corresponds to the capital cost share. Moreover, the intrasectoral heterogeneity is greatly pronounced and is significant in almost all cases, even at a 1 % significance level.

As far as the constant which represents the (exogenous) productivity level is concerned, both inter- and intrasectoral heterogeneity are highly significant for almost all EU member countries. With regard to inter-sectoral heterogeneity, the constant for slaughtering is generally lower as compared to other food processing sectors.

#### 4.1.1.2 Fruits and vegetables

Table 4.2 presents the estimated first-order parameter of the input distance function for the fruits and vegetables sector. As compared to Table 4.1, only parameters capturing intersectoral heterogeneity, i.e.  $\beta_{0\_F\&V}$ ,  $\beta_{L\_F\&V}$  and  $\beta_{M\_F\&V}$ , differ. In other words, the parameters  $\beta_0$ ,  $\beta_L$  and  $\beta_M$  and parameters capturing intrasectoral heterogeneity, i.e.  $\beta_{0_\eta}$ ,  $\beta_{L_\eta}$  and  $\beta_{M_\eta}$ , are the same for all sectors. Thus, we can predominantly concentrate only on the discussion of intersectoral heterogeneity, since for other first-order parameters, what we stated in the previous chapter holds true. As far as the theoretical consistency of the estimate is concerned, the monotonicity and diminishing marginal returns requirements are met even if intersectoral heterogeneity is considered. This holds for the majority of analyzed countries.<sup>7</sup>

<sup>6</sup> In other words,  $\beta_M$  represents the materials cost shares of other food processing sectors not controlling for sector dummies, whereas  $\beta_{M\_Slaughter}$  is the sector-specific effect. Thus, the materials cost share for slaughtering is the sum of  $\beta_M$  and  $\beta_{M\_Slaughter}$  if  $\beta_{M\_Slaughter}$  is significant.

<sup>7</sup> The intersectoral heterogeneity is not estimated for Ireland due to the data availability. There is no observation for the fruits and vegetables sector in the case of Ireland.

Table 4.2 First-order parameters – fruits and vegetables

Country		Constant			Labour			Materials		
		$\beta_0$	$\beta_{0\_F\&V}$	$\beta_{0\eta}$	$\beta_L$	$\beta_{L\_F\&V}$	$\beta_{L\eta}$	$\beta_M$	$\beta_{M\_F\&V}$	$\beta_{M\eta}$
Austria	Coeff.	0.0819	-0.0838	0.0799	0.2155	0.0125	0.0391	0.6527	0.1462	0.1123
		***	***	***	***		***	***	***	***
Belgium	Coeff.	0.0553	0.0711	0.0372	0.2139	-0.0381	0.0078	0.5930	0.0786	0.2241
		***	***	***	***	***	***	***	***	***
Bulgaria	Coeff.	0.4220	-0.7682	0.6360	0.3734	0.1062	0.6343	0.3808	0.3498	0.2831
		***	***	***	***		***	***	***	***
Czech Republic	Coeff.	0.1817	-0.0157	0.0807	0.1206	-0.0206	0.1071	0.8381	0.0008	0.1459
		***		***	***		***	***		***
Germany	Coeff.	0.0214	0.0138	0.1501	0.2315	0.0122	0.1783	0.7101	0.0152	0.1078
		***		***	***		***	***		***
Denmark	Coeff.	0.0016	0.0479	0.0903	0.1105	-0.0139	0.0393	0.8179	0.1085	0.0759
			**	***	***		***	***	**	***
Estonia	Coeff.	0.0657	0.1465	0.0815	0.0911	0.2606	0.0918	0.7700	0.1137	0.1120
		***		***	***		***	***		***
Spain	Coeff.	0.0671	-0.0855	0.1968	0.2284	-0.0911	0.0751	0.7530	0.1182	0.1259
		***	***	***	***	***	***	***	***	***
Finland	Coeff.	0.1356	-0.0140	0.0380	0.1440	0.0295	0.0938	0.5466	0.0310	0.1082
					***		***	***		***
France	Coeff.	0.0876	-0.0679	0.0966	0.1791	0.0665	0.0567	0.6647	0.0625	0.0998
		***	***	***	***	***	***	***	***	***
United Kingdom	Coeff.	0.0944	-0.0791	0.1090	0.1098	-0.0144	0.0850	0.8745	0.0383	0.1709
		***	***	***	***	***	***	***	***	***
Greece	Coeff.	0.0882	-0.0916	0.0747	0.1119	-0.0981	0.0601	0.8164	0.1489	0.1275
		***	***	***	***	***	***	***	***	***
Hungary	Coeff.	-0.0344	-0.0830	0.2329	0.1903	-0.1085	0.0283	0.6018	0.1376	0.2054
		**	***	***	***	***	***	***	***	***
Ireland	Coeff.	-0.0174	NA	0.1060	0.0640	NA	0.0272	0.9104	NA	0.0479
				***	***		***	***		***
Italy	Coeff.	0.2359	-0.2456	0.1333	0.2726	-0.2517	0.1352	0.7009	0.3308	0.2693
		***	***	***	***	***	***	***	***	***
Lithuania	Coeff.	0.0125	0.0090	0.1079	0.0987	-0.0221	0.0548	0.8704	0.0379	0.0673
				***	***		***	***		***
Latvia	Coeff.	0.1149	0.0927	0.0486	0.0128	-0.1584	0.1650	0.9040	0.2824	0.1539
		***		***	**		***	***		***
Netherlands	Coeff.	0.0955	-0.0848	0.2348	0.0912	-0.0160	0.0014	0.8539	-0.0105	0.0766
		***	***	***	***			***		***
Poland	Coeff.	0.2813	-0.0779	0.2117	0.1842	-0.0409	0.1050	0.7583	-0.0033	0.2001
		***	***	***	***	***	***	***		***
Portugal	Coeff.	0.0781	0.1027	0.0191	0.1677	-0.1993	0.0038	0.6750	0.5364	0.1971
		***	***	***	***	***		***	***	***
Romania	Coeff.	0.2151	-0.0194	0.1601	0.2110	-0.0344	0.0607	0.7116	0.0090	0.1862
		***		***	***		***	***		***
Sweden	Coeff.	0.0378	0.0146	0.1500	0.1704	0.0166	0.0508	0.6994	0.1600	0.1264
		***	**	***	***		***	***	***	***
Slovenia	Coeff.	-0.0328	-0.1627	0.0318	0.2968	0.0581	0.0282	0.6156	0.3019	0.0173
			***	***	***		***	***	*	**
Slovakia	Coeff.	0.1149	-0.0148	0.1338	0.1061	-0.1229	0.0643	0.8516	0.0213	0.1482
		***		***	***	***	***	***		***
Serbia	Coeff.	0.1333	0.1204	0.1435	0.0931	-0.5145	0.1316	0.8759	0.1135	0.0654
		***	***	***	***	***	***	***	***	***

Source: own calculations

As in the case of slaughtering, the intersectoral heterogeneity is significantly pronounced. This especially holds for the constant which represents the (exogenous) productivity level.  $\beta_{0\_F\&V}$  is significant in 16 countries, and in all cases the productivity level is lower as compared to other food processing sectors; only Belgium, Denmark, Portugal, Sweden and Serbia are exceptions. This result was expected for the fruits and vegetables sector.

The intersectoral heterogeneity for labour and materials inputs is pronounced only for some countries. As far as the labour cost share is concerned, significant intersectoral heterogeneity was revealed by the estimate for only 11 countries (namely Belgium, Spain, France, United Kingdom, Greece, Hungary, Italy, Poland, Portugal, Slovakia and Serbia). The labour cost share for these countries is lower in the fruits and vegetables sector as compared to other food processing sectors, except for France. That is, the employed technology is more labour-saving, as compared to other food processing sectors which are not controlled in the estimate by dummy variables.

The intersectoral heterogeneity of the materials cost share is pronounced in 14 countries (namely Austria, Belgium, Bulgaria, Denmark, Spain, France, United Kingdom, Greece, Hungary, Italy, Portugal, Sweden, Slovenia and Serbia). As could be expected, since raw materials dominates in materials inputs in the fruits and vegetables sector, the materials cost share is in all cases higher as compared to other food processing sectors.

#### 4.1.1.3 Dairy

Table 4.3 provides information on the significance of intersectoral heterogeneity for the dairy food processing sector. The estimate revealed that intersectoral heterogeneity is pronounced for almost all EU member states. As far as the theoretical consistency of the estimate is concerned, the monotonicity and diminishing marginal returns requirements are met even if intersectoral heterogeneity is considered. This holds for the majority of countries.

In the case of the constant, exogenous productivity level, the intersectoral heterogeneity is pronounced in 17 countries. If the parameter is significant, the productivity level is predominantly lower as compared to other food processing sectors.

The intersectoral heterogeneity for labour input is significant in 18 countries. No common pattern can be observed. The technology is more labour saving in Austria, Spain, United Kingdom, Greece, Italy, Lithuania, the Netherlands and Poland, and more labour using in Belgium, Bulgaria, Germany, Denmark, Estonia, France, Hungary, Latvia, Portugal and Serbia, as compared to other food processing sectors in a given country.

The intersectoral heterogeneity of the materials cost share is also pronounced in 17 countries. As in the case of the fruits and vegetables sector, it could be expected that since raw materials dominates in materials inputs in the dairy sector, the materials cost share is in almost all cases higher as compared to other food processing sectors; only Hungary, Latvia, Poland and Slovakia are exceptions.

Table 4.3 First-order parameters – dairy

Country	Coeff.	Constant			Labour			Materials		
		$\beta_0$	$\beta_{0\_Dairy}$	$\beta_{0\eta}$	$\beta_L$	$\beta_{L\_Dairy}$	$\beta_{L\eta}$	$\beta_M$	$\beta_{M\_Dairy}$	$\beta_{M\eta}$
Austria	0.0819	-0.1910	0.0799	0.2155	-0.1125	0.0391	0.6527	0.1777	0.1123	
	***	***	***	***	***	***	***	***	***	
Belgium	0.0553	-0.0935	0.0372	0.2139	0.0372	0.0078	0.5930	0.0484	0.2241	
	***	***	***	***	***	***	***	***	***	
Bulgaria	0.4220	-0.1955	0.6360	0.3734	0.0931	0.6343	0.3808	0.3388	0.2831	
	***	***	***	***	*	***	***	***	***	
Czech Republic	0.1817	-0.0621	0.0807	0.1206	-0.0097	0.1071	0.8381	-0.0137	0.1459	
	***		***	***		***	***		***	
Germany	0.0214	0.0137	0.1501	0.2315	0.0212	0.1783	0.7101	0.0090	0.1078	
	***	*	***	***	***	***	***		***	
Denmark	0.0016	-0.0289	0.0903	0.1105	0.2494	0.0393	0.8179	-0.3906	0.0759	
			***	***	**	***	***		***	
Estonia	0.0657	0.0032	0.0815	0.0911	0.1079	0.0918	0.7700	-0.0244	0.1120	
	***		***	***	**	***	***		***	
Spain	0.0671	-0.0159	0.1968	0.2284	-0.0416	0.0751	0.7530	0.0446	0.1259	
	***	***	***	***	***	***	***	***	***	
Finland	0.1356	-0.0135	0.0380	0.1440	0.0066	0.0938	0.5466	0.0059	0.1082	
				***		***	***		***	
France	0.0876	-0.0929	0.0966	0.1791	0.0816	0.0567	0.6647	0.0227	0.0998	
	***	***	***	***	***	***	***	***	***	
United Kingdom	0.0944	-0.1600	0.1090	0.1098	-0.0510	0.0850	0.8745	0.1957	0.1709	
	***	***	***	***	***	***	***	***	***	
Greece	0.0882	-0.1155	0.0747	0.1119	-0.0547	0.0601	0.8164	0.0647	0.1275	
	***	***	***	***	***	***	***	***	***	
Hungary	-0.0344	0.1525	0.2329	0.1903	0.4162	0.0283	0.6018	-0.3803	0.2054	
	**	***	***	***	***	***	***	***	***	
Ireland	-0.0174	-0.0812	0.1060	0.0640	-0.0337	0.0272	0.9104	0.0341	0.0479	
			***	***		***	***		***	
Italy	0.2359	-0.1567	0.1333	0.2726	-0.0809	0.1352	0.7009	0.0654	0.2693	
	***	***	***	***	***	***	***	***	***	
Lithuania	0.0125	-0.0246	0.1079	0.0987	-0.0413	0.0548	0.8704	0.0582	0.0673	
		**	***	***	**	***	***	***	***	
Latvia	0.1149	-0.0064	0.0486	0.0128	0.0988	0.1650	0.9040	-0.1004	0.1539	
	***		***	*	***	***	***	***	***	
Netherlands	0.0955	-0.1001	0.2348	0.0912	-0.0393	0.0014	0.8539	0.0327	0.0766	
	***	***	***	***	***		***	***	***	
Poland	0.2813	-0.1203	0.2117	0.1842	-0.0222	0.1050	0.7583	-0.0297	0.2001	
	***	***	***	***	***	***	***	***	***	
Portugal	0.0781	0.1681	0.0191	0.1677	0.0691	0.0038	0.6750	0.2101	0.1971	
	***	***	***	***	***		***	***	***	
Romania	0.2151	-0.0577	0.1601	0.2110	0.0330	0.0607	0.7116	0.1645	0.1862	
	***	***	***	***	***	***	***	***	***	
Sweden	0.0378	0.2075	0.1500	0.1704	0.0309	0.0508	0.6994	0.2498	0.1264	
	***	***	***	***		***	***	***	***	
Slovenia	-0.0328	0.0545	0.0318	0.2968	0.1222	0.0282	0.6156	-0.0516	0.0173	
			***	***		***	***		**	
Slovakia	0.1149	0.0289	0.1338	0.1061	0.0092	0.0643	0.8516	-0.1184	0.1482	
	***		***	***		***	***	***	***	
Serbia	0.1333	-0.0849	0.1435	0.0931	0.1050	0.1316	0.8759	-0.0712	0.0654	
	***	*	***	***	*	***	***	***	***	

Source: own calculations

#### 4.1.1.4 Milling

The first-order parameters on milling are provided in Table 4.4. As compared to slaughtering, fruits and vegetables and dairy, intersectoral heterogeneity is less pronounced for the milling sector. If the parameter on intersectoral heterogeneity is significant, it holds true in the

**Table 4.4 First-order parameters – milling**

Country	Coeff.	Constant			Labour			Materials		
		$\beta_0$	$\beta_{0\_Milling}$	$\beta_{0_\eta}$	$\beta_L$	$\beta_{L\_Milling}$	$\beta_{L_\eta}$	$\beta_M$	$\beta_{M\_Milling}$	$\beta_{M_\eta}$
Austria		NA	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	0.0553	-0.0296	0.0372	0.2139	0.0069	0.0078	0.5930	0.0137	0.2241	
	***	***	***	***		***	***		***	
Bulgaria	0.4220	0.2651	0.6360	0.3734	0.6383	0.6343	0.3808	0.1021	0.2831	
	***		***	***	***	***	***		***	
Czech Republic	0.1817	0.0480	0.0807	0.1206	0.0138	0.1071	0.8381	-0.0010	0.1459	
	***	**	***	***		***	***		***	
Germany	0.0214	-0.0631	0.1501	0.2315	-0.0523	0.1783	0.7101	0.0324	0.1078	
	***	***	***	***	***	***	***		***	
Denmark	0.0016	-0.0033	0.0903	0.1105	0.2021	0.0393	0.8179	-0.1812	0.0759	
			***	***	***	***	***	***	***	
Estonia	0.0671	0.0040	0.1968	0.2284	-0.0046	0.0751	0.7530	-0.0076	0.1259	
	***		***	***		***	***		***	
Spain	0.0671	0.004	0.1968	0.2284	-0.005	0.0751	0.7530	-0.008	0.1259	
	***		***	***		***	***		***	
Finland	0.1356	-0.0060	0.0380	0.1440	0.0065	0.0938	0.5466	0.0072	0.1082	
				***		***	***		***	
France	0.0876	0.0858	0.0966	0.1791	0.1219	0.0567	0.6647	-0.0486	0.0998	
	***	***	***	***	***	***	***	***	***	
United Kingdom	0.0944	-0.0071	0.1090	0.1098	0.0650	0.0850	0.8745	-0.0840	0.1709	
	***		***	***	***	***	***	***	***	
Greece	0.0882	0.0373	0.0747	0.1119	-0.0075	0.0601	0.8164	0.0307	0.1275	
	***	***	***	***		***	***		***	
Hungary	-0.0344	-0.0061	0.2329	0.1903	0.0941	0.0283	0.6018	0.0426	0.2054	
	**		***	***	***	***	***		***	
Ireland	-0.0174	-0.0149	0.1060	0.0640	-0.2576	0.0272	0.9104	0.0972	0.0479	
			***	***	***	***	***	***	***	
Italy	0.2359	-0.1186	0.1333	0.2726	-0.0279	0.1352	0.7009	-0.0503	0.2693	
	***	***	***	***	***	***	***	***	***	
Lithuania	0.0125	0.0319	0.1079	0.0987	0.0082	0.0548	0.8704	0.0008	0.0673	
			***	***		***	***		***	
Latvia	0.1149	0.1546	0.0486	0.0128	0.1779	0.1650	0.9040	-0.1118	0.1539	
	***		***	**		***	***		***	
Netherlands	0.0955	-0.0426	0.2348	0.0912	0.2511	0.0014	0.8539	-0.2010	0.0766	
	***		***	***	***		***	***	***	
Poland	0.2813	-0.0505	0.2117	0.1842	-0.0100	0.1050	0.7583	-0.0541	0.2001	
	***	***	***	***		***	***	***	***	
Portugal	0.0781	0.0302	0.0191	0.1677	-0.0437	0.0038	0.6750	-0.0044	0.1971	
	***	*	***	***	*		***		***	
Romania	0.2151	-0.0358	0.1601	0.2110	-0.0310	0.0607	0.7116	0.0364	0.1862	
	***	*	***	***		***	***	**	***	
Sweden	0.0378	-0.0755	0.1500	0.1704	0.1180	0.0508	0.6994	-0.1340	0.1264	
	***	***	***	***	***	***	***	***	***	
Slovenia	-0.0328	-0.2266	0.0318	0.2968	0.0816	0.0282	0.6156	-0.1000	0.0173	
			***	***		***	***		**	
Slovakia	0.1149	0.0179	0.1338	0.1061	0.0168	0.0643	0.8516	-0.1421	0.1482	
	***		***	***		***	***	***	***	
Serbia	0.1333	-0.0631	0.1435	0.0931	-0.0293	0.1316	0.8759	-0.0872	0.0654	
	***	***	***	***	**	***	***	***	***	

Source: own calculations

majority of cases that theoretical consistency of the estimate is not violated.

As far as the constant is concerned, significant intersectoral heterogeneity was estimated for only 11 countries: Belgium, the Czech Republic, Germany, France, Greece, Italy, Poland, Portugal, Romania, Sweden and Serbia. The exogenous productivity level is higher in the Czech Republic, France, Greece and Portugal and lower in other countries as compared to other food processing sectors in a given country.

The intersectoral heterogeneity for labour input is significant in 12 countries. As in the case of the dairy sector, no common pattern can be observed. The technology is more labour saving in Germany, Ireland, Italy and Portugal, and more labour using in Bulgaria, Denmark, France, United Kingdom, Hungary, the Netherlands, Sweden and Serbia, as compared to other food processing sectors.

The intersectoral heterogeneity of the materials cost share is pronounced in only 11 countries. The materials cost share is predominantly lower, except for Ireland and Romania.

#### 4.1.2 Technological change

Table 4.5 provides the parameter estimate on technological change and biased technological change. We found that technological change made a significant positive contribution to the production possibilities in the majority of countries. Only Germany, Spain, United Kingdom, Greece, Hungary, Ireland, Italy, Portugal and Serbia are exceptions; technological change actually made a negative contribution in Germany, United Kingdom, Greece and Italy.  $\beta_T$  was not significant in Spain, Hungary, Ireland, Portugal and Serbia. Since  $\beta_{TT}$  is predominantly significant and negative, the positive contribution of technological change decelerates over time and the negative contribution accelerates over time, respectively. Moreover, both inter- and intrasectoral differences in technological progress were revealed by the estimate. Slaughtering experienced higher positive technological progress in the majority of countries as compared to other sectors. The specific technological effect on the fruits and vegetables sector was pronounced in only 12 countries. This effect was positive in 6 countries and negative in the others. One common pattern can be observed. If  $\beta_T$  is negative, then the sector-specific effect in slaughtering and fruits and vegetables is positive. The sector-specific effect in the dairy sector is significant in 14 countries and is positive in the majority of cases. Thus, as for slaughtering, we can conclude that technological progress was higher in the dairy sector as compared to other food processing sectors in the majority of EU countries. The sector-specific effect in milling was pronounced in 12 countries. The effect was in all cases negative. That is, as opposed to the slaughtering and dairy sectors, the milling sector experienced lower technological progress as compared to other food processing sectors. Intrasectoral heterogeneity in technology was pronounced in 18 countries. However, its contribution was rather small, except for Bulgaria and Finland.

Biased technical change is pronounced in almost all countries, except for Austria and Portugal, where we cannot reject Hicks neutral technological progress. Contrary to our expectations, labour-saving technological change was estimated in only 6 countries, namely Spain, France, Greece, Hungary, Italy and Sweden. On the other hand, materials-saving biased technological change was estimated for most European countries (17 countries).

Table 4.5 Technological change and biased technological change

Country		Time							Biased technological change	
		$\beta_T$	$\beta_{TT}$	$\beta_{T\_Slaughter}$	$\beta_{T\_F\&V}$	$\beta_{L\_Dairy}$	$\beta_{L\_Milling}$	$\beta_{L_\eta}$	$\beta_{LT}$	$\beta_{MT}$
Austria	Coeff.	0.0075	0.0002	0.0149	-0.0002	-0.0067	NA	0.0100	-0.0027	0.0017
		***		***				***		
Belgium	Coeff.	0.0071	-0.0033	0.0135	0.0028	0.0140	-0.0137	0.0034	0.0021	-0.0030
		***	***	***		***	***	***	***	***
Bulgaria	Coeff.	0.0913	-0.0002	-0.0170	-0.1855	-0.1934	0.0051	0.1929	0.1523	-0.0871
		***		*	***	***		***	***	***
Czech Republic	Coeff.	0.0146	-0.0068	0.0143	-0.0147	0.0124	-0.0284	0.0068	0.0011	-0.0181
		***	***	***		**	***	***		***
Germany	Coeff.	-0.0059	-0.0024	0.0145	0.0067	0.0173	0.0008	0.0028	0.0056	-0.0063
		***	*	***		***		***	***	***
Denmark	Coeff.	0.0146	-0.0045	-0.0123	-0.0007	0.0109	0.0003	0.0002	0.0080	-0.0046
		***							**	*
Estonia	Coeff.	0.0068	-0.0004	0.0198	-0.0032	0.0124	NA	0.0017	0.0091	0.0025
		**		***		*			**	
Spain	Coeff.	0.0002	-0.0010	0.0124	0.0067	0.0103	-0.0119	0.0023	-0.0009	-0.0022
			**	***	***	***	***	***	**	***
Finland	Coeff.	0.2049	-0.0441	-0.1171	-0.0351	-0.0612	-0.0239	0.1860	0.0570	-0.0291
		***	***	***	*	***		***	***	***
France	Coeff.	0.0064	0.0000	0.0116	0.0073	0.0078	-0.0214	0.0066	-0.0031	0.0016
		***		***	**	**	***	***	***	***
United Kingdom	Coeff.	-0.0164	-0.0057	0.0035	0.0099	-0.0035	-0.0039	0.0003	0.0039	-0.0056
		***	***	***	***				***	***
Greece	Coeff.	-0.0023	-0.0016	0.0063	0.0026	0.0170	-0.0302	0.0002	-0.0033	0.0027
		*		*		***	***		***	**
Hungary	Coeff.	0.0018	0.0002	0.0001	0.0104	-0.0082	-0.0236	0.0221	-0.0185	0.0147
								***	***	***
Ireland	Coeff.	0.0026	0.0009	0.0001	NA	0.0090	-0.0002	0.0085	0.0077	-0.0111
								***	***	***
Italy	Coeff.	-0.0018	-0.0076	0.0181	0.0233	0.0047	-0.0131	0.0020	-0.0013	-0.0013
		**	***	***	***	**	***	***	**	***
Lithuania	Coeff.	0.0141	-0.0029	0.0233	-0.0023	-0.0022	-0.0221	0.0069	0.0099	-0.0098
		***	**	***			**	***	***	***
Latvia	Coeff.	0.0108	-0.0054	0.0229	0.0075	0.0247	0.0337	0.0021	0.0163	-0.0089
		***	***	***		***			***	***
Netherlands	Coeff.	0.0071	-0.0017	0.0112	0.0061	0.0290	-0.0015	0.0077	-0.0011	-0.0027
		***		**	*	***		***		***
Poland	Coeff.	0.0123	-0.0068	0.0085	-0.0108	0.0028	-0.0179	0.0001	0.0041	-0.0102
		***	***	***	***		***		***	***
Portugal	Coeff.	0.0030	-0.0063	0.0137	0.0036	-0.0125	-0.0446	0.0057	-0.0023	0.0004
			***	**		*	***	***		
Romania	Coeff.	0.0364	-0.0338	0.0294	-0.0240	0.0094	-0.0326	0.0002	0.0159	-0.0314
		***	***	***	*		**		***	***
Sweden	Coeff.	0.0136	-0.0014	-0.0041	-0.0063	0.0088	-0.0233	0.0181	-0.0056	0.0077
		***	**	**	**		***	***	***	***
Slovenia	Coeff.	0.0391	-0.0024	-0.0163	0.0482	0.0075	-0.0719	0.0409	0.0000	-0.0125
		***		***	***			***		**
Slovakia	Coeff.	0.0099	-0.0053	0.0126	-0.0141	0.0209	-0.0244	0.0174	0.0124	-0.0243
		***	***	**		***	***	***	***	***
Serbia	Coeff.	-0.0030	-0.0032	-0.0020	-0.0365	0.0090	0.0030	0.0134	-0.0019	0.0002
			**		***			***		

Source: own calculations

### 4.1.3 Technical efficiency

This chapter provides the technical efficiency estimates for the slaughtering, fruits and vegetables, dairy and milling sectors in the analysed EU member countries. Since the technical efficiency estimates are country specific, we concentrate predominantly on discussing the significance of technical efficiency and its distribution, and on comparing trends in technical efficiency developments. The overall comparison of the level of technical efficiency among analysed countries will be carried out using metafrontier analysis (Chapter 4.2).

#### 4.1.3.1 Slaughtering

Table 4.6 provides estimates of the parameters  $\sigma$ ,  $\beta$  and the statistical characteristics of the estimated technical efficiency for slaughtering. The parameter  $\sigma$  provides information about the joint variation of  $u_{it}$  and  $v_{it}$ .  $\lambda$  is the relation between the variance of  $u_{it}$  and  $v_{it}$ . Thus, this parameter indicates the significance of TE in the residual variation. A value less than one suggests that variation in  $u_{it}$  is less pronounced than variation in the random component  $v_{it}$ . Since  $\lambda$  is highly significant in a majority of EU member countries and greater than one, the estimates indicate that efficiency differences among food processors are important reasons for variations in production. Only Denmark, Finland, United Kingdom, Greece, Romania and Slovenia are exceptions with  $\lambda$  less than one, which suggests that the differences in efficiency of the inputs used are rather small among food processors in these countries. Moreover, the estimate revealed that there are no differences in technical efficiency among food processors in Ireland and Lithuania. In other words, the food processors seem to be on the same level of technical efficiency in these countries.

Table 4.6 Technical efficiency – slaughtering

Country	Sigma	Lamb da	Statistical characteristics of technical efficiency - slaughtering							
			Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.0505	1.1158	0.9729	0.0053	0.9570	0.9810	0.9657	0.9781	0.9630	0.9750
Belgium	0.2027	2.9501	0.8831	0.0496	0.6470	0.9840	0.8194	0.9340	0.7313	0.8998
Bulgaria	0.3063	1.5222	0.8264	0.0739	0.3344	0.9535	0.7551	0.8857	0.4901	0.8016
Czech Republic	0.2913	2.7448	0.8464	0.0435	0.4963	0.9672	0.7933	0.8910	0.6140	0.8495
Germany	0.1697	1.3086	0.9096	0.0161	0.8451	0.9727	0.8907	0.9283	0.8770	0.9408
Denmark	0.0810	0.9225	0.9584	0.0125	0.9116	0.9848	0.9417	0.9684	0.9299	0.9665
Estonia	0.0892	2.5161	0.9451	0.0253	0.8289	0.9783	0.9221	0.9743	0.8662	0.9409
Spain	0.1675	1.9484	0.9019	0.0437	0.3472	0.9891	0.8668	0.9357	0.5077	0.8286
Finland	0.3181	0.1334	0.9667	0.0012	0.9628	0.9700	0.9654	0.9682	0.9646	0.9682
France	0.2432	1.5899	0.8681	0.0387	0.5688	0.9718	0.8273	0.9051	0.6695	0.8711
United Kingdom	0.1279	0.8605	0.9386	0.0140	0.8726	0.9806	0.9202	0.9538	0.8996	0.9536
Greece	0.1204	0.5953	0.9534	0.0068	0.9236	0.9669	0.9458	0.9610	0.9344	0.9561
Hungary	0.2681	1.9434	0.8371	0.0789	0.2325	0.9826	0.7389	0.9133	0.4201	0.7951
Ireland	0.0671	0.0000	x	x	x	x	x	x	x	x
Italy	0.2242	1.8853	0.8724	0.0426	0.4972	0.9852	0.8256	0.9154	0.6192	0.8632
Lithuania	0.0777	0.0000	x	x	x	x	x	x	x	x
Latvia	0.1043	1.4589	0.9382	0.0259	0.8295	0.9785	0.9144	0.9629	0.8667	0.9412
Netherlands	0.1688	8.3834	0.9046	0.0509	0.7334	0.9712	0.8253	0.9550	0.7929	0.9118
Poland	0.1822	2.4417	0.8926	0.0521	0.4874	0.9810	0.8491	0.9353	0.6108	0.8576
Portugal	0.1792	1.8003	0.9007	0.0234	0.7523	0.9607	0.8696	0.9293	0.8044	0.9086
Romania	0.3863	0.9631	0.8151	0.0534	0.2620	0.9457	0.7724	0.8698	0.4329	0.7748
Sweden	0.0860	1.3533	0.9511	0.0143	0.8621	0.9804	0.9330	0.9665	0.8916	0.9508
Slovenia	0.0573	0.0424	0.9981	0.0002	0.9980	0.9981	0.9980	0.9981	0.9981	0.9981
Slovakia	0.1688	3.1761	0.9061	0.0290	0.8191	0.9650	0.8655	0.9414	0.8556	0.9285
Serbia	0.2116	6.9171	0.8817	0.0763	0.5492	0.9743	0.8300	0.9450	0.8671	0.9177

Source: own calculations

The average technical efficiency in EU member countries and Serbia is about 0.9, with a variation of approximately +/- 10 %. This suggests that, on average, food processing companies in slaughtering greatly exploit their production possibilities in most analysed countries. The table shows that the average technical efficiency in individual countries is the lowest in Romania (0.82) and Bulgaria (0.83) and the highest in Slovenia (0.998) and Austria (0.97). However, Table 4.6 provides only country-specific estimates of technical efficiency, which cannot be used for comparative purposes. This comparison will be done using the metafrontier analysis in Chapter 4.2.

The variation in average technical efficiency is quite small for all EU member countries as well as for Serbia, even though huge differences among the best and worst food processors exist in some countries (especially in Bulgaria, the Czech Republic, Spain, France, Hungary, Italy, Poland, Romania and Serbia). High technical efficiency of the top 10 % of food processors in slaughtering is a common feature in all countries. In particular,

the technical efficiency in this case is higher than 0.87, and for most countries exceeds 0.9. That is, the top 10 % of producers greatly exploit their production possibilities. On the other hand, the bottom 10 % differ significantly among countries. The bottom 10 % of food processors have a technical efficiency lower than 0.8 in Bulgaria, the Czech Republic, Hungary and Romania. This means that the largest differences in the use of production possibilities can be found in new member states, which suggests that these countries may face another structural change in the slaughtering sector. Using information from the 1<sup>st</sup> quartile, the differences in technical efficiency among the worst performing food processing companies are also pronounced.

The spread between the 1<sup>st</sup> and 10<sup>th</sup> decile is, on average, 6.6 %. That is, 80 % of the farmers have a technical efficiency between 0.85 and 0.97. This interval is significantly smaller for Austria (1.2 %), Germany (3.8 %), Denmark (2.7 %), Finland (0.3), Greece (1.5 %), Sweden (3.3 %) and Slovenia (13 %). On the other hand, there are countries with considerable differences in technical efficiency (Bulgaria (13 %), Hungary (17 %) and the Netherlands (13 %)).

Table 4.7 provides the development of technical efficiency in slaughtering. The development in technical efficiency is rather stochastic in many EU member countries. However, in general we can conclude that we cannot observe significant changes in technical efficiency. Positive, although very weak, trends were estimated for almost all countries except Bulgaria, Germany, Hungary, Lithuania, Poland, Slovakia and Serbia. Despite the rather stochastic development of technical efficiency, one common pattern for some countries can be observed. Technical efficiency experienced a small decrease in the years 2008 and 2009 and an increase in subsequent years. That is, the financial crisis had a rather small effect on slaughtering. Moreover, we cannot observe any negative effect on TE development in new member states in the years after EU enlargement.

**Table 4.7 Development of technical efficiency – slaughtering**

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	NA	NA	0.970	0.976	0.972	0.969	0.975	0.973	NA	$y = 0.971 + 0.0003t$	0.04
Belgium	0.882	0.877	0.884	0.889	0.886	0.883	0.869	0.888	0.886	0.899	$y = 0.878 + 0.001t$	0.19
Bulgaria	0.839	0.828	0.822	0.818	0.824	0.828	0.805	0.843	0.839	0.789	$y = 0.833 - 0.002t$	0.11
Czech Republic	0.859	0.835	0.841	0.845	0.858	0.850	0.840	0.853	0.836	0.908	$y = 0.834 + 0.003t$	0.18
Germany	0.914	0.896	0.907	0.909	0.915	0.907	0.906	0.914	0.912	0.896	$y = 0.910 - 0.0002t$	0.01
Denmark	NA	NA	NA	NA	0.966	0.952	0.955	0.960	0.960	0.963	$y = 0.958 + 0.001t$	0.03
Estonia	0.964	0.936	0.938	0.929	0.952	0.938	0.952	0.938	0.964	0.942	$y = 0.943 + 0.0003t$	0.01
Spain	0.907	0.900	0.907	0.903	0.901	0.900	0.890	0.905	0.905	0.910	$y = 0.902 + 0.0001t$	0.00
Finland	0.968	0.967	0.967	0.966	0.966	0.966	0.966	0.967	0.968	0.968	$y = 0.967 + 0.00002t$	0.00
France	0.874	0.864	0.866	0.873	0.858	0.854	0.873	0.884	0.868	0.866	$y = 0.866 + 0.0003t$	0.01
United Kingdom	0.935	0.935	0.943	0.948	0.950	0.937	0.924	0.937	0.943	0.949	$y = 0.938 + 0.0004t$	0.02
Greece	0.954	0.955	0.954	0.952	0.953	0.956	0.950	0.952	0.956	0.956	$y = 0.953 + 0.0001t$	0.03
Hungary	NA	0.832	0.862	0.816	0.825	0.827	0.837	0.871	0.817	NA	$y = 0.836 - 0.00003t$	0.00
Ireland	x	x	x	x	x	x	x	x	x	x	x	x
Italy	0.876	0.870	0.875	0.870	0.873	0.871	0.861	0.882	0.886	0.941	$y = 0.857 + 0.004t$	0.33
Lithuania	x	x	x	x	x	x	x	x	x	x	x	x
Latvia	0.939	0.932	0.944	0.954	0.946	0.943	0.927	0.937	0.933	0.898	$y = 0.951 - 0.003t$	0.33
Netherlands	0.892	0.867	0.912	0.934	0.895	0.937	0.887	0.919	0.897	NA	$y = 0.893 + 0.002t$	0.06
Poland	0.888	0.889	0.895	0.897	0.901	0.884	0.880	0.908	0.897	0.862	$y = 0.896 - 0.001t$	0.06
Portugal	0.897	0.900	0.906	0.896	0.904	0.906	0.891	0.902	0.906	NA	$y = 0.899 + 0.0003t$	0.03
Romania	0.830	0.816	0.800	0.777	0.840	0.837	0.796	0.809	0.824	NA	$y = 0.814 + 0.0001t$	0.00
Sweden	0.943	0.953	0.951	0.957	0.960	0.950	0.936	0.951	0.958	0.950	$y = 0.950 + 0.0001t$	0.00
Slovenia	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	NA	$y = 0.998 + 0.0000001t$	0.00
Slovakia	0.932	0.913	0.906	0.902	0.897	0.876	0.908	0.917	0.913	NA	$y = 0.914 - 0.002t$	0.07
Serbia	NA	0.877	0.881	0.878	0.898	0.883	0.927	0.851	0.841	0.901	$y = 0.886 - 0.001t$	0.01

Source: own calculations

The question of stability can be analysed using the figures provided in Table 4.8, which presents the Spearman’s rank correlations of technical efficiency in the analysed countries. Since the order of food processors in slaughtering changes dramatically in all countries, leapfrogging appears to be a common phenomenon for all member countries. That is, catching-up and falling-behind processes are important characteristics for slaughtering houses/producers in all countries. This also holds true even if we take into consideration the character of the data. Since we have an unbalanced panel, the values are affected to some extent by the entry and exit of producers, to and from the sample.

The highest Spearman’s rank correlations were found in the Czech Republic, Germany, Finland, France, United Kingdom, Greece, Italy, Poland, Portugal and Romania. This suggests that in these countries we may find groups of producers that tend to strengthen their positions.

**Table 4.8 Spearman's rank correlation coefficient of TE – slaughtering**

Country	Spearman's rank correlation coefficients of technical efficiency								
	2004/ 2003	2005/ 2004	2006/ 2005	2007/ 2006	2008/ 2007	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011
Austria	LNO	LNO	LNO	1.0000	0.0238	-0.4857	0.3143	-0.3818	LNO
Belgium	0.6774	0.5862	0.5042	0.1846	0.7220	0.4846	0.4585	0.7006	0.7939
Bulgaria	-0.2857	0.1818	0.3636	0.3008	0.3217	0.1315	-0.1569	-0.3235	LNO
Czech Republic	0.8438	0.3226	0.5370	0.1084	0.4148	0.5073	0.5892	0.1291	LNO
Germany	0.4000	0.8667	0.3010	0.5362	0.4084	-0.0213	0.5217	0.5405	0.4000
Denmark	LNO	LNO	LNO	LNO	-1.0000	0.1786	0.4524	0.7143	0.0000
Estonia	-0.6000	-0.2000	-0.0286	-0.9000	0.0000	0.1429	0.4857	-0.6000	LNO
Spain	0.4710	0.4569	0.2846	0.1669	0.3655	0.2188	0.3046	0.4938	1.0000
Finland	0.7714	0.7099	0.9536	0.8456	0.6945	0.4675	0.8700	0.9559	0.5000
France	0.6954	0.6187	0.6979	0.4660	0.7311	0.4185	0.6010	0.7194	0.4320
United Kingdom	0.9118	0.7751	0.3936	0.5251	-0.0138	0.6438	0.5536	0.5134	0.7143
Greece	0.8614	0.5544	0.4130	0.2589	0.2446	0.6500	0.8128	0.5354	-0.8000
Hungary	LNO	1.0000	0.2000	-0.4643	0.4498	0.0524	0.2524	0.2348	LNO
Ireland	x	x	x	x	x	x	x	x	x
Italy	0.5590	0.6370	0.6192	0.4359	0.4732	0.6884	0.7659	0.6475	LNO
Lithuania	x	x	x	x	x	x	x	x	x
Latvia	0.6000	-0.5000	0.8286	0.6571	0.3143	-0.0857	0.6429	0.5000	LNO
Netherlands	0.2000	-1.0000	1.0000	-0.0857	0.6000	-0.8000	0.8000	0.6000	LNO
Poland	0.3612	0.5816	0.5202	0.2492	0.3640	0.4540	0.5985	0.5910	-0.2000
Portugal	1.0000	0.8000	1.0000	0.3250	0.2949	0.5593	0.5058	0.5503	LNO
Romania	0.6662	0.6098	0.4681	0.1702	0.4227	0.4677	0.6929	0.4898	LNO
Sweden	-0.0404	-0.1779	0.0633	0.3263	-0.0072	-0.0686	0.2759	0.1666	0.1648
Slovenia	0.0286	-0.3714	0.8857	0.0286	0.4857	0.7143	0.3714	-0.3714	NA
Slovakia	0.7000	-0.5429	0.9286	-0.7667	0.3667	0.3500	0.1923	0.1273	NA
Serbia	NA	-0.4286	-0.4857	-0.3714	0.3143	0.2571	-0.0857	0.6571	-0.4286

Note: LNO – Low Number of Observations

Source: own calculations

#### 4.1.3.2 Fruits and vegetables

Table 4.9 provides estimates of the parameters  $\sigma$ ,  $\lambda$  and the statistical characteristics of the estimated technical efficiency for fruits and vegetables. Since we estimated the joint input distance function with a control for inter- and intrasectoral heterogeneity, the parameters  $\sigma$  and  $\lambda$  are the same for all sectors, and were commented on in the previous chapter. In this chapter we concentrate only on estimated technical efficiency in the fruits and vegetables sector.

Statistical characteristics show that food processing companies in the fruits and vegetables sector greatly exploit their production possibilities in a majority of EU member states. The average technical efficiency is about 0.9. The highest average technical efficiency can be found in Slovenia (0.9981), where the smallest variation between the minimum (0.9979) and maximum (0.9982) levels of technical efficiency is also observed. The same result for technical efficiency variation can be seen in Finland, where the average technical efficiency

is 0.9664 and the variation range is 0.0078. On the other hand, Romania (0.7922), Bulgaria (0.8234), Hungary (0.8376) and Serbia (0.8080) are the countries with the lowest average technical efficiency (TE) for fruit and vegetable processing companies, and with a high standard deviation of TE. As stated in Chapter 4.1.3.1, these results represent only country-specific characteristics that cannot be used for comparative purposes. The comparison will be done by the metafrontier analysis, see Chapter 4.2.

**Table 4.9 Technical efficiency – fruits and vegetables**

Country	Sigma	Lamb da	Statistical characteristics of technical efficiency							
			Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.0505	1.1158	0.9709	0.0114	0.9352	0.9877	0.9604	0.9825	0.9681	0.9777
Belgium	0.2027	2.9501	0.8703	0.0710	0.2915	0.9884	0.7795	0.9477	0.4657	0.8142
Bulgaria	0.3063	1.5222	0.8234	0.0624	0.6509	0.9600	0.7378	0.8876	0.7282	0.8828
Czech Republic	0.2913	2.7448	0.8431	0.0450	0.7112	0.9300	0.7754	0.8960	0.7659	0.8753
Germany	0.1697	1.3086	0.9063	0.0290	0.7189	0.9566	0.8668	0.9349	0.7783	0.8972
Denmark	0.0810	0.9225	0.9589	0.0106	0.9286	0.9760	0.9451	0.9720	0.9404	0.9642
Estonia	0.0892	2.5161	0.9332	0.0555	0.7889	0.9824	0.8449	0.9767	0.8372	0.9340
Spain	0.1675	1.9484	0.8919	0.0649	0.2564	0.9891	0.8270	0.9448	0.4396	0.8059
Finland	0.3181	0.1334	0.9664	0.0012	0.9607	0.9685	0.9651	0.9676	0.9626	0.9666
France	0.2432	1.5899	0.8653	0.0397	0.6357	0.9820	0.8245	0.9069	0.7223	0.8955
United Kingdom	0.1279	0.8605	0.9377	0.0154	0.8526	0.9764	0.9190	0.9541	0.8835	0.9455
Greece	0.1204	0.5953	0.9517	0.0156	0.7873	0.9817	0.9398	0.9638	0.8359	0.9331
Hungary	0.2681	1.9434	0.8376	0.0982	0.2350	0.9739	0.7922	0.9130	0.4198	0.7892
Ireland	0.0671	0.0000	x	x	x	x	x	x	x	x
Italy	0.2242	1.8853	0.8687	0.0560	0.1562	0.9822	0.8066	0.9167	0.3627	0.7757
Lithuania	0.0777	0.0000	x	x	x	x	x	x	x	x
Latvia	0.1043	1.4589	0.9314	0.0323	0.8657	0.9817	0.8730	0.9750	0.8947	0.9527
Netherlands	0.1688	8.3834	0.9025	0.0411	0.8285	0.9823	0.8473	0.9647	0.8669	0.9439
Poland	0.1822	2.4417	0.8895	0.0483	0.6743	0.9811	0.8271	0.9431	0.7510	0.9044
Portugal	0.1792	1.8003	0.8771	0.0909	0.2184	0.9563	0.8035	0.9364	0.4029	0.7719
Romania	0.3863	0.9631	0.7922	0.1116	0.2578	0.9658	0.6799	0.9020	0.4348	0.7888
Sweden	0.0860	1.3533	0.9496	0.0176	0.8914	0.9808	0.9266	0.9686	0.9137	0.9584
Slovenia	0.0573	0.0424	0.9981	0.0006	0.9979	0.9982	0.9979	0.9981	0.9980	0.9981
Slovakia	0.1688	3.1761	0.8974	0.0830	0.5264	0.9534	0.8714	0.9472	0.6332	0.8466
Serbia	0.2116	6.9171	0.8080	0.1365	0.5492	0.9914	0.6154	0.9643	0.6774	0.9282

Source: own calculations

The variation in individual technical efficiency is relatively low in the majority of countries. However, huge differences between the best and worst fruit and vegetable processors can be seen in Italy (variation range 0.83), Portugal (0.74), Hungary (0.74), Spain (0.73), Romania (0.71) and Belgium (0.70). Similarly to slaughtering, high technical efficiency of the top 10 % of fruit and vegetable processors is a common feature in all EU member countries. Individual technical efficiency in this case is higher than 0.89, and for most

countries exceeds 0.9 (Bulgaria and the Czech Republic are the exceptions). On the other hand, the values of technical efficiency of the bottom 10 % of processors differ among the analysed countries. The bottom 10 % of fruit and vegetable processors have technical efficiency lower than 0.8 in Belgium, Bulgaria, the Czech Republic, Hungary, Romania and Serbia. Using information from the quartiles, large differences in technical efficiency among companies are also pronounced. We can conclude that except for Belgium, the largest differences in the use of production possibilities can be observed in the new member states.

*Table 4.10 Development of technical efficiency – fruits and vegetables*

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	NA	NA	0.980	0.970	0.969	0.976	0.980	0.959	NA	$y = 0.979 - 0.002t$	0.20
Belgium	0.861	0.864	0.898	0.884	0.851	0.868	0.861	0.862	0.883	0.902	$y = 0.864 + 0.002t$	0.09
Bulgaria	0.723	0.810	0.874	0.818	0.816	0.871	0.789	0.840	0.815	0.833	$y = 0.792 + 0.005t$	0.12
Czech Republic	0.829	0.834	0.822	0.836	0.840	0.874	0.831	0.854	0.860	0.867	$y = 0.821 + 0.004t$	0.53
Germany	0.913	0.894	0.913	0.904	0.897	0.909	0.910	0.919	0.896	0.888	$y = 0.910 - 0.001t$	0.08
Denmark	NA	NA	NA	NA	0.962	0.962	0.954	0.959	0.956	0.976	$y = 0.956 + 0.002t$	0.15
Estonia	LNO	x	x									
Spain	0.896	0.898	0.891	0.903	0.904	0.886	0.872	0.894	0.886	0.893	$y = 0.899 - 0.001t$	0.16
Finland	0.968	0.966	0.967	0.966	0.966	0.966	0.966	0.967	0.967	0.967	$y = 0.966 + 0.00001t$	0.00
France	0.867	0.858	0.864	0.874	0.852	0.849	0.862	0.874	0.886	0.874	$y = 0.857 + 0.002t$	0.18
United Kingdom	0.932	0.931	0.942	0.947	0.944	0.945	0.929	0.937	0.935	0.938	$y = 0.938 - 0.000004t$	0.00
Greece	0.951	0.949	0.956	0.953	0.953	0.954	0.946	0.951	0.951	0.960	$y = 0.951 + 0.0003t$	0.06
Hungary	NA	0.848	0.801	0.809	0.827	0.853	0.821	0.868	0.832	0.828	$y = 0.822 + 0.002t$	0.07
Ireland	x	x	x	x	x	x	x	x	x	x	x	x
Italy	0.841	0.851	0.872	0.883	0.882	0.872	0.862	0.867	0.877	0.886	$y = 0.853 + 0.003t$	0.38
Lithuania	x	x	x	x	x	x	x	x	x	x	x	x
Latvia	0.943	0.920	0.962	0.880	0.919	0.936	0.928	0.940	0.934	0.975	$y = 0.919 + 0.003t$	0.09
Netherlands	0.908	0.872	0.917	0.929	0.894	0.887	0.895	0.919	0.906	0.866	$y = 0.907 - 0.001t$	0.04
Poland	0.871	0.882	0.887	0.897	0.884	0.875	0.900	0.906	0.906	0.927	$y = 0.868 + 0.005t$	0.69
Portugal	0.876	0.848	0.887	0.886	0.881	0.901	0.878	0.856	0.862	NA	$y = 0.878 - 0.001t$	0.01
Romania	0.830	0.788	0.771	0.687	0.870	0.785	0.774	0.782	0.816	NA	$y = 0.787 + 0.001t$	0.00
Sweden	0.938	0.947	0.960	0.962	0.955	0.953	0.925	0.947	0.956	0.964	$y = 0.947 + 0.001t$	0.03
Slovenia	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	NA	$y = 0.998 - 0.0000004t$	0.00
Slovakia	0.909	0.882	0.925	0.935	0.828	0.918	0.891	0.895	0.922	NA	$y = 0.900 + 0.0001t$	0.00
Serbia	NA	0.887	0.816	0.776	0.794	0.784	0.748	0.865	0.746	0.855	$y = 0.825 - 0.003t$	0.03

Source: own calculations

The spread between the best and worst 10 % of fruit and vegetable processors is, on average, 9.0 % (slightly higher than in the case of slaughtering). We can conclude that 80 % of processors have technical efficiency between 0.81 and 0.99. However this interval is significantly smaller in Slovenia (0.02 %), Finland (0.25 %), Austria (2.0 %), Greece (2.4 %) and Denmark (2.7 %), and higher in Romania (22.2 %), Belgium (16.8 %), Bulgaria (15 %), Portugal (13.3 %) and Estonia (13.2 %).

The development of technical efficiency in the fruit and vegetable processing sector is provided in Table 4.10. TE development is rather stochastic in the majority of countries; the Czech Republic and Poland are exceptions. These countries are characterised by a positive trend in technical efficiency development. In the rest of the analysed countries, we cannot observe significant changes in technical efficiency in the fruit and vegetable processing sector. Considering the economic crisis, one can find only a small decrease in technical efficiency, especially in the year 2009, and an increase in subsequent years in almost all EU countries. That is, the influence of the economic crisis was very weak in the fruit and vegetable processing sector. In addition, we cannot observe any significant changes related to the EU enlargement.

**Table 4.11 Spearman's rank correlation coefficient of TE – fruits and vegetables**

Country	Spearman's rank correlation coefficients of technical efficiency								
	2004/ 2003	2005/ 2004	2006/ 2005	2007/ 2006	2008/ 2007	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011
Austria	NA	NA	NA	LNO	-0.7143	-0.1000	0.5000	-1.0000	LNO
Belgium	0.8517	0.6729	0.4542	0.7039	0.3622	0.5755	0.4674	0.7603	0.7000
Bulgaria	-1.0000	0.5000	-1.0000	0.3095	-0.6000	-0.7333	-0.3000	-0.0238	LNO
Czech Republic	-0.2000	0.0714	0.3214	0.1190	-0.5714	0.1786	0.8810	0.9762	LNO
Germany	1.0000	-0.5000	0.6190	0.4376	0.5974	0.0701	0.6568	0.2326	1.0000
Denmark	NA	NA	NA	LNO	-0.2000	-0.5000	0.8286	-0.4286	LNO
Estonia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO
Spain	0.5641	0.4924	0.3365	0.0669	0.2335	0.0832	0.0897	0.2517	0.2500
Finland	0.9000	-0.2000	0.5000	0.5000	0.2000	0.6000	0.8286	-0.2000	-1.0000
France	0.3854	0.7667	0.5885	0.6165	0.6296	0.2096	0.6262	0.7794	0.7063
United Kingdom	0.6353	0.5694	0.6516	0.4025	0.3412	0.2865	0.6264	0.4855	0.5356
Greece	0.5826	0.5470	0.6877	0.5133	0.7146	0.5459	0.7079	0.5639	0.6071
Hungary	LNO	LNO	1.0000	-0.4000	0.5564	-0.0877	0.0260	0.2180	1.0000
Ireland	x	x	x	x	x	x	x	x	x
Italy	0.3126	0.6732	0.7163	0.5663	0.5350	0.3949	0.4213	0.4780	0.7188
Lithuania	x	x	x	x	x	x	x	x	x
Latvia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO
Netherlands	0.1667	-0.1786	0.0357	0.8810	-0.2000	-0.2000	0.7000	0.2000	LNO
Poland	0.4914	0.3200	0.2414	0.0682	0.3401	0.0020	0.2125	0.0970	1.0000
Portugal	LNO	1.0000	-0.5000	0.5989	0.0110	0.7582	0.3758	0.4121	LNO
Romania	0.1484	0.5956	-0.1091	-0.3818	-0.7286	0.2000	0.5330	0.3022	LNO
Sweden	-0.0070	-0.5175	0.0154	0.1264	-0.3179	-0.3143	0.1446	0.0898	-0.4000
Slovenia	1.0000	-1.0000	1.0000	-1.0000	-1.0000	1.0000	1.0000	-1.0000	LNO
Slovakia	LNO	LNO	LNO	0.4000	-0.5000	-0.5000	-0.5000	1.0000	LNO
Serbia	NA	-0.2571	0.7143	0.5429	-0.0857	-0.0286	-0.2571	-0.5429	-0.3143

Note: LNO – Low Number of Observations

Source: own calculations

The question of stability was analysed using the Spearman's rank correlation coefficient of technical efficiency. Table 4.11 shows that the highest and most stable values of Spearman's rank correlation coefficient can be found in Belgium, Greece, France, United

Kingdom and Italy. The high and positive values in these countries suggest that fruit and vegetable producers tend to strengthen their positions. In other countries, the order of fruit and vegetable processors varied significantly in the analysed period. This suggests that as far as technical efficiency is concerned, leapfrogging appears to be a common phenomenon in fruit and vegetable processing in these countries.

#### 4.1.3.3 Dairy

The estimates of the parameters  $\sigma$ ,  $\lambda$  and the statistical characteristics of the estimated technical efficiency for dairy are provided in Table 4.12. As we have already mentioned, since we estimated the joint input distance function with a control for inter- and intrasectoral heterogeneity, the parameters  $\sigma$  and  $\lambda$  are the same for all sectors, and were commented on in the previous chapter. In this chapter, we concentrate only on estimated technical efficiency in the dairy sector.

*Table 4.12 Technical efficiency – dairy*

Country	Sigma	Lambd a	Statistical characteristics of technical efficiency							
			Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.0505	1.1158	0.9716	0.0095	0.9398	0.9856	0.9586	0.9808	0.9689	0.9777
Belgium	0.2027	2.9501	0.8762	0.0639	0.5376	0.9833	0.8137	0.9335	0.6490	0.8719
Bulgaria	0.3063	1.5222	0.8349	0.0440	0.6872	0.9219	0.7705	0.8870	0.7459	0.8632
Czech Republic	0.2913	2.7448	0.8377	0.0530	0.6161	0.9506	0.7683	0.8965	0.6997	0.8670
Germany	0.1697	1.3086	0.9050	0.0381	0.6623	0.9690	0.8785	0.9356	0.7390	0.8923
Denmark	0.0810	0.9225	0.9599	0.0064	0.9479	0.9762	0.9550	0.9644	0.9550	0.9692
Estonia	0.0892	2.5161	0.9346	0.0434	0.7868	0.9852	0.8711	0.9738	0.8364	0.9356
Spain	0.1675	1.9484	0.9010	0.0395	0.6740	0.9824	0.8576	0.9386	0.7511	0.0530
Finland	0.3181	0.1334	0.9664	0.0009	0.9637	0.9681	0.9652	0.9676	0.9648	0.9670
France	0.2432	1.5899	0.8679	0.0397	0.5931	0.9604	0.8262	0.9063	0.6849	0.8686
United Kingdom	0.1279	0.8605	0.9378	0.0262	0.4885	0.9743	0.9225	0.9548	0.6100	0.8529
Greece	0.1204	0.5953	0.9535	0.0059	0.9307	0.9674	0.9463	0.9600	0.9399	0.9583
Hungary	0.2681	1.9434	0.8421	0.0636	0.6415	0.9617	0.7306	0.9070	0.7216	0.8817
Ireland	0.0671	0.0000	x	x	x	x	x	x	x	x
Italy	0.2242	1.8853	0.8726	0.0396	0.5821	0.9852	0.8310	0.9098	0.6828	0.8844
Lithuania	0.0777	0.0000	x	x	x	x	x	x	x	x
Latvia	0.1043	1.4589	0.9357	0.0291	0.8264	0.9834	0.8985	0.9647	0.8656	0.9441
Netherlands	0.1688	8.3834	0.9032	0.0454	0.7419	0.9777	0.8549	0.9547	0.8009	0.9188
Poland	0.1822	2.4417	0.8947	0.0553	0.4771	0.9881	0.8488	0.9348	0.6048	0.8604
Portugal	0.1792	1.8003	0.8853	0.0495	0.7114	0.9715	0.8156	0.9341	0.7764	0.9065
Romania	0.3863	0.9631	0.8132	0.0586	0.0505	0.9480	0.7696	0.8609	0.2749	0.7236
Sweden	0.0860	1.3533	0.9500	0.0158	0.9228	0.9771	0.9285	0.9705	0.9364	0.9635
Slovenia	0.0573	0.0424	0.9981	0.0002	0.9980	0.9981	0.9980	0.9981	0.9981	0.9981
Slovakia	0.1688	3.1761	0.8948	0.0552	0.6534	0.9767	0.8303	0.9415	0.7342	0.8959
Serbia	0.2116	6.9171	0.9032	0.0309	0.8111	0.9532	0.8599	0.9336	0.8866	0.9259

Source: own calculations

The statistical characteristics presented in Table 4.12 show that food processing companies in the dairy sector greatly exploit their production possibilities in most EU member states and Serbia. The average technical efficiency is about 0.9. The highest average technical efficiency can be found in Slovenia (0.9981), Austria (0.971) and Finland (0.9664), and the lowest in Romania (0.8132), Bulgaria (0.8340) and the Czech Republic (0.8377).

The variability of individual technical efficiency is low in all analysed countries. Considering the variation range between the minimum and maximum values of technical efficiency at the country level, huge differences between the best and worst dairy processors can be found in Romania (0.90), United Kingdom (0.49) and Belgium (0.45). However, the spread between the best and worst producers is much closer than in the case of the fruits and vegetables sector.

The dairy processing sector is characterised by the high technical efficiency of the top 10 % of processors in all EU member countries, including Serbia. The individual technical efficiency of the best dairy processors is higher than 0.86 and for the majority of countries

**Table 4.13 Development of technical efficiency – dairy**

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	NA	NA	0.976	0.975	0.958	0.977	0.974	0.972	NA	$y = 0.972 - 0.0001t$	0.00
Belgium	0.860	0.867	0.880	0.897	0.866	0.865	0.885	0.882	0.880	NA	$y = 0.867 + 0.002t$	0.16
Bulgaria	0.823	0.784	0.859	0.863	0.827	0.828	0.838	0.840	0.829	NA	$y = 0.823 + 0.002t$	0.06
Czech Republic	0.829	0.823	0.819	0.867	0.846	0.814	0.849	0.834	0.857	0.862	$y = 0.822 + 0.003t$	0.27
Germany	0.897	0.899	0.905	0.919	0.903	0.890	0.913	0.908	0.903	0.936	$y = 0.895 + 0.002t$	0.27
Denmark	NA	NA	NA	NA	0.948	0.961	0.964	0.961	0.958	0.959	$y = 0.954 + 0.001t$	0.20
Estonia	0.948	0.868	0.922	0.975	0.966	0.946	0.962	0.918	0.915	0.969	$y = 0.924 + 0.003t$	0.06
Spain	0.906	0.902	0.908	0.918	0.896	0.875	0.891	0.904	0.916	0.895	$y = 0.905 - 0.001t$	0.03
Finland	0.968	0.967	0.966	0.966	0.966	0.966	0.966	0.966	0.967	NA	$y = 0.967 + 0.00003t$	0.01
France	0.849	0.848	0.860	0.874	0.913	0.885	0.874	0.891	0.889	0.882	$y = 0.852 + 0.004t$	0.42
United Kingdom	0.936	0.936	0.939	0.953	0.947	0.931	0.931	0.938	0.934	0.950	$y = 0.938 + 0.0002t$	0.01
Greece	0.952	0.954	0.954	0.956	0.954	0.955	0.950	0.953	0.955	0.956	$y = 0.953 + 0.0002t$	0.07
Hungary	0.721	0.915	0.763	0.866	0.838	0.840	0.838	0.860	0.846	NA	$y = 0.794 + 0.008t$	0.13
Ireland	x	x	x	x	x	x	x	x	x	x	x	x
Italy	0.851	0.855	0.872	0.886	0.877	0.870	0.878	0.878	0.880	0.880	$y = 0.858 + 0.003t$	0.50
Lithuania	x	x	x	x	x	x	x	x	x	x	x	x
Latvia	0.920	0.924	0.938	0.954	0.946	0.946	0.945	0.916	0.930	0.946	$y = 0.932 + 0.001t$	0.03
Netherlands	0.903	0.899	0.920	0.903	0.887	0.883	0.912	0.903	0.909	0.911	$y = 0.901 + 0.001t$	0.02
Poland	0.879	0.893	0.905	0.914	0.903	0.855	0.900	0.899	0.909	NA	$y = 0.890 + 0.001t$	0.03
Portugal	0.783	0.757	0.863	0.898	0.897	0.887	0.886	0.882	0.899	NA	$y = 0.788 + 0.015t$	0.56
Romania	0.833	0.806	0.794	0.773	0.838	0.828	0.804	0.810	0.827	NA	$y = 0.807 + 0.001t$	0.02
Sweden	0.950	0.930	0.942	0.967	0.971	0.953	0.950	0.944	0.942	NA	$y = 0.949 + 0.0002t$	0.00
Slovenia	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	NA	$y = 0.998 - 0.000001t$	0.03
Slovakia	0.875	0.882	0.921	0.930	0.919	0.864	0.894	0.851	0.923	NA	$y = 0.897 - 0.0003t$	0.00
Serbia	NA	0.891	0.898	0.907	0.885	0.898	0.937	0.915	0.893	0.9037	$y = 0.894 + 0.002t$	0.09

Source: own calculations

exceeds 0.9 (Bulgaria, Romania and the Czech Republic are the exceptions). The values of technical efficiency of the bottom 10 % of processors differ slightly more among the analysed countries. The bottom 10 % of dairy processors have technical efficiency lower than 0.8 in Bulgaria, the Czech Republic, Hungary and Romania.

The spread between the top and bottom 10 % of dairy processors is, on average, 7.4 %. That is, 80 % of processors have technical efficiency between 0.83 and 0.98. However, this interval is significantly smaller in Slovenia (0.01 %), Finland (0.24 %), Denmark (0.94 %), Greece (1.4 %) and Austria (2.2 %), and significantly larger in Hungary (17.6 %), the Czech Republic (12.8 %), Belgium (12.0 %), Portugal (11.9 %) and Bulgaria (11.7 %).

The development of technical efficiency in the dairy processing sector is provided in Table 4.13. We can again observe a rather stochastic TE development in the majority of EU

**Table 4.14 Spearman's rank correlation coefficient of TE – dairy**

Country	Spearman's rank correlation coefficients of technical efficiency								
	2004/ 2003	2005/ 2004	2006/ 2005	2007/ 2006	2008/ 2007	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011
Austria	NA	NA	NA	-0.5000	-0.1429	0.1429	0.2000	-1.0000	NA
Belgium	0.8030	0.8155	0.8681	0.8452	0.5769	0.7907	0.3903	0.5121	NA
Bulgaria	0.5000	-0.5000	0.7000	-0.2143	0.3455	0.1455	0.5000	0.0182	NA
Czech Republic	0.2571	0.2726	0.0095	0.4482	0.2286	0.2051	0.5274	0.6545	NA
Germany	0.8922	0.6078	0.9232	0.7164	0.7562	0.4867	0.1696	0.7459	1.0000
Denmark	NA	NA	NA	NA	-0.2500	-1.0000	0.5000	0.5000	0.5000
Estonia	-1.0000	0.8000	0.8000	-0.4000	0.4000	-1.0000	1.0000	0.2000	NA
Spain	0.6602	0.4452	0.2762	0.3028	0.0959	0.3984	0.3595	0.4598	NA
Finland	0.9048	0.9048	0.8095	1.0000	0.7818	0.5273	0.9524	0.4667	NA
France	0.7479	0.5872	0.6590	0.5693	0.7595	0.2499	0.7017	0.3066	-0.5000
United Kingdom	0.8331	0.6830	0.7712	0.7361	0.5923	0.7025	0.7125	0.5406	0.9515
Greece	0.6175	0.6677	0.5298	0.5156	0.4816	0.6348	0.6374	0.5923	0.4000
Hungary	NA	1.0000	-0.5000	-0.5000	0.6606	0.7637	0.1000	0.6000	NA
Ireland	x	x	x	x	x	x	x	x	x
Italy	0.5710	0.6271	0.5448	0.5868	0.3250	0.5330	0.5090	0.5137	1.0000
Lithuania	x	x	x	x	x	x	x	x	x
Latvia	0.6786	0.7857	0.5357	0.1071	0.0000	0.7143	0.6000	0.1429	0.4000
Netherlands	0.4286	0.8857	-0.2857	0.7857	1.0000	-0.4000	0.1000	0.4000	1.0000
Poland	0.3797	0.2256	0.4577	0.2404	0.0076	0.1628	0.5477	0.7115	NA
Portugal	LNO	LNO	1.0000	0.4965	0.0727	0.5818	0.6455	0.6818	NA
Romania	0.5328	0.6241	0.8590	0.3147	0.5593	-0.0582	0.8063	0.6381	NA
Sweden	0.5000	0.5000	-1.0000	0.5000	-1.0000	-0.5000	0.5000	-0.5000	NA
Slovenia	0.5000	-0.5000	0.5000	-1.0000	1.0000	0.5000	-1.0000	0.5000	NA
Slovakia	0.3714	-0.2143	0.4909	0.6000	-0.0545	0.5000	0.4303	-0.4643	NA
Serbia	NA	-0.7000	0.9000	0.4000	-0.2000	-0.2000	0.2000	0.9000	-0.2000

Note: LNO – Low Number of Observations

Source: own calculations

member countries, including Serbia. A rather strong positive development can be observed only in Italy and Romania. In the rest of the analysed countries, we cannot observe significant changes in technical efficiency in the dairy processing sector during the analysed period.

Considering the significant economic and institutional changes in the analysed time period, we can conclude that significant short-term changes in technical efficiency are caused by economic crises. A small decrease in technical efficiency can be found, especially in the year 2008, and an increase in subsequent years in almost all EU countries. A slightly longer decrease in technical efficiency only occurred in France and Romania. The impact of EU enlargement is not pronounced.

The question of stability was analysed using the Spearman's rank correlation coefficient. Table 4.14 shows that the order of dairy processors in all EU countries and in Serbia changes dramatically; leapfrogging appears to be a common phenomenon for all member countries. That is, with regard to the use of production possibilities, falling-behind processes are important characteristics for dairy processors in all EU countries. The most stable values of the Spearman's rank coefficient are in Greece, United Kingdom, Spain, Belgium and Italy. Some dairy producers seem to strengthen their positions only in these countries. In other countries, the order of dairy processors varied significantly in the analysed period.

#### 4.1.3.4 Milling

Table 4.15 provides the statistical characteristics of technical efficiency in the milling sector. The high averages of TE suggest that companies greatly exploit their production possibilities in most EU member states, including Serbia. The average technical efficiency is about 0.9. The highest average technical efficiency can be found in Slovenia (0.9981), Finland (0.9668), Denmark (0.9575) and Greece (0.9528). On the other hand, the lowest values for technical efficiency were estimated in Romania (0.8123), the Czech Republic (0.8348) and Bulgaria (0.8385).

The variability in technical efficiency in the milling sector is much higher than in the case of previous sectors. The highest value of the standard deviation was observed in Belgium (0.6282). However, a high value can also be found in France (0.3868). On the other hand, the lowest standard deviations were estimated for Slovenia and Finland (similarly to other analysed sectors).

Table 4.15 Technical efficiency – milling

Country	Sigma	Lambda	Statistical characteristics of technical efficiency							
			Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.0505	1.1158	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	0.2027	2.9501	0.8692	0.6282	0.6927	0.9665	0.7698	0.9366	0.7612	0.8981
Bulgaria	0.3063	1.5222	0.8385	0.0389	0.6962	0.9078	0.7969	0.8765	0.7491	0.8549
Czech Republic	0.2913	2.7448	0.8348	0.0616	0.6405	0.9232	0.7433	0.9056	0.7112	0.8525
Germany	0.1697	1.3086	0.9038	0.0723	0.1944	0.9613	0.8704	0.9438	0.3861	0.7696
Denmark	0.0810	0.9225	0.9575	0.0139	0.9269	0.9797	0.9351	0.9747	0.9401	0.9665
Estonia	0.0892	2.5161	0.9374	0.0345	0.8781	0.9794	0.9031	0.9794	0.9034	0.9541
Spain	0.1675	1.9484	0.8967	0.0445	0.7373	0.9690	0.8345	0.9494	0.7952	0.9111
Finland	0.3181	0.1334	0.9668	0.0011	0.9649	0.9689	0.9653	0.9679	0.9659	0.9679
France	0.2432	1.5899	0.8652	0.3868	0.6518	0.9631	0.8177	0.9091	0.7296	0.8853
United Kingdom	0.1279	0.8605	0.9375	0.0185	0.8595	0.9796	0.9142	0.9565	0.8896	0.9496
Greece	0.1204	0.5953	0.9528	0.0107	0.8808	0.9691	0.9416	0.9631	0.9029	0.9470
Hungary	0.2681	1.9434	0.8437	0.0749	0.5275	0.9483	0.7725	0.9061	0.6327	0.8431
Ireland	0.0671	0.0000	x	x	x	x	x	x	x	x
Italy	0.2242	1.8853	0.8668	0.0596	0.5324	0.9799	0.7792	0.9271	0.6443	0.8680
Lithuania	0.0777	0.0000	x	x	x	x	x	x	x	x
Latvia	0.1043	1.4589	0.9372	0.0276	0.8729	0.9671	0.8799	0.9628	0.8965	0.9436
Netherlands	0.1688	8.3834	0.8791	0.0916	0.6724	0.9815	0.7306	0.9680	0.7497	0.9043
Poland	0.1822	2.4417	0.8786	0.0655	0.5526	0.9818	0.7915	0.9464	0.6599	0.8745
Portugal	0.1792	1.8003	0.8840	0.0620	0.5118	0.9818	0.8055	0.9396	0.6293	0.8643
Romania	0.3863	0.9631	0.8123	0.0603	0.1458	0.9292	0.7766	0.8595	0.3417	0.7333
Sweden	0.0860	1.3533	0.9444	0.0311	0.7967	0.9843	0.9057	0.9735	0.8436	0.9374
Slovenia	0.0573	0.0424	0.9981	0.0004	0.9980	0.9981	0.9980	0.9981	0.9980	0.9981
Slovakia	0.1688	3.1761	0.8953	0.0442	0.7736	0.9703	0.8331	0.9502	0.8228	0.9211
Serbia	0.2116	6.9171	0.8776	0.0714	0.5492	0.9768	0.7967	0.9511	0.8529	0.9228

Source: own calculations

The variation in individual technical efficiency is relatively small in the majority of countries. However, huge differences between the best and worst milling processors can be seen in Romania (variation range 0.78) and Germany (0.77). Similarly to the previous analysed sectors, the high technical efficiency of the top 10 % of milling processors is a common feature in all EU member countries, including Serbia. Individual technical efficiency in this case is higher than 0.86, and for most countries exceeds 0.9. There are two exceptions: Romania, with the lowest value of technical efficiency of the top 10 % of processors (0.8595), and Bulgaria. The values of technical efficiency of the bottom 10 % of processors differ slightly among the analysed countries. The bottom 10 % of milling processors have a technical efficiency lower than 0.8 in Belgium, Bulgaria, the Czech Republic, Hungary, Italy, the Netherlands, Poland, Romania and Serbia. This suggests that the ability to use production possibilities is much lower in the milling sector than in the other analysed sectors.

Table 4.16 Development of technical efficiency – milling

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	x	x									
Belgium	0.873	0.865	0.917	0.910	0.834	0.765	0.868	0.929	0.866	0.913	$y = 0.866 + 0.001t$	0.01
Bulgaria	0.843	0.855	0.872	0.827	0.845	0.816	0.802	0.838	0.868	NA	$y = 0.849 - 0.001t$	0.04
Czech Republic	0.847	0.803	0.848	0.871	0.815	0.765	0.842	0.868	0.850	NA	$y = 0.827 + 0.001t$	0.01
Germany	0.880	0.889	0.929	0.926	0.893	0.892	0.926	0.892	0.895	0.906	$y = 0.900 + 0.001t$	0.01
Denmark	NA	NA	NA	NA	0.968	0.950	0.958	0.964	0.949	0.963	$y = 0.961 - 0.001t$	0.02
Estonia	LNO	x	x									
Spain	0.880	0.879	0.929	0.945	0.904	0.829	0.875	0.935	0.884	0.908	$y = 0.896 + 0.0002t$	0.00
Finland	0.968	0.967	0.967	0.966	0.965	0.965	0.966	0.968	0.967	0.968	$y = 0.967 + 0.0001t$	0.02
France	0.845	0.844	0.884	0.894	0.872	0.822	0.864	0.897	0.858	0.877	$y = 0.855 + 0.002t$	0.06
United Kingdom	0.933	0.929	0.943	0.950	0.946	0.929	0.927	0.944	0.937	0.942	$y = 0.9363 + 0.0003t$	0.01
Greece	0.948	0.950	0.960	0.962	0.953	0.945	0.949	0.957	0.950	0.957	$y = 0.952 + 0.0001t$	0.00
Hungary	NA	NA	0.878	0.882	0.859	0.788	0.832	0.884	0.836	NA	$y = 0.872 - 0.005t$	0.10
Ireland	x	x	x	x	x	x	x	x	x	x	x	x
Italy	0.858	0.874	0.919	0.917	0.829	0.760	0.880	0.907	0.858	0.894	$y = 0.871 - 0.0002t$	0.00
Lithuania	x	x	x	x	x	x	x	x	x	x	x	x
Latvia	0.932	0.918	0.956	0.959	0.933	0.903	0.938	0.959	0.938	NA	$y = 0.933 + 0.0009t$	0.02
Netherlands	0.846	0.921	0.890	0.949	0.864	0.871	0.784	0.943	NA	NA	$y = 0.891 - 0.002t$	0.01
Poland	0.879	0.899	0.909	0.935	0.871	0.772	0.842	0.924	0.896	NA	$y = 0.894 - 0.003t$	0.02
Portugal	0.837	0.829	0.895	0.906	0.871	0.831	0.904	0.901	0.893	NA	$y = 0.842 + 0.006t$	0.28
Romania	0.814	0.802	0.811	0.814	0.832	0.816	0.797	0.819	0.807	NA	$y = 0.813 - 0.0001t$	0.00
Sweden	0.929	0.953	0.959	0.967	0.952	0.907	0.918	0.963	0.949	0.961	$y = 0.943 + 0.0005t$	0.01
Slovenia	LNO	x	x									
Slovakia	0.860	0.888	0.906	0.936	0.891	0.871	0.871	0.909	0.902	NA	$y = 0.884 + 0.002t$	0.04
Serbia	NA	0.895	0.854	0.862	0.914	0.894	0.856	0.864	0.884	0.8748	$y = 0.882 - 0.0008t$	0.01

Note: LNO – Low Number of Observations

Source: own calculations

The spread between the best and worst 10 % of milling processors is, on average, 9.7 % (slightly higher than in the case of the other analysed sectors). We can conclude that 80 % of processors have a technical efficiency between 0.80 and 0.99. However, this interval is significantly smaller in Slovenia (0.01 %), Finland (0.26 %) and Greece (2.2 %), and higher in the Netherlands (23.7 %), Belgium (16.7 %), the Czech Republic (16.2 %) and Poland (15.5 %). Using information from the quartiles, the differences among companies are also pronounced.

Table 4.16 provides information on the development of technical efficiency in the milling sector. In general, we can conclude that we cannot observe significant changes in technical efficiency. Positive, though very weak, trends were estimated for almost all countries except Bulgaria, Denmark, Hungary, Italy, the Netherlands, Poland, Romania and Serbia. Two common patterns for some countries can be observed. Technical efficiency experienced a small short-term increase in the Czech Republic, Poland and Slovakia following the entrance of the mentioned countries into the EU. In almost all countries, we can see a slight decrease in the years 2008 and 2009 and an increase in subsequent years. That is, the economic crisis had a rather small effect on milling.

Finally, Table 4.17 provides the Spearman's rank correlation coefficient of technical efficiency. Since the order of milling processors in all EU countries changes dramatically, leapfrogging appears to be a common phenomenon for all member countries. That is, when

**Table 4.17 Spearman's rank correlation coefficient of TE – milling**

Country	Spearman's rank correlation coefficients of technical efficiency								
	2004/ 2003	2005/ 2004	2006/ 2005	2007/ 2006	2008/ 2007	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011
Austria	NA	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	0.8260	0.3735	0.4289	0.4118	0.7035	0.3421	0.6789	0.6078	-1.0000
Bulgaria	-1.0000	1.0000	1.0000	-0.5000	0.5000	-1.0000	-0.8000	0.4000	NA
Czech Republic	-0.1667	0.1515	0.2238	0.1648	0.4126	0.1364	0.5874	0.7545	NA
Germany	1.0000	0.6000	0.7500	0.9091	0.6783	0.4176	0.2598	-0.0821	1.0000
Denmark	NA	NA	NA	NA	1.0000	-0.6429	-0.1429	0.2857	-1.0000
Estonia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO
Spain	0.6287	0.5941	0.7616	-0.0587	0.5620	0.4850	-0.0137	0.2252	-1.0000
Finland	1.0000	1.0000	1.0000	0.5000	0.5000	-0.5000	1.0000	-0.6000	1.0000
France	0.1016	0.2937	0.3796	0.3607	0.0281	0.2150	0.5336	0.8373	0.9021
United Kingdom	0.7323	0.0247	0.5563	0.6601	0.8496	0.5110	0.4903	0.6460	0.4505
Greece	0.3846	0.6923	0.8392	-0.1399	0.8462	0.7552	0.6044	0.0945	1.0000
Hungary	NA	NA	LNO	LNO	-0.2000	0.3500	0.1748	0.1030	NA
Ireland	x	x	x	x	x	x	x	x	x
Italy	0.4581	0.5734	0.6993	0.5612	0.5785	0.4317	0.6887	0.5863	0.7143
Lithuania	x	x	x	x	x	x	x	x	x
Latvia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	NA
Netherlands	-1.0000	-0.5000	-1.0000	-1.0000	-0.5000	-1.0000	LNO	LNO	NA
Poland	0.7377	0.0072	0.5800	-0.0288	0.3778	0.3678	0.1487	0.5193	NA
Portugal	-1.0000	0.5000	0.6000	0.7059	0.7762	0.2143	0.4534	0.6559	NA
Romania	0.3348	0.7574	0.5054	-0.1558	0.5861	-0.0869	0.8362	0.5992	NA
Sweden	-0.7667	0.0952	-0.2727	0.3000	0.4755	0.0909	0.3626	-0.1692	1.0000
Slovenia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO
Slovakia	LNO	LNO	1.0000	0.4000	0.4000	0.0000	-0.7000	-0.5000	LNO
Serbia	NA	-0.4000	0.3500	0.6912	-0.4059	0.4441	0.7206	-0.2765	0.0676

Note: LNO – Low Number of Observations

Source: own calculations

considering only technical efficiency, leapfrogging is an important characteristic for milling processors in all countries. More stable values of the Spearman's rank coefficient are observed only in Italy, United Kingdom and France, where some milling producers tend to strengthen their positions.

## 4.2 Metafrontier analysis

This chapter provides the results of the metafrontier analysis. We focus on a country comparison of technical efficiency and total factor productivity in the slaughtering, fruits and vegetables, dairy and milling sectors. Thus, we provide an overview of which countries are performing better in terms of technical efficiency and productivity, and which countries are falling behind.

### 4.2.1 Slaughtering

#### 4.2.1.1 Parameter estimate and heterogeneity

Table 4.18 provides a parameter estimate of the stochastic metafrontier input distance function for the slaughtering sector in 24 EU member states (Cyprus, Luxembourg and Malta are missing) and Serbia. As expected, the first-order parameters normally discussed in the production function estimate as well as the parameters on unobservable fixed management are highly significant, even at a 1 % significance level, except for materials, which is significant at a 10 % significance level. This also holds for all second-order parameters.

As far as theoretical consistency of the estimate is concerned, we can conclude that monotonicity requirements as well as requirements on diminishing marginal returns (concavity) in inputs are met, evaluated on the sample mean.

Since all variables are normalised in logarithm by their sample mean, the first-order parameters represent the cost shares. That is, the cost share of labour is 14 % and the materials cost share is 80 % for the analysed sample. These estimates correspond to the values estimated for individual countries (see Chapter 4.1).

Table 4.18 Parameter estimates – metafrontier slaughtering

Means for random parameters				Coefficient on unobservable fixed management			
Variable	Coeff.	SE	P [ z >Z*]	Variable	Coeff.	SE	P [ z >Z*]
<b>Const.</b>	-0.0307	0.0012	0.0000	<b>Alpha_m</b>	0.3089	0.0008	0.0000
<b>A</b>	0.1406	0.0006	0.0000	<b>A</b>	0.1663	0.0005	0.0000
<b>M</b>	0.8011	0.0006	0.0000	<b>M</b>	-0.2024	0.0005	0.0000
<b>T</b>	0.0172	0.0003	0.0000	<b>T</b>	0.0006	0.0003	0.0563
				<b>Alpha_mm</b>	0.2309	0.0010	0.0000

  

Variable	Coeff.	SE	P [ z >Z*]
<b>TT</b>	-0.0022	0.0003	0.0000
<b>AT</b>	0.0038	0.0002	0.0000
<b>MT</b>	-0.0056	0.0001	0.0000
<b>AA</b>	0.0847	0.0002	0.0000
<b>MM</b>	0.1038	0.0001	0.0000
<b>AM</b>	-0.0823	0.0001	0.0000

  

<b>Sigma</b>	0.1878	0.0002	0.0000
<b>Lambda</b>	4.0612	0.0339	0.0000

Source: own calculations

The parameters on unobservable management are highly significant, which suggests that the chosen specification approximates well the estimated relationship, and that heterogeneity among firms is an important characteristic of food processors with slaughtering specialisation in EU member countries and Serbia. Unobservable management contributes positively to production, and its impact is accelerating. The increase in management has a positive impact on the production elasticities of materials inputs and a negative impact on labour inputs. If we reinterpret for the relationship between management and technical efficiency, then an increase in materials inputs lead to an increase in technical efficiency for a given level of management. The opposite holds true for labour inputs. The impact of technological change on technical efficiency is not pronounced (the coefficient is almost zero).

Technological change makes a significant positive contribution ( $\beta_T > 0$ ) to production, and the impact of technical change decelerates over time ( $\beta_{TT} < 0$ ). Moreover, biased technological change is pronounced. The technological change is labour-using and materials-saving. This direction of the technological change corresponds to our expectations. The adoption of innovations leads to a situation where materials are processed in a more efficient way.

The parameter  $\lambda$  is highly significant and equals about four. This means that the variation in  $u_{it}$  is more pronounced than the variation in the random component  $v_{it}$ . That is, the estimates indicate that efficiency differences among food processors are important reasons for variations in production (a comparison of TE among the countries is provided in the next chapter).

### 4.2.1.2 Technical efficiency comparison

Table 4.19 provides the statistical characteristics of technical efficiency. The mean of technical efficiency suggests that, on average, food processing companies in the slaughtering sector greatly exploit their production possibilities in the majority of EU countries, including Serbia. The slaughtering sector is most technically efficient in Germany (0.9233). Moreover, German food processors in the slaughtering sector operate very close to the estimated mean value (std. dev.: 0.04). Italy, Belgium, France, the Czech Republic, Sweden, Slovenia, Poland, Estonia, Austria and Spain are other countries with technical efficiency higher than 0.9. On the other hand, the average technical efficiency of Romanian processors in the slaughtering sector is 0.7869, with a high standard deviation of 0.16.

**Table 4.19 Technical efficiency comparison – slaughtering**

Country	Statistical characteristics of technical efficiency							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.9097	0.0508	0.6401	0.9770	0.8795	0.9483	0.8922	0.9364
Belgium	0.9210	0.0543	0.4181	0.9910	0.8675	0.9683	0.9076	0.9507
Bulgaria	0.8119	0.1575	0.4181	0.9930	0.5728	0.9653	0.7562	0.9282
Czech Republic	0.9114	0.0392	0.5836	0.9776	0.8778	0.9424	0.9034	0.9310
Germany	0.9233	0.0396	0.7119	0.9910	0.8857	0.9604	0.9088	0.9478
Denmark	0.8555	0.0724	0.7076	0.9671	0.7853	0.9288	0.8105	0.8994
Estonia	0.9063	0.0294	0.8150	0.9708	0.8624	0.9355	0.8957	0.9239
Spain	0.9095	0.0466	0.4181	0.9908	0.8637	0.9502	0.8951	0.9365
Finland	0.8956	0.0642	0.6595	0.9813	0.8041	0.9548	0.8709	0.9379
France	0.9144	0.0566	0.4242	0.9930	0.8503	0.9700	0.8898	0.9524
United Kingdom	0.8945	0.0464	0.6531	0.9812	0.8275	0.9468	0.8634	0.9313
Greece	0.8744	0.0573	0.7255	0.9735	0.7900	0.9417	0.8355	0.9198
Hungary	0.8693	0.1140	0.4181	0.9882	0.7651	0.9526	0.8585	0.9312
Ireland	0.8571	0.0598	0.7192	0.9713	0.7734	0.9308	0.8040	0.9113
Italy	0.9215	0.0501	0.4181	0.9930	0.8666	0.9690	0.9036	0.9524
Lithuania	0.8772	0.0592	0.6305	0.9722	0.8043	0.9404	0.8545	0.9159
Latvia	0.8925	0.0581	0.5831	0.9749	0.8325	0.9427	0.8794	0.9278
Netherlands	0.8993	0.0726	0.4629	0.9930	0.8159	0.9539	0.8794	0.9397
Poland	0.9088	0.0457	0.4181	0.9894	0.8790	0.9404	0.9019	0.9281
Portugal	0.8996	0.0527	0.6078	0.9840	0.8423	0.9505	0.8783	0.9301
Romania	0.7869	0.1628	0.4181	0.9930	0.5168	0.9684	0.6977	0.9252
Sweden	0.9091	0.0477	0.7321	0.9907	0.8402	0.9597	0.8842	0.9415
Slovenia	0.9030	0.0416	0.7835	0.9638	0.8406	0.9503	0.8824	0.9350
Slovakia	0.8965	0.0929	0.4181	0.9783	0.8728	0.9438	0.8944	0.9327
Serbia	0.8896	0.0863	0.5139	0.9709	0.7965	0.9627	0.8447	0.9565

Source: own calculations

The most efficient processors in the slaughtering sector operate very close to the production frontiers, with technical efficiency exceeding 0.96. On the other hand, the worst companies have technical efficiency lower than 0.5 in Belgium, Bulgaria, Spain, France, Hungary, Italy,

Poland, Romania and Slovakia. That is, huge differences among the best and worst food processors exist in some countries (especially in Belgium, Bulgaria, Spain, Hungary, Italy, Romania, Poland, Hungary, France, the Netherlands and Slovakia). In these countries, the variation range is higher than 0.5.

High technical efficiency of the top 10 % of processors in slaughtering is a common feature in all countries. In particular, the technical efficiency in this case is higher than 0.93 for all countries. That is, the top 10 % of producers greatly exploit their production possibilities. On the other hand, the technical efficiency of the bottom 10 % differs among countries. The bottom 10 % of food processors have a technical efficiency lower than 0.8 in Bulgaria, Denmark, Greece, Hungary, Ireland, Romania and Serbia. Using information from the 1<sup>st</sup> quartile, the differences in technical efficiency among the worst-performing food processing companies are also pronounced.

The spread between the 1<sup>st</sup> and 9<sup>th</sup> decile is, on average, 13.9 %. However, this spread is 45.6 % in Romania and 39.3 % in Bulgaria. These countries are falling behind in efficient input use, and we can expect another structural change. On the other hand, the mentioned spread has a low value in Austria (6.9 %), the Czech Republic (6.5 %), Germany (7.5 %), Estonia (7.3 %), Poland (6.1 %) and Slovakia (7.1 %).

#### 4.2.1.3 TFP development and comparison

Table 4.20 provides the statistical characteristics of total factor productivity for slaughtering. The TFP estimates revealed significant differences among EU member countries, including Serbia. In line with our expectations, the highest TFP was estimated for old member states with traditional meat production: Belgium, Germany, France, Italy and the Netherlands. Hungary is an exception, with a TFP of 1.16. This is due to the nature of the data set, which contains predominantly mid-size and large companies. In recent years, these companies invested a lot in Hungary and significantly improved their performance. Nevertheless, a significant variation can be observed among these Hungarian companies, with a standard deviation of 0.54. On the other hand, the lowest TFP can be observed in the Baltic countries (Estonia, Lithuania, Latvia) and Serbia. The TFP level in these countries is lower than 0.8, and in Lithuania and Latvia even below 0.7. Unlike the best-performing countries, where the variation among companies is large, the variation among food processing companies in the worst-performing countries is quite small. This suggests that if companies lose competitiveness, there will be consequences for the size of the slaughtering sector in these countries.

Table 4.20 TFP – slaughtering

Country	Statistical characteristics of total factor productivity							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.9855	0.1003	0.6108	1.2644	0.9005	1.0968	0.9378	1.0411
Belgium	1.3017	0.4795	0.8731	4.1419	0.9899	1.5960	1.0523	1.3497
Bulgaria	0.9490	0.5915	0.3739	4.9809	0.6351	1.1621	0.7242	0.9384
Czech Republic	0.9057	0.1283	0.6883	2.5515	0.7950	1.0011	0.8421	0.9500
Germany	1.0861	0.1281	0.8290	1.7303	0.9751	1.2445	1.0134	1.1319
Denmark	0.8739	0.1020	0.6233	1.2018	0.7486	0.9978	0.8082	0.9641
Estonia	0.7511	0.0641	0.6210	0.8810	0.6647	0.8391	0.7018	0.7970
Spain	1.0078	0.2285	0.2732	5.1831	0.8522	1.1623	0.9038	1.0481
Finland	1.0787	0.2011	0.7512	2.1004	0.8525	1.2701	0.9424	1.1838
France	1.2647	0.4397	0.6744	5.7085	1.0148	1.4320	1.0887	1.2599
United Kingdom	0.8490	0.1022	0.6078	2.4991	0.7411	0.9585	0.7895	0.8969
Greece	0.8033	0.0808	0.5752	1.0133	0.6929	0.9085	0.7587	0.8567
Hungary	1.1602	0.5377	0.7654	3.8195	0.8473	1.7291	0.8968	1.0987
Ireland	0.8135	0.0690	0.6120	0.9911	0.7340	0.9066	0.7651	0.8471
Italy	1.1996	0.6930	0.4766	21.8927	0.9638	1.3960	1.0256	1.2325
Lithuania	0.6624	0.0816	0.4049	0.8464	0.5610	0.7612	0.6025	0.7232
Latvia	0.6443	0.0988	0.3618	0.8790	0.5222	0.7752	0.5791	0.7153
Netherlands	1.0578	0.2915	0.4769	2.6480	0.8318	1.3011	0.9273	1.1362
Poland	0.8185	0.1088	0.3348	2.0582	0.7050	0.9141	0.7592	0.8657
Portugal	0.9686	0.2614	0.7471	3.6102	0.8544	1.0397	0.8903	0.9719
Romania	0.8909	0.3917	0.1917	5.8675	0.6460	1.0907	0.7356	0.9232
Sweden	0.9957	0.1270	0.6563	1.4322	0.8449	1.1618	0.9087	1.0748
Slovenia	0.8397	0.0647	0.6996	0.9358	0.7325	0.9136	0.8024	0.8885
Slovakia	0.8712	0.2649	0.6833	2.9323	0.7469	0.9202	0.7860	0.8637
Serbia	0.7436	0.0900	0.3687	0.8892	0.6582	0.8391	0.6988	0.8043

Source: own calculations

In general, we can conclude that the majority of old member states have a TFP higher than 0.9, and the majority of new member states reach an average TFP smaller than 0.9, despite the fact that some exceptions can be found.

The variation in TFP is large. Huge differences between the best- and worst-performing food processing companies can be found in all countries. If we take the difference between the best- and worst-performing 10 % of companies, the largest spreads are in Belgium (0.61), Bulgaria (0.53), Finland (0.42), France (0.42), Hungary (0.88), Italy (0.43) and Romania (0.44). On the other hand, the smallest spreads can be observed in Austria (0.19), Estonia (0.17), Ireland (0.17), Portugal (0.19), Slovenia (0.18), Slovakia (0.17) and Serbia (0.18). As was already stated, the countries with a smaller spread could face substantial structural changes in the slaughtering sector if food processors have problems with competitiveness.

Table 4.21 presents the TFP development. We can observe a positive trend in TFP in the majority of EU member countries. Only Bulgaria and Serbia are exceptions. However,

some countries experienced a rather stochastic development (Denmark, Ireland, the Netherlands and Romania). A rather strong positive trend in TFP was seen in Belgium, the Czech Republic, Estonia, Spain, Finland, Hungary, Italy, Lithuania, Latvia, Portugal and Sweden. That is, we can observe that some countries with average or poor performance are catching up. However, countries with high productivity further improved their performance. In other words, the catching-up processes are not so strong. Moreover, countries that cannot keep pace with competitors are falling more and more behind.

*Table 4.21 TFP development – slaughtering*

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	NA	NA	0.965	0.975	0.954	0.948	1.012	1.034	NA	$y = 0.937 + 0.013t$	0.05
Belgium	1.119	1.223	1.256	1.286	1.305	1.342	1.361	1.381	1.376	1.379	$y = 1.159 + 0.026t$	0.86
Bulgaria	1.037	0.959	1.209	0.819	0.854	0.908	0.900	0.963	1.068	0.823	$y = 1.024 - 0.013t$	0.10
Czech Republic	0.815	0.839	0.862	0.891	0.913	0.929	0.933	0.963	0.977	1.001	$y = 0.803 + 0.020t$	0.99
Germany	1.003	1.042	1.064	1.057	1.068	1.063	1.102	1.135	1.115	1.069	$y = 1.019 + 0.010t$	0.60
Denmark	NA	NA	NA	NA	0.875	0.847	0.863	0.889	0.895	0.877	$y = 0.856 + 0.005t$	0.31
Estonia	0.679	0.700	0.714	0.730	0.753	0.770	0.792	0.798	0.819	0.859	$y = 0.659 + 0.019t$	0.99
Spain	0.925	0.941	0.967	0.988	1.018	1.021	1.041	1.074	1.061	1.087	$y = 0.912 + 0.018t$	0.97
Finland	0.935	0.927	1.014	1.102	1.128	1.114	1.109	1.151	1.171	1.112	$y = 0.943 + 0.024t$	0.71
France	1.157	1.195	1.234	1.247	1.319	1.314	1.314	1.313	1.301	1.300	$y = 1.182 + 0.016t$	0.69
United Kingdom	0.771	0.779	0.805	0.828	0.854	0.840	0.869	0.891	0.895	0.897	$y = 0.760 + 0.015t$	0.95
Greece	0.739	0.747	0.776	0.796	0.802	0.813	0.818	0.843	0.853	0.869	$y = 0.728 + 0.014t$	0.98
Hungary	NA	0.919	1.020	1.085	1.045	1.191	1.181	1.244	1.182	NA	$y = 0.923 + 0.040t$	0.81
Ireland	NA	NA	0.828	0.800	0.777	0.778	0.817	0.847	0.839	0.903	$y = 0.771 + 0.012t$	0.47
Italy	1.086	1.112	1.139	1.163	1.198	1.188	1.206	1.216	1.221	1.314	$y = 1.074 + 0.020t$	0.90
Lithuania	0.554	0.574	0.620	0.634	0.670	0.693	0.712	0.727	0.758	0.751	$y = 0.541 + 0.023t$	0.97
Latvia	0.533	0.556	0.596	0.613	0.641	0.689	0.683	0.688	0.707	0.689	$y = 0.534 + 0.019t$	0.88
Netherlands	1.021	1.093	1.143	1.013	1.004	1.021	1.064	1.072	1.140	1.058	$y = 1.047 + 0.003t$	0.03
Poland	0.720	0.768	0.788	0.806	0.827	0.837	0.852	0.869	0.849	0.821	$y = 0.746 + 0.012t$	0.69
Portugal	0.868	0.869	0.887	0.944	0.982	0.945	0.984	1.001	0.999	NA	$y = 0.849 + 0.019t$	0.86
Romania	0.653	0.732	0.768	0.789	1.111	1.106	0.921	0.938	0.938	NA	$y = 0.687 + 0.040t$	0.46
Sweden	0.903	0.936	0.944	0.967	0.984	1.000	1.014	1.051	1.048	1.057	$y = 0.895 + 0.017t$	0.98
Slovenia	0.783	0.781	0.820	0.837	0.866	0.857	0.870	0.883	0.860	NA	$y = 0.779 + 0.012t$	0.80
Slovakia	0.771	0.771	0.818	0.838	0.957	0.975	0.872	0.884	0.874	NA	$y = 0.779 + 0.017t$	0.40
Serbia	NA	0.741	0.759	0.785	0.782	0.780	0.770	0.690	0.716	0.671	$y = 0.794 - 0.010t$	0.43

Source: own calculations

Technological change was an important factor, which contributed predominantly positively to TFP development. Thus, the adoption of innovations seems to be a significant source of growth in many EU countries. The contribution of technical efficiency to TFP development was rather stochastic, as we observed in the previous chapter. Moreover, the contribution of the management (heterogeneity) component was specific for each country, and we cannot observe any common patterns. This suggests that, despite some common factors, EU member countries are characterised by rather idiosyncratic developments in TFP.

As opposed to Spearman's rank correlation calculated for technical efficiency, Spearman's rank correlation for TFP suggests that the order of food processing companies is stable over time. That is, leapfrogging can be excluded, as far as TFP development is concerned. Structural change seems to occur in such a way that the most successful producers strengthen their positions. Producers with poor performance will not be able to catch up with the developments of the sector leaders, and are therefore expected to fall more and more behind.

*Table 4.22 Spearman's rank correlation coefficient of TFP – slaughtering*

Country	Spearman's rank correlation coefficients of TFP								
	2004/ 2003	2005/ 2004	2006/ 2005	2007/ 2006	2008/ 2007	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011
Austria	NA	NA	NA	1.000	0.143	0.143	0.943	0.988	NA
Belgium	0.960	0.968	0.982	0.963	0.975	0.982	0.986	0.987	0.927
Bulgaria	0.810	0.853	0.960	0.878	0.809	0.824	0.870	0.830	1.000
Czech Republic	0.814	0.809	0.925	0.965	0.943	0.964	0.863	0.802	LNO
Germany	1.000	0.936	0.860	0.943	0.853	0.848	0.915	0.911	0.900
Denmark	NA	NA	NA	NA	1.000	0.901	0.851	0.917	0.939
Estonia	0.452	0.881	0.667	0.429	0.821	0.976	0.929	1.000	LNO
Spain	0.962	0.971	0.975	0.953	0.939	0.925	0.959	0.968	1.000
Finland	0.853	0.733	0.961	0.895	0.940	0.795	0.978	0.993	1.000
France	0.960	0.960	0.968	0.861	0.974	0.910	0.975	0.961	0.872
United Kingdom	0.958	0.949	0.938	0.870	0.927	0.857	0.904	0.911	0.965
Greece	0.869	0.863	0.930	0.784	0.858	0.890	0.932	0.936	1.000
Hungary	NA	-1.000	1.000	0.714	0.889	0.920	0.919	0.953	NA
Ireland	NA	NA	1.000	0.714	0.753	0.214	0.871	0.864	1.000
Italy	0.953	0.975	0.964	0.980	0.953	0.960	0.980	0.981	1.000
Lithuania	0.596	0.811	0.517	0.842	0.756	0.777	0.907	0.837	1.000
Latvia	0.909	0.871	0.843	0.887	0.903	0.900	0.944	0.869	0.867
Netherlands	0.993	0.964	0.988	0.967	0.964	1.000	0.943	1.000	NA
Poland	0.910	0.927	0.947	0.922	0.920	0.938	0.921	0.877	0.900
Portugal	1.000	0.929	0.989	0.900	0.860	0.912	0.838	0.801	NA
Romania	0.818	0.831	0.698	0.258	0.794	0.405	0.751	0.613	NA
Sweden	0.904	0.886	0.963	0.968	0.958	0.965	0.989	0.975	0.956
Slovenia	0.943	0.943	1.000	0.829	0.943	0.943	0.771	0.771	NA
Slovakia	0.952	0.891	0.713	0.593	0.776	0.440	0.973	0.890	NA
Serbia	NA	1.000	0.600	0.829	1.000	1.000	0.943	1.000	0.771

Note: LNO – Low Number of Observations

Source: own calculations

## 4.2.2 Fruits and vegetables

### 4.2.2.1 Parameter estimate and heterogeneity

Table 4.23 provides the parameter estimate of the stochastic metafrontier model for the fruits and vegetables sector. First, we will again discuss the parameter estimate. As in the case of slaughtering, the first-order as well as second-order parameters are highly significant, even at a 1 % significance level. Moreover, the monotonicity and concavity (diminishing marginal returns) requirements are met.

The cost share of labour is higher as compared to slaughtering, at 19.3 %, whereas the materials cost share is lower, at about 76 % for the analysed sample. These estimates correspond to the values estimated for individual countries, as well as to the information we have in the data set (see Chapter 4.1).

The parameters on unobservable management are again highly significant. That is, the chosen specification approximates well the estimated relationship. Moreover, heterogeneity among firms is also an important characteristic of food processors with a fruits and vegetables specialisation in the EU member countries and Serbia. Unobservable management contributes positively to production and, as in the case of slaughtering, the impact is accelerating. The increase in management has a positive impact on the production elasticities of materials inputs and a negative impact on labour inputs. That is, an increase in materials inputs leads to an increase in technical efficiency for a given level of management. The opposite holds true for labour inputs. The impact of technological change on technical efficiency is again not pronounced (the coefficient is almost zero).

*Table 4.23 Parameter estimate – metafrontier fruits and vegetables*

Means for random parameters				Coefficient on unobservable fixed management			
Variable	Coeff.	SE	P [ z >Z*]	Variable	Coeff.	SE	P [ z >Z*]
<b>Const.</b>	0.0920	0.0019	0.0000	<b>Alpha_m</b>	0.2718	0.0012	0.0000
<b>A</b>	0.1929	0.0009	0.0000	<b>A</b>	0.1359	0.0010	0.0000
<b>M</b>	0.7588	0.0008	0.0000	<b>M</b>	-0.1590	0.0006	0.0000
<b>T</b>	0.0106	0.0004	0.0000	<b>T</b>	-0.0016	0.0004	0.0000
				<b>Alpha_mm</b>	0.1527	0.0015	0.0000
Variable	Coeff.	SE	P [ z >Z*]				
<b>TT</b>	-0.0056	0.0004	0.0000				
<b>AT</b>	0.0018	0.0003	0.0000				
<b>MT</b>	-0.0052	0.0002	0.0000				
<b>AA</b>	0.0778	0.0007	0.0000				
<b>MM</b>	0.0919	0.0003	0.0000				
<b>AM</b>	-0.0789	0.0004	0.0000				
<b>Sigma</b>	0.2084	0.0002	0.0000				
<b>Lambda</b>	3.1883	0.0321	0.0000				

Source: own calculations

Technological change makes a significant positive contribution ( $\beta_T > 0$ ) to production, approximately 1 % a year. However, the impact of technological change is decelerating over

time ( $\beta_{TT} < 0$ ). Moreover, biased technological change is pronounced. The technological change is labour-using and materials-saving. This direction of the technological change corresponds to our expectations. As in the case of slaughtering, the adoption of innovations leads to a situation in which materials are processed in a more efficient way.

The parameter  $\lambda$  is highly significant and equals about 3.2. That is, the variation in  $u_{it}$  is more pronounced than the variation in the random component  $v_{it}$ . Efficiency differences among food processors are therefore important reasons for variations in production.

#### 4.2.2.2 Technical efficiency comparison

The comparison of technical efficiency in the fruits and vegetables sector is based on the statistical characteristics presented in Table 4.24.

**Table 4.24 Technical efficiency comparison – fruits and vegetables**

Country	Statistical characteristics of technical efficiency							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.8900	0.0447	0.7479	0.9593	0.8354	0.9245	0.8601	0.9192
Belgium	0.8979	0.0494	0.6336	0.9850	0.8499	0.9514	0.8827	0.9248
Bulgaria	0.7992	0.1265	0.5442	0.9860	0.6299	0.9517	0.7252	0.9296
Czech Republic	0.8961	0.0283	0.8088	0.9540	0.8618	0.9285	0.8790	0.9146
Germany	0.9116	0.0283	0.7208	0.9695	0.8813	0.9426	0.8988	0.9295
Denmark	0.8901	0.0454	0.7716	0.9625	0.8493	0.9415	0.8653	0.9215
Estonia	0.8645	0.0407	0.8077	0.9515	0.8303	0.9087	0.8359	0.8892
Spain	0.8858	0.0500	0.3042	0.9905	0.8303	0.9359	0.8645	0.9170
Finland	0.8286	0.1455	0.3962	0.9840	0.5133	0.9218	0.8187	0.9100
France	0.8933	0.0645	0.3086	0.9842	0.8494	0.9361	0.8839	0.9217
United Kingdom	0.8708	0.0493	0.6910	0.9757	0.8044	0.9295	0.8384	0.9058
Greece	0.8395	0.0735	0.4339	0.9669	0.7628	0.9192	0.8028	0.8910
Hungary	0.8606	0.1081	0.4367	0.9801	0.6805	0.9353	0.8599	0.9191
Ireland	NA	NA	NA	NA	NA	NA	NA	NA
Italy	0.9052	0.0497	0.3042	0.9894	0.8642	0.9535	0.8875	0.9333
Lithuania	0.8516	0.0458	0.7647	0.9227	0.7948	0.9066	0.8175	0.8841
Latvia	0.8662	0.0516	0.7677	0.9822	0.7968	0.9047	0.8189	0.9004
Netherlands	0.8605	0.0651	0.5694	0.9624	0.7804	0.9188	0.8198	0.9061
Poland	0.8922	0.0282	0.6943	0.9729	0.8555	0.9211	0.8777	0.9107
Portugal	0.8750	0.0718	0.5251	0.9672	0.7975	0.9453	0.8568	0.9173
Romania	0.6950	0.2290	0.3042	0.9898	0.3417	0.9782	0.5044	0.8957
Sweden	0.8838	0.0611	0.4742	0.9590	0.8362	0.9347	0.8661	0.9192
Slovenia	0.8729	0.0860	0.5791	0.9520	0.8034	0.9468	0.8589	0.9266
Slovakia	0.8745	0.0478	0.7875	0.9522	0.8321	0.9454	0.8424	0.9170
Serbia	0.8372	0.1422	0.3042	0.9846	0.6874	0.9668	0.7949	0.9375

Source: own calculations

The mean of technical efficiency again suggests that, on average, food processing companies in the fruits and vegetables sector greatly exploit their production possibilities in the majority of EU countries. However, this value is slightly lower than in the case of the

slaughtering sector. The highest value of technical efficiency can again be observed in Germany (0.912), with a very low standard deviation of 0.028. Italy is another country with average technical efficiency exceeding 0.9. On the other hand, Romania is the country with the lowest average technical efficiency in the fruits and vegetables sector (0.695), and the highest standard deviation of technical efficiency (0.229). In general, most EU countries have an average technical efficiency between 0.85 and 0.9.

The most efficient processors in the fruits and vegetables sector have technical efficiency of about 0.99 and can be found in Spain, Italy, Romania and Serbia. On the other hand, the worst processors, with technical efficiency of about 0.304, are also from Spain, Italy, Romania and Serbia. In other words, huge differences between the best and worst food processors exist in these countries.

Similarly to slaughtering, high technical efficiency of the top 10 % of fruit and vegetable processors is a common feature in all the analysed countries. In particular, the technical efficiency in this case is higher than 0.9 for all countries. That is, the top 10 % of food producers greatly exploit their production possibilities. On the other hand, the technical efficiency of the bottom 10 % differs among countries. The bottom 10 % of food processors have a technical efficiency lower than 0.7 in Bulgaria, Finland, Hungary, Romania and Serbia.

The spread between the 1<sup>st</sup> and 9<sup>th</sup> deciles is, on average, 16.2 %. However, this spread is significantly higher in Romania (63.7 %), Finland (40.9 %) and Bulgaria (32.2 %). On the other hand, the spread has a low value in Germany (6.1 %), Poland (6.6 %), the Czech Republic (6.7 %) and Estonia (7.8 %).

We can conclude that Romania, Bulgaria and Serbia fall behind in the fruits and vegetables sector as far as efficient input use is concerned. On the other hand, Austria, the Czech Republic, Germany, Denmark, Estonia, Lithuania, Latvia and Slovakia are countries with very efficient input use.

#### 4.2.2.3 TFP development and comparison

Table 4.25 provides the statistical characteristics of total factor productivity for the fruits and vegetables sector. As in the case of slaughtering, the TFP estimates revealed significant differences among EU member countries, including Serbia. In line with our expectations, the highest TFP was estimated for old member states: Belgium (1.42), Germany (1.10), France (1.24), Italy (1.23) and the Netherlands (1.14). Hungary is again an exception, with a TFP of 1.19, but with large differences among food processors (std. dev. is 0.59). That is, we got identical results as for slaughtering, as far as the most productive countries are concerned. On the other hand, the lowest TFP can be observed in the Baltic countries (especially Lithuania (0.67) and Latvia (0.78)), Greece (0.75), Romania (0.77), Slovakia (0.77) and Serbia (0.64). Unlike the best-performing countries, where the variation among companies is large in the majority of cases, the variation among food processing companies in the worst-performing countries is quite small. This again suggests that if companies lose competitiveness, there will be negative consequences for the size of the fruits and vegetables sector in these countries.

Table 4.25 TFP – fruits and vegetables

Country	Statistical characteristics of total factor productivity							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	1.0187	0.1002	0.8178	1.1960	0.8906	1.1512	0.9550	1.1129
Belgium	1.4230	0.4750	0.8294	3.6350	1.0606	1.6370	1.2210	1.4569
Bulgaria	0.7545	0.1411	0.4499	1.2919	0.5863	0.9356	0.6711	0.8335
Czech Republic	0.8810	0.1081	0.6288	1.1915	0.7772	0.9799	0.8118	0.9402
Germany	1.1031	0.1393	0.8542	1.7354	0.9660	1.2888	1.0170	1.1668
Denmark	0.9394	0.1060	0.7738	1.1641	0.8089	1.1472	0.8745	0.9701
Estonia	0.8252	0.0365	0.7887	0.8898	0.7900	0.8856	0.7929	0.8472
Spain	1.0310	0.2445	0.1479	5.2836	0.8422	1.2571	0.9038	1.0863
Finland	1.0584	0.5597	0.7398	4.7044	0.7765	1.2902	0.8497	1.0741
France	1.2410	0.2654	0.8670	3.5527	1.0369	1.4377	1.0988	1.3037
United Kingdom	0.8411	0.1314	0.2582	1.2784	0.7159	1.0156	0.7688	0.9153
Greece	0.7512	0.1107	0.2792	1.1474	0.6215	0.8795	0.6815	0.8215
Hungary	1.1901	0.5927	0.7418	3.5559	0.8155	1.8777	0.8684	1.2016
Ireland	NA	NA	NA	NA	NA	NA	NA	NA
Italy	1.2251	1.2013	0.1514	24.0636	0.9369	1.3775	1.0184	1.2210
Lithuania	0.6743	0.0645	0.5430	0.7674	0.5594	0.7374	0.6613	0.7233
Latvia	0.7757	0.0627	0.6622	0.9265	0.6979	0.8473	0.7297	0.8010
Netherlands	1.1365	0.4175	0.7484	2.4590	0.7924	1.7082	0.8130	1.2156
Poland	0.8306	0.1296	0.5797	1.6204	0.6986	0.9440	0.7503	0.8773
Portugal	1.0133	0.3359	0.3359	2.9987	0.8270	1.2722	0.8749	1.0652
Romania	0.7675	0.3351	0.2617	2.7282	0.4301	1.0491	0.5756	0.8479
Sweden	1.0071	0.1786	0.4150	1.3921	0.8103	1.2664	0.8650	1.1265
Slovenia	0.8367	0.1042	0.5453	0.9579	0.7169	0.9415	0.7905	0.9215
Slovakia	0.7690	0.0846	0.5938	0.9332	0.6270	0.8562	0.7458	0.8317
Serbia	0.6403	0.1571	0.1858	0.8496	0.4333	0.7875	0.5482	0.7593

Source: own calculations

In general, we can conclude that the majority of old member states have a TFP higher than 1.0, and the majority of new member states reach an average TFP smaller than 0.9, despite the fact that some exceptions can be found. In other words, there are large differences between old and new member states in the processing of fruits and vegetables.

Moreover, the variation in TFP is large. Huge differences between the best- and worst-performing food processing companies can be found in almost all countries. If we take the difference between the best- and worst-performing 10 % of companies, the largest spread is in Belgium (0.58), Spain (0.41), Finland (0.51), Hungary (1.06), the Netherlands (0.92), Portugal (0.45), Romania (0.61) and Sweden (0.46). On the other hand, the smallest spread can be observed in the Czech Republic (0.20), Estonia (0.10), Lithuania (0.17) and Latvia (0.15). As was already stated, countries with a smaller spread can face substantial structural changes in the fruits and vegetables sector if food processors have problems with competitiveness.

Table 4.26 TFP development – fruits and vegetables

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	NA	NA	1.004	0.975	1.002	1.017	1.067	1.050	NA	$y = 0.967 + 0.015t$	0.69
Belgium	1.339	1.325	1.418	1.444	1.454	1.455	1.439	1.462	1.462	1.287	$y = 1.385 + 0.004t$	0.04
Bulgaria	0.695	0.641	0.732	0.707	0.733	0.825	0.757	0.796	0.765	0.747	$y = 0.677 + 0.012t$	0.45
Czech Republic	0.778	0.831	0.819	0.887	0.918	0.901	0.920	0.927	0.912	0.823	$y = 0.818 + 0.010t$	0.30
Germany	0.982	1.030	1.046	1.091	1.076	1.108	1.127	1.138	1.097	1.135	$y = 1.001 + 0.015t$	0.79
Denmark	NA	NA	NA	NA	0.945	0.934	0.930	0.940	0.941	0.991	$y = 0.921 + 0.008t$	0.40
Estonia	0.796	0.792	0.790	0.814	0.789	0.855	0.817	0.825	0.885	0.890	$y = 0.767 + 0.011t$	0.69
Spain	0.983	1.012	1.053	1.069	1.076	1.054	1.070	1.073	1.051	1.052	$y = 1.017 + 0.006t$	0.36
Finland	1.026	0.833	1.811	0.875	0.987	1.014	1.002	1.088	1.075	1.042	$y = 1.121 - 0.008t$	0.01
France	1.150	1.188	1.229	1.292	1.270	1.315	1.219	1.245	1.261	1.295	$y = 1.189 + 0.011t$	0.38
United Kingdom	0.765	0.782	0.822	0.845	0.831	0.843	0.849	0.873	0.882	0.885	$y = 0.769 + 0.012t$	0.89
Greece	0.674	0.697	0.731	0.764	0.770	0.775	0.754	0.787	0.787	0.797	$y = 0.687 + 0.012t$	0.80
Hungary	NA	0.802	0.976	1.181	1.166	1.235	1.185	1.255	1.189	0.990	$y = 0.979 + 0.026t$	0.22
Ireland	NA	x	x									
Italy	1.037	1.164	1.204	1.255	1.214	1.300	1.275	1.274	1.262	1.094	$y = 1.151 + 0.010t$	0.13
Lithuania	0.617	0.612	0.634	0.664	0.709	0.683	0.698	0.729	0.695	0.731	$y = 0.605 + 0.013t$	0.82
Latvia	0.669	0.717	0.820	0.773	0.781	0.820	0.781	0.819	0.793	0.794	$y = 0.719 + 0.010t$	0.42
Netherlands	1.123	1.178	1.291	1.273	1.243	1.111	0.945	1.145	0.877	0.873	$y = 1.312 - 0.038t$	0.53
Poland	0.771	0.802	0.833	0.837	0.857	0.838	0.844	0.852	0.832	0.722	$y = 0.823 - 0.001t$	0.00
Portugal	0.933	0.896	0.913	1.102	1.093	1.028	0.981	0.987	0.956	NA	$y = 0.952 + 0.007t$	0.07
Romania	0.535	0.581	0.652	0.606	1.081	1.027	0.740	0.787	0.795	NA	$y = 0.568 + 0.038t$	0.29
Sweden	0.961	1.004	1.025	1.030	0.969	0.955	1.023	1.041	1.046	0.982	$y = 0.986 + 0.003t$	0.08
Slovenia	0.716	0.758	0.691	0.826	0.877	0.899	0.922	0.942	0.898	NA	$y = 0.685 + 0.030t$	0.79
Slovakia	0.839	0.862	0.624	0.803	0.729	0.777	0.752	0.759	0.795	NA	$y = 0.792 - 0.004t$	0.03
Serbia	NA	0.606	0.552	0.659	0.643	0.703	0.629	0.655	0.703	0.611	$y = 0.603 + 0.008t$	0.19

Source: own calculations

Table 4.26 presents the TFP development. We can observe a positive trend in TFP in the majority of EU member countries, including Serbia. Finland, the Netherlands, Poland and Slovakia are exceptions. However, many countries experienced a rather stochastic development. A rather strong positive trend in TFP was seen in Austria, Germany, Estonia, United Kingdom, Greece, Lithuania and Slovenia. That is, we can observe that some countries with average or poor performance are catching up. However, countries with high productivity further improved their performance. In other words, as in the case of slaughtering, the catching-up processes are not so strong. Moreover, countries that cannot keep pace with competitors are falling more and more behind.

Technological change was an important factor, which contributed predominantly positively to TFP development. Thus, the adoption of innovations seems to be a significant source of growth in many EU countries. The second important factor was management (heterogeneity) component. The contribution of the management component was specific

for each country, and we cannot observe any common patterns. This suggests that, despite some common factors, the EU member countries are characterised by rather idiosyncratic developments in TFP.

As in the case of slaughtering, Spearman's rank correlation for TFP suggests that the order of food processing companies is stable over time. That is, leapfrogging can be excluded as far as TFP development is concerned. Structural change seems to occur in such a way that the most successful producers strengthen their positions. Producers with poor performance will not be able to catch up with the developments of the sector leaders, and therefore are expected to fall more and more behind.

*Table 4.27 Spearman's rank correlation coefficient of TFP – fruits and vegetables*

Country	Spearman's rank correlation coefficients of TFP								
	2004/ 2003	2005/ 2004	2006/ 2005	2007/ 2006	2008/ 2007	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011
Austria	NA	NA	NA	LNO	0.964	0.700	1.000	0.800	NA
Belgium	0.973	0.978	0.949	0.980	0.968	0.948	0.988	0.977	0.900
Bulgaria	1.000	1.000	0.500	0.810	0.450	0.583	0.517	0.857	LNO
Czech Republic	0.800	0.643	0.857	0.619	0.857	0.321	0.905	0.952	LNO
Germany	1.000	1.000	1.000	0.914	0.952	0.895	0.968	0.963	1.000
Denmark	NA	NA	NA	NA	1.000	0.600	0.943	0.786	LNO
Estonia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO
Spain	0.983	0.980	0.980	0.927	0.952	0.951	0.968	0.960	0.982
Finland	0.900	0.800	0.500	0.500	0.800	0.400	0.943	0.900	1.000
France	0.953	0.986	0.957	0.918	0.963	0.958	0.952	0.952	0.951
United Kingdom	0.937	0.926	0.970	0.879	0.915	0.903	0.951	0.891	0.891
Greece	0.827	0.878	0.935	0.890	0.897	0.741	0.783	0.807	0.964
Hungary	NA	LNO	1.000	0.800	0.887	0.746	0.779	0.896	1.000
Ireland	NA	NA	NA	NA	NA	NA	NA	NA	NA
Italy	0.940	0.976	0.978	0.958	0.936	0.936	0.971	0.971	0.956
Lithuania	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	LNO
Latvia	-1.000	1.000	1.000	1.000	1.000	1.000	1.000	-1.000	LNO
Netherlands	0.976	1.000	0.964	0.976	1.000	1.000	0.900	1.000	LNO
Poland	0.975	0.957	0.914	0.945	0.869	0.917	0.938	0.911	-1.000
Portugal	LNO	1.000	0.500	0.989	0.908	0.969	0.930	0.956	NA
Romania	0.038	0.534	0.200	0.064	0.161	0.218	0.577	0.577	NA
Sweden	1.000	0.986	0.987	0.967	0.729	0.939	0.983	0.981	0.800
Slovenia	-1.000	-1.000	1.000	-1.000	1.000	1.000	1.000	1.000	NA
Slovakia	LNO	LNO	LNO	0.800	0.500	1.000	1.000	1.000	NA
Serbia	NA	0.829	0.886	0.714	0.943	0.429	0.771	0.257	0.600

Note: LNO – Low Number of Observations

Source: own calculations

### 4.2.3 Dairy

#### 4.2.3.1 Parameter estimate and heterogeneity

Table 4.28 provides the parameter estimate of the stochastic metafrontier model for the dairy food processing sector. As in the case of previous food processing sectors, all of the first-order as well as second-order parameters are highly significant, even at a 1 % significance level. Moreover, the monotonicity and concavity (diminishing returns to scale) requirements are met.

The estimated cost shares correspond to information we have in the data set, and are in line with the country parameter estimate as well. The labour cost share was estimated at a high of 18 %, and the materials cost share is about 77 %. These values are very close to the cost shares estimated for slaughtering and fruits and vegetables.

*Table 4.28 Parameter estimate – metafrontier dairy*

Means for random parameters				Coefficient on unobservable fixed management			
Variable	Coeff.	SE	P [ z >Z*]	Variable	Coeff.	SE	P [ z >Z*]
<b>Const.</b>	0.0571	0.0019	0.0000	<b>Alpha_m</b>	0.2754	0.0015	0.0000
<b>A</b>	0.1803	0.0009	0.0000	<b>A</b>	0.1435	0.0010	0.0000
<b>M</b>	0.7721	0.0010	0.0000	<b>M</b>	-0.1627	0.0010	0.0000
<b>T</b>	0.0133	0.0004	0.0000	<b>T</b>	-0.0011	0.0004	0.0097
				<b>Alpha_mm</b>	0.1393	0.0024	0.0000

  

Variable	Coeff.	SE	P [ z >Z*]
<b>TT</b>	-0.0067	0.0004	0.0000
<b>AT</b>	0.0038	0.0003	0.0000
<b>MT</b>	-0.0050	0.0003	0.0000
<b>AA</b>	0.1028	0.0009	0.0000
<b>MM</b>	0.1314	0.0004	0.0000
<b>AM</b>	-0.1137	0.0005	0.0000

  

<b>Sigma</b>	0.1516	0.0003	0.0000
<b>Lambda</b>	2.7159	0.0255	0.0000

Source: own calculations

The parameters on unobservable management are again highly significant. That is, the chosen specification approximates well the estimated relationship. Moreover, heterogeneity among firms is an important characteristic of food processors with dairy specialisation in EU member countries and Serbia. Unobservable management contributes positively to production and, as in the case of slaughtering and fruits and vegetables, the impact is accelerating. The increase in management has a positive impact on the production elasticities of materials inputs and a negative impact on labour inputs. In other words, an increase in materials inputs leads to an increase in technical efficiency for a given level of management. The opposite holds true for labour inputs. The impact of technological change on technical efficiency is again not pronounced (the coefficient is almost zero).

Technological change makes a significant positive contribution ( $\beta_T > 0$ ) to production, approximately 1.3 % per year. However, the impact of technological change is decelerating over time ( $\beta_{TT} < 0$ ). Moreover, biased technological change is pronounced. The technological change is labour-using and materials-saving. This direction of the technological change corresponds to our expectations. As in the case of slaughtering and fruits and vegetables, the adoption of innovations leads to a situation in which material inputs are processed in a more efficient way.

The parameter  $\lambda$  is highly significant and equals about 2.7. That is, the variation in  $u_{it}$  is more pronounced than the variation in the random component  $v_{it}$ . Efficiency differences among food processors are therefore important reasons for variations in production.

#### 4.2.3.2 Technical efficiency comparison

Table 4.29 presents the statistical characteristics of technical efficiency for the dairy sector in the EU countries and Serbia. The fact that the average technical efficiency is higher than 0.9 for the majority of analysed countries suggests that, on average, food processing

**Table 4.29 Technical efficiency comparison – dairy**

Country	Statistical characteristics of technical efficiency							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	0.9270	0.0182	0.8835	0.9648	0.9033	0.9479	0.9199	0.9375
Belgium	0.9208	0.0321	0.6010	0.9702	0.8897	0.9515	0.9087	0.9391
Bulgaria	0.8629	0.1231	0.4409	0.9906	0.7088	0.9707	0.8300	0.9355
Czech Republic	0.9083	0.0666	0.4711	0.9921	0.8547	0.9557	0.8992	0.9396
Germany	0.9126	0.0431	0.6985	0.9846	0.8627	0.9498	0.9007	0.9375
Denmark	0.9121	0.0354	0.8522	0.9663	0.8606	0.9614	0.8860	0.9313
Estonia	0.9205	0.0161	0.8821	0.9516	0.9028	0.9442	0.9091	0.9293
Spain	0.9207	0.0293	0.7602	0.9847	0.8880	0.9498	0.9107	0.9389
Finland	0.9020	0.0482	0.7563	0.9715	0.8321	0.9501	0.8818	0.9333
France	0.9223	0.0355	0.7104	0.9851	0.8809	0.9554	0.9061	0.9459
United Kingdom	0.8998	0.0467	0.3844	0.9849	0.8481	0.9443	0.8780	0.9293
Greece	0.8983	0.0430	0.7366	0.9780	0.8388	0.9491	0.8679	0.9323
Hungary	0.8541	0.1412	0.4469	0.9877	0.5777	0.9505	0.8614	0.9373
Ireland	0.8470	0.0618	0.7243	0.9191	0.7520	0.9029	0.7874	0.8932
Italy	0.9222	0.0356	0.6190	0.9898	0.8913	0.9518	0.9110	0.9405
Lithuania	0.9074	0.0360	0.7822	0.9643	0.8599	0.9522	0.8839	0.9344
Latvia	0.9146	0.0335	0.7715	0.9792	0.8945	0.9464	0.9080	0.9329
Netherlands	0.9215	0.0398	0.8197	0.9794	0.8643	0.9623	0.8924	0.9495
Poland	0.9141	0.0495	0.5135	0.9881	0.8965	0.9398	0.9116	0.9327
Portugal	0.9112	0.0386	0.7965	0.9755	0.8510	0.9516	0.8909	0.9426
Romania	0.8583	0.1175	0.3741	0.9921	0.7022	0.9692	0.8020	0.9439
Sweden	0.9055	0.0417	0.7913	0.9656	0.8611	0.9495	0.8764	0.9355
Slovenia	0.9201	0.0241	0.8708	0.9566	0.8850	0.9471	0.8999	0.9390
Slovakia	0.8936	0.0975	0.4258	0.9896	0.8396	0.9420	0.9072	0.9309
Serbia	0.9154	0.0328	0.8055	0.9715	0.8861	0.9423	0.9055	0.9367

Source: own calculations

companies in this sector greatly exploit their production possibilities and, compared to the previous sectors, producers in the dairy sector are slightly more technically efficient.

The highest value of technical efficiency can be observed in Austria (0.927). Moreover, all Austrian dairy food processors operate very close to the production frontier. An average technical efficiency exceeding 0.9 characterises the majority of other countries, namely Belgium, the Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Italy, Lithuania, Latvia, the Netherlands, Poland, Portugal, Serbia, Sweden and Slovenia. On the other hand, the lowest technical efficiency was estimated for Hungary (0.8541), Romania (0.8583) and Bulgaria (0.8629).

The most efficient processors in the dairy sector operate almost on the production frontier. The differences among countries are minor. On the other hand, the worst food processing companies have a technical efficiency lower than 0.6 and can be found in Bulgaria, the Czech Republic, United Kingdom, Hungary, Poland, Romania and Slovakia. That is, the least efficient processors are found primarily in new member states.

Similarly to previous sectors, high technical efficiency of the top 10 % of dairy processors is a common feature in all analysed countries. In particular, the technical efficiency in this case is higher than 0.9 for all countries. That is, the top 10 % of producers greatly exploit their production possibilities. On the other hand, the technical efficiency of the bottom 10 % differs among countries. The bottom 10 % of food processors have a technical efficiency lower than 0.8 in Bulgaria, Hungary, Ireland and Romania. In other words, the huge differences among the best and worst food processors also exist between dairy processors.

The spread between the 1<sup>st</sup> and 9<sup>th</sup> decile is, on average, 10.8 %, much lower in comparison to previous sectors. However, this spread is significantly higher in Hungary (37.3 %), Romania (26.7 %) and Bulgaria (26.2 %). This confirms our expectation that the newest member states will face further structural changes. This also holds true for Hungary. On the other hand, the spread has a low value in Estonia (4.1 %), Poland (4.3 %), Austria (4.5 %), Latvia (5.2 %), Serbia (5.6 %), Italy (6.1 %), Spain (6.2 %) and Slovenia (6.2 %).

### 4.2.3.3 TFP development and comparison

Table 4.30 TFP – dairy

Country	Statistical characteristics of total factor productivity							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	1.0165	0.0677	0.9027	1.1436	0.9203	1.1139	0.9681	1.0569
Belgium	1.1722	0.1412	0.8972	2.1814	1.0227	1.3237	1.0752	1.2591
Bulgaria	0.7610	0.1695	0.3845	1.4135	0.5896	0.9849	0.6636	0.8510
Czech Republic	0.9531	0.1415	0.6918	1.5465	0.8050	1.1317	0.8627	1.0021
Germany	1.0939	0.1682	0.6963	2.1505	0.9603	1.2667	1.0011	1.1508
Denmark	0.9922	0.0687	0.8659	1.0987	0.9141	1.0745	0.9318	1.0559
Estonia	0.8030	0.0626	0.6715	0.8927	0.7335	0.8851	0.7552	0.8615
Spain	1.0872	0.2197	0.7401	2.2958	0.9162	1.2706	0.9694	1.1187
Finland	0.9610	0.0884	0.7793	1.1544	0.8512	1.0850	0.9004	1.0235
France	1.2327	0.2533	0.8867	2.5887	1.0241	1.5323	1.0825	1.2798
United Kingdom	0.8908	0.0937	0.4842	1.4676	0.7879	1.0144	0.8378	0.9440
Greece	0.8273	0.0916	0.5816	1.1826	0.7271	0.9504	0.7764	0.8638
Hungary	1.1722	0.5139	0.8339	2.8960	0.8822	1.9067	0.9001	1.0522
Ireland	0.8397	0.0265	0.8000	0.8835	0.8035	0.8750	0.8193	0.8608
Italy	1.1579	0.2029	0.6458	3.8133	1.0025	1.3222	1.0598	1.2000
Lithuania	0.7169	0.1021	0.4251	0.9584	0.5901	0.8732	0.6561	0.7782
Latvia	0.7022	0.0877	0.4307	0.8254	0.5899	0.7870	0.6557	0.7707
Netherlands	1.1429	0.2278	0.7918	1.6503	0.8841	1.4974	0.9579	1.2810
Poland	0.8347	0.1598	0.5549	2.5183	0.7075	0.9423	0.7549	0.8799
Portugal	1.0992	0.2754	0.8935	2.0552	0.9080	1.2360	0.9580	1.1018
Romania	0.7668	0.1739	0.2342	1.6926	0.5691	0.9834	0.6591	0.8478
Sweden	0.8881	0.1265	0.6800	1.1074	0.7239	1.0738	0.8027	0.9835
Slovenia	0.8583	0.0516	0.7694	0.9468	0.7879	0.9199	0.8155	0.8980
Slovakia	0.8876	0.2250	0.6749	2.6745	0.7527	0.9653	0.7998	0.9080
Serbia	0.7337	0.0820	0.5855	0.9068	0.6421	0.8743	0.6796	0.7602

Source: own calculations

Table 4.30 provides the statistical characteristics of total factor productivity for the dairy sector. As in the previous sectors, the TFP estimates revealed significant differences among EU member countries, including Serbia, and there were particularly significant differences between old and new member states. In line with our expectations, the highest TFP was estimated for old member states: Belgium (1.17), Germany (1.09), Spain (1.09), France (1.23), Italy (1.16), the Netherlands (1.14) and Portugal (1.09). Hungary is again an exception, with a TFP of 1.17, but with large differences among dairy processors (std. dev. is 0.51). That is, we got a similar result as for slaughtering and fruits and vegetables, as far as the most productive countries are concerned. On the other hand, the lowest TFP can be observed in the Baltic countries (Estonia (0.80), Lithuania (0.72) and Latvia (0.70)), Bulgaria (0.76), Romania (0.77) and Serbia (0.73). Moreover, it again holds true that the variation among food processing companies in the worst-performing countries is quite small. That is, the productivity differences are rather small among the dairy

processors in these countries, which suggests that the sector may face substantial structural changes if companies lose competitiveness.

In general, we can conclude that the majority of old member states have TFP higher than or very close to 1.0, and the majority of new member states reach an average TFP smaller than 0.9, despite the fact that some exceptions can be found. In other words, there are large differences between old and new member countries in dairy processing.

*Table 4.31 TFP development – dairy*

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	NA	NA	0.954	1.018	1.015	1.047	1.034	1.003	NA	$y = 0.979 + 0.009t$	0.29
Belgium	1.071	1.110	1.141	1.178	1.186	1.186	1.219	1.217	1.224	NA	$y = 1.079 + 0.018t$	0.90
Bulgaria	0.633	0.687	0.826	0.728	0.717	0.815	0.786	0.787	0.781	NA	$y = 0.676 + 0.015t$	0.41
Czech Republic	0.838	0.864	0.919	0.970	0.991	0.986	0.998	1.007	1.006	0.920	$y = 0.875 + 0.014t$	0.45
Germany	1.046	1.054	1.036	1.098	1.083	1.091	1.111	1.116	1.106	1.385	$y = 0.984 + 0.023t$	0.50
Denmark	NA	NA	NA	NA	0.999	0.961	1.021	0.981	0.991	1.011	$y = 0.983 + 0.003t$	0.08
Estonia	0.726	0.748	0.782	0.819	0.825	0.823	0.793	0.833	0.834	0.882	$y = 0.734 + 0.013t$	0.77
Spain	1.001	1.025	1.087	1.104	1.092	1.093	1.128	1.118	1.104	1.119	$y = 1.026 + 0.011t$	0.66
Finland	0.843	0.892	0.937	0.995	0.973	0.969	0.998	0.993	1.011	NA	$y = 0.867 + 0.018t$	0.75
France	1.160	1.195	1.227	1.272	1.272	1.242	1.245	1.228	1.251	1.325	$y = 1.183 + 0.011t$	0.52
United Kingdom	0.807	0.837	0.881	0.916	0.907	0.887	0.915	0.919	0.898	0.940	$y = 0.831 + 0.011t$	0.66
Greece	0.720	0.755	0.797	0.840	0.839	0.843	0.873	0.862	0.863	0.847	$y = 0.746 + 0.014t$	0.71
Hungary	0.859	1.708	1.663	1.928	1.121	1.144	1.149	1.076	0.956	NA	$y = 1.566 - 0.055t$	0.16
Ireland	NA	NA	0.800	0.844	0.836	0.814	0.842	0.850	0.869	NA	$y = 0.804 + 0.008t$	0.57
Italy	1.054	1.101	1.140	1.181	1.182	1.154	1.203	1.192	1.177	1.327	$y = 1.062 + 0.020t$	0.71
Lithuania	0.579	0.641	0.654	0.717	0.768	0.732	0.747	0.760	0.770	0.810	$y = 0.599 + 0.022t$	0.84
Latvia	0.601	0.626	0.665	0.711	0.727	0.737	0.768	0.742	0.748	0.702	$y = 0.625 + 0.014t$	0.60
Netherlands	0.938	0.991	1.037	1.192	1.144	1.236	1.182	1.249	1.199	1.487	$y = 0.915 + 0.046t$	0.79
Poland	0.736	0.771	0.840	0.858	0.856	0.852	0.858	0.869	0.851	NA	$y = 0.767 + 0.013t$	0.60
Portugal	0.989	1.033	1.360	1.104	1.100	1.090	1.122	1.077	1.050	NA	$y = 1.112 - 0.002t$	0.00
Romania	0.590	0.646	0.693	0.774	0.861	0.854	0.816	0.812	0.831	NA	$y = 0.615 + 0.030t$	0.70
Sweden	0.818	0.802	0.802	0.901	0.904	0.907	0.940	0.955	0.964	NA	$y = 0.777 + 0.022t$	0.88
Slovenia	0.788	0.785	0.821	0.853	0.875	0.882	0.914	0.914	0.894	NA	$y = 0.773 + 0.017t$	0.88
Slovakia	0.754	0.775	0.836	0.859	0.876	0.903	0.930	0.925	1.155	NA	$y = 0.700 + 0.038t$	0.80
Serbia	NA	0.672	0.696	0.727	0.754	0.762	0.748	0.742	0.755	0.747	$y = 0.692 + 0.008t$	0.57

Source: own calculations

Moreover, the variation in TFP is large. Huge differences between the best- and worst-performing food processing companies can be found in almost all countries. If we take the difference between the best- and worst-performing 10 % of companies, the largest spreads are in Belgium (0.30), the Czech Republic (0.33), Germany (0.31), Spain (0.35), France (0.50), Hungary (1.02), Italy (0.32), the Netherlands (0.61), Portugal (0.32), Romania (0.41) and Sweden (0.34). On the other hand, the smallest spreads can be observed in Austria (0.19), Denmark (0.16), Estonia (0.15), Ireland (0.07), Latvia (0.20) and Slovenia

(0.13). As was already stated, the countries with a lower spread could face substantial structural changes in dairy processing if food processors lose their competitiveness.

Table 4.31 presents the TFP development. We can observe a positive trend in TFP in the majority of EU member countries, including Serbia. Hungary and Portugal are exceptions. A rather strong positive trend in TFP was seen in Belgium, Germany, Finland, Italy, Lithuania, the Netherlands, Romania, Sweden and Slovakia. That is, we can again observe that some countries with average or poor performance are catching up. However, countries with high productivity are further improving their performance. That is, as in the case of previous sectors, the catching-up processes are not so strong. Moreover, countries that cannot keep pace with competitors are falling more and more behind.

Technological change and management was important factors determining TFP development. Whereas technological change contributed predominantly positively to TFP development, the contribution of the management was country specific.

**Table 4.32 Spearman's rank correlation coefficient of TFP – dairy**

Country	Spearman's rank correlation coefficients of TFP								
	2004/ 2003	2005/ 2004	2006/ 2005	2007/ 2006	2008/ 2007	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011
Austria	NA	NA	NA	1.000	0.943	0.964	0.800	1.000	NA
Belgium	0.990	0.942	0.984	0.965	0.937	0.947	0.945	0.969	NA
Bulgaria	1.000	0.500	0.900	0.964	0.394	0.527	0.945	0.936	NA
Czech Republic	0.888	0.600	0.798	0.980	0.965	0.972	0.873	0.776	NA
Germany	0.944	0.985	0.875	0.976	0.981	0.956	0.894	0.966	1.000
Denmark	NA	NA	NA	NA	1.000	1.000	0.500	1.000	0.500
Estonia	1.000	1.000	1.000	0.800	0.800	1.000	1.000	1.000	LNO
Spain	0.983	0.939	0.962	0.940	0.935	0.971	0.960	0.965	LNO
Finland	0.976	0.929	0.952	1.000	0.939	0.891	1.000	0.967	NA
France	0.986	0.979	0.977	0.929	0.955	0.961	0.982	0.962	1.000
United Kingdom	0.960	0.900	0.974	0.975	0.935	0.964	0.972	0.856	0.879
Greece	0.926	0.895	0.947	0.935	0.866	0.887	0.856	0.929	1.000
Hungary	LNO	1.000	1.000	0.500	0.952	0.962	0.500	0.820	NA
Ireland	NA	NA	LNO	LNO	1.000	-0.500	1.000	0.500	NA
Italy	0.976	0.966	0.964	0.968	0.949	0.958	0.967	0.975	1.000
Lithuania	-0.050	0.617	0.718	0.900	0.917	0.900	0.545	0.923	1.000
Latvia	0.964	0.964	1.000	1.000	0.893	0.829	0.829	0.762	1.000
Netherlands	0.943	1.000	0.464	1.000	1.000	0.100	1.000	0.800	1.000
Poland	0.962	0.955	0.969	0.970	0.957	0.953	0.977	0.979	NA
Portugal	LNO	LNO	1.000	0.979	0.991	1.000	0.964	0.991	NA
Romania	0.648	0.825	0.846	0.828	0.721	0.715	0.963	0.950	NA
Sweden	1.000	0.500	0.500	1.000	0.500	0.500	1.000	0.500	NA
Slovenia	0.500	1.000	0.500	-0.500	0.500	1.000	0.500	1.000	NA
Slovakia	0.943	0.786	0.842	0.830	0.718	0.936	0.939	0.964	NA
Serbia	NA	1.000	0.900	0.900	0.900	0.700	1.000	0.900	1.000

Note: LNO – Low Number of Observations

Source: own calculations

As in the case of slaughtering and fruits and vegetables, Spearman's rank correlation for TFP suggests that the order of food processing companies is stable over time. That is, leapfrogging can be excluded as far as TFP development is concerned. Structural change seems to occur in such a way that the most successful producers strengthen their positions. Producers with poor performance will not be able to catch up with the developments of the sector leaders, and are therefore expected to fall more and more behind.

#### 4.2.4 Milling

##### 4.2.4.1 Parameter estimate and heterogeneity

Table 4.33 provides the parameter estimate of the stochastic metafrontier model for the milling food processing sector. As in the case of the previous food processing sectors, all of the first-order as well as second-order parameters are highly significant, even at a 1 % significance level, except for the time coefficient on unobservable fixed management, which is significant at a 5 % significance level. Moreover, the monotonicity and concavity (diminishing returns to scale) requirements are met.

*Table 4.33 Parameter estimate – metafrontier milling*

Means for random parameters				Coefficient on unobservable fixed management			
Variable	Coeff.	SE	P [ z >Z*]	Variable	Coeff.	SE	P [ z >Z*]
<b>Const.</b>	0.1162	0.0040	0.0000	<b>Alpha_m</b>	0.2303	0.0030	0.0000
<b>A</b>	0.1420	0.0021	0.0000	<b>A</b>	0.0982	0.0019	0.0000
<b>M</b>	0.7273	0.0021	0.0000	<b>M</b>	-0.2038	0.0019	0.0000
<b>T</b>	-0.0111	0.0009	0.0000	<b>T</b>	-0.0021	0.0009	0.0238
				<b>Alpha_mm</b>	0.1824	0.0046	0.0000
Variable	Coeff.	SE	P [ z >Z*]				
<b>TT</b>	-0.0080	0.0008	0.0000				
<b>AT</b>	0.0023	0.0007	0.0006				
<b>MT</b>	-0.0045	0.0004	0.0000				
<b>AA</b>	0.0539	0.0015	0.0000				
<b>MM</b>	0.1395	0.0008	0.0000				
<b>AM</b>	-0.0881	0.0010	0.0000				
<b>Sigma</b>	0.2154	0.0014	0.0000				
<b>Lambda</b>	3.3316	0.1072	0.0000				

Source: own calculations

The labour cost share is on the same level as in the case of slaughtering, about 14 %. The materials cost share is about 72 % for the analysed sample. These estimates again correspond to the values estimated for individual countries, as well as to the information we have in the data set (see Chapter 4.1).

The parameters on unobservable management are again highly significant. That is, the chosen specification approximates well the estimated relationship. Moreover, heterogeneity among firms is also an important characteristic of food processors with milling specialisation in the EU member countries and Serbia. Unobservable management

contributes positively to production and, as in the case of previous analysed sectors, the impact is accelerating. The increase in management has a positive impact on the production elasticities of materials inputs and a negative impact on labour inputs. That is, an increase in materials inputs leads to an increase in technical efficiency for a given level of management. The opposite holds true for labour inputs. The impact of technological change on technical efficiency is again not pronounced (the coefficient is almost zero).

As opposed to slaughtering, fruits and vegetables and dairy, technological change makes a significant negative contribution ( $\beta_T < 0$ ) to production, approximately 1.1 % per year. Moreover, the negative impact of technological change is accelerating over time ( $\beta_{TT} < 0$ ). Biased technological change is pronounced. The technological change is labour-using and materials-saving.

The parameter  $\lambda$  is highly significant and equals about 3.3. That is, the variation in  $u_{it}$  is more pronounced than the variation in the random component  $v_{it}$ . Efficiency differences among food processors are therefore important reasons for variations in production.

#### 4.2.4.2 Technical efficiency comparison

Table 4.34 shows that the mean of technical efficiency in the milling sector is in the interval from 0.79 to 0.91. Compared to the previous analysed sectors, technical efficiency in the milling sector is lower, on average. Highly technically efficient milling food processors can be found particularly in Belgium (0.91), the Czech Republic (0.89), Germany (0.89), Spain (0.90), France (0.89), Hungary (0.89), Italy (0.91), the Netherlands (0.91), Portugal (0.89) and Serbia (0.89). On the other hand, low average technical efficiency was estimated for Bulgaria (0.79) and Lithuania (0.78).

The most efficient processors (as in the case of previous sectors) operate almost on the production frontier. On the other hand, the worst companies have very low efficiency, not exceeding 0.5 (Bulgaria, Germany, Italy and Romania). These food processing companies will not be able to keep pace with competitors, and it is assumed they will be restructured or leave the market.

The top 10 % of food processors in the milling sector have a technical efficiency higher than 0.86 in all analysed countries. In other words, the best processors in the milling sector are highly efficient; however, technical efficiency is lower compared to the previous analysed sectors. This also holds true for the bottom 10 % of companies. The bottom 10 % of food processors have quite low technical efficiency (lower than 0.7), especially in Bulgaria, Lithuania and Romania.

Table 4.34 Technical efficiency comparison – milling

Country	Statistical characteristics of technical efficiency							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	0.9088	0.0419	0.6608	0.9819	0.8706	0.9551	0.8941	0.9350
Bulgaria	0.7877	0.1782	0.3834	0.9800	0.4530	0.9431	0.7740	0.9103
Czech Republic	0.8983	0.0352	0.7698	0.9677	0.8572	0.9391	0.8793	0.9196
Germany	0.8966	0.0702	0.3053	0.9821	0.8305	0.9493	0.8725	0.9361
Denmark	0.8273	0.0700	0.7064	0.9635	0.7398	0.9315	0.7779	0.8808
Estonia	0.8426	0.0228	0.8038	0.8789	0.8161	0.8738	0.8341	0.8571
Spain	0.8992	0.0331	0.7751	0.9629	0.8531	0.9393	0.8787	0.9226
Finland	0.8834	0.0556	0.7654	0.9692	0.7973	0.9473	0.8580	0.9270
France	0.8872	0.0634	0.5428	0.9893	0.8084	0.9529	0.8530	0.9294
United Kingdom	0.8449	0.0611	0.6878	0.9709	0.7625	0.9293	0.8028	0.8868
Greece	0.8521	0.0601	0.5818	0.9459	0.7742	0.9237	0.8177	0.8961
Hungary	0.8919	0.0647	0.6587	0.9707	0.8156	0.9502	0.8702	0.9395
Ireland	0.8354	0.0733	0.7074	0.9716	0.7203	0.9232	0.7773	0.8811
Italy	0.9103	0.0456	0.4466	0.9841	0.8680	0.9486	0.8964	0.9357
Lithuania	0.7819	0.0799	0.6473	0.9561	0.6828	0.8709	0.7304	0.8280
Latvia	0.8069	0.0423	0.7047	0.8971	0.7717	0.8592	0.7851	0.8257
Netherlands	0.9076	0.0269	0.8452	0.9701	0.8768	0.9296	0.8985	0.9183
Poland	0.8728	0.0404	0.7233	0.9749	0.8237	0.9209	0.8471	0.8994
Portugal	0.8913	0.0438	0.6107	0.9547	0.8541	0.9379	0.8728	0.9204
Romania	0.8154	0.1372	0.3053	0.9904	0.6365	0.9419	0.7753	0.9064
Sweden	0.8721	0.0588	0.7014	0.9644	0.7802	0.9412	0.8418	0.9218
Slovenia	0.8642	0.0573	0.7558	0.9498	0.8121	0.9389	0.8297	0.9012
Slovakia	0.8668	0.0572	0.6846	0.9573	0.7786	0.9193	0.8477	0.9042
Serbia	0.8901	0.0565	0.5250	0.9792	0.8614	0.9356	0.8764	0.9138

Source: own calculations

The spread between the 1<sup>st</sup> and 9<sup>th</sup> decile is 14.4 %, on average. However, this spread is 49.0 % in Bulgaria and 30.5 % in Romania. That is, we can expect that the newest member states will also face further structural changes in the milling sector. On the other hand, the spread has a low value in the Netherlands (5.3 %), Estonia (5.8 %) and Serbia (7.4 %).

#### 4.2.5 TFP development and comparison

Table 4.35 provides the statistical characteristics of total factor productivity for the milling sector. As in the previous sectors, the TFP estimates revealed significant differences among EU member countries, including Serbia. In line with our expectations, the highest TFP was estimated for old member states: Belgium (1.12), Germany (1.17), France (1.23), Italy (1.09), the Netherlands (1.07), Portugal (1.14) and Sweden (1.05). Bulgaria (1.03), the Czech Republic (1.01) and Hungary (1.01) have the highest TFP of the new member states. However, Bulgaria is characterised by large differences among the milling companies

(std. dev. is 0.42). On the other hand, the lowest TFP can again be observed in Lithuania (0.71), Latvia (0.80), Slovenia (0.78) and Serbia (0.75). Moreover, the variation among food processing companies in the worst-performing countries is quite small. This again suggests potential problems with the competitiveness of the sector if a company faces tough international competition on the domestic market.

**Table 4.35 TFP – milling**

Country	Statistical characteristics of total factor productivity							
	Mean	Std. Dev.	Min.	Max.	1st Decile	9th Decile	1st Quartile	3rd Quartile
Austria	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	1.1167	0.1286	0.5741	1.5827	0.9943	1.2714	1.0384	1.1811
Bulgaria	1.0351	0.4209	0.6489	2.7261	0.7465	1.2266	0.8166	1.0887
Czech Republic	1.0141	0.0994	0.8505	1.3549	0.9022	1.1206	0.9548	1.0550
Germany	1.1708	0.1855	0.3864	1.8028	0.9943	1.3706	1.0399	1.2663
Denmark	0.8451	0.0694	0.7392	1.0453	0.7540	0.9510	0.7984	0.8792
Estonia	0.8428	0.0227	0.8033	0.8826	0.8152	0.8661	0.8319	0.8611
Spain	1.0164	0.0956	0.7634	1.4025	0.9075	1.1454	0.9526	1.0708
Finland	0.9958	0.0753	0.8805	1.1691	0.9074	1.0854	0.9280	1.0450
France	1.2302	0.2354	0.7078	2.2279	0.9921	1.4926	1.0837	1.3186
United Kingdom	0.9198	0.1162	0.7233	1.5564	0.8046	1.0377	0.8472	0.9707
Greece	0.8650	0.0842	0.4409	1.0717	0.7680	0.9703	0.8087	0.9155
Hungary	1.0083	0.1427	0.7640	1.7334	0.8772	1.1448	0.9302	1.0998
Ireland	0.9160	0.0689	0.7600	1.0383	0.8210	1.0086	0.8893	0.9592
Italy	1.0904	0.1382	0.4936	1.8351	0.9696	1.2263	1.0152	1.1329
Lithuania	0.7144	0.0784	0.5627	0.8757	0.6136	0.8433	0.6650	0.7687
Latvia	0.7982	0.0441	0.7017	0.8617	0.7339	0.8530	0.7665	0.8220
Netherlands	1.0712	0.0592	0.9745	1.1640	0.9869	1.1405	1.0175	1.1205
Poland	0.8929	0.0942	0.3620	1.1606	0.7701	0.9913	0.8548	0.9433
Portugal	1.1382	0.6745	0.8654	7.1405	0.9102	1.2006	0.9709	1.0635
Romania	0.8291	0.1950	0.0550	2.1312	0.6473	0.9883	0.7452	0.9097
Sweden	1.0522	0.1538	0.7588	1.6166	0.8652	1.2648	0.9455	1.1371
Slovenia	0.7794	0.0463	0.7047	0.8472	0.7259	0.8444	0.7437	0.8155
Slovakia	0.9210	0.1568	0.7523	1.2558	0.7852	1.2155	0.8117	1.0202
Serbia	0.7535	0.1096	0.3115	0.9875	0.6170	0.8824	0.7041	0.8081

Source: own calculations

Despite the fact that some exceptions can be found, the old member states have higher TFP than the new member states. In other words, there are large differences between the old and new in the processing of fruits and vegetables. The exceptions are, in particular, Bulgaria, the Czech Republic and Hungary.

Furthermore, the variation in TFP is large. Huge differences between the best- and worst-performing food processing companies were revealed by the estimate in almost all analysed countries. If we take the difference between the best- and worst-performing 10 % of companies, the largest spreads are in Belgium (0.48), Germany (0.37), France (0.50), Romania (0.34), Sweden (0.40) and Slovakia (0.43). On the other hand, the smallest spreads

can be observed in Denmark (0.20), Estonia (0.05), Ireland (0.19), Latvia (0.15), the Netherlands (0.15) and Slovenia (0.12). As was already stated, the countries with a lower spread could face substantial structural changes in the milling sector if food processors have problems with competitiveness.

*Table 4.36 TFP development – milling*

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Trend function	R2
Austria	NA	x	x									
Belgium	1.145	1.131	1.168	1.177	1.142	1.086	1.108	1.094	1.013	0.995	$y = 1.199 - 0.017t$	0.71
Bulgaria	0.708	0.729	0.803	0.949	0.969	0.965	1.313	1.463	0.944	NA	$y = 0.634 + 0.070t$	0.57
Czech Republic	0.987	1.037	1.066	1.060	1.031	0.989	0.997	0.992	0.956	NA	$y = 1.052 - 0.008t$	0.33
Germany	1.195	1.157	1.291	1.257	1.226	1.118	1.152	1.141	1.128	0.994	$y = 1.272 - 0.019t$	0.49
Denmark	NA	NA	NA	NA	0.826	0.828	0.846	0.860	0.815	0.943	$y = 0.798 + 0.016t$	0.40
Estonia	0.832	0.837	0.861	0.883	0.862	0.847	0.842	0.803	0.818	NA	$y = 0.862 - 0.004t$	0.19
Spain	1.026	1.024	1.065	1.072	1.015	0.997	1.012	0.997	0.939	1.013	$y = 1.058 - 0.008t$	0.39
Finland	0.966	0.990	1.076	1.076	0.975	0.902	0.975	1.066	0.980	0.960	$y = 1.015 - 0.003t$	0.03
France	1.304	1.297	1.324	1.331	1.219	1.091	1.202	1.228	1.105	1.087	$y = 1.362 - 0.026t$	0.66
United Kingdom	0.930	0.943	0.999	1.021	0.921	0.865	0.904	0.935	0.854	0.845	$y = 0.992 - 0.013t$	0.44
Greece	0.852	0.859	0.917	0.940	0.890	0.840	0.856	0.868	0.793	0.783	$y = 0.914 - 0.010t$	0.38
Hungary	NA	NA	1.090	0.960	1.051	0.969	0.994	1.015	0.998	NA	$y = 1.043 - 0.008t$	0.14
Ireland	NA	NA	NA	0.971	0.904	0.801	0.896	1.001	0.915	NA	$y = 0.904 + 0.003t$	0.01
Italy	1.088	1.099	1.152	1.160	1.132	1.089	1.058	1.064	1.001	1.020	$y = 1.156 - 0.013t$	0.53
Lithuania	0.671	0.690	0.789	0.778	0.718	0.680	0.705	0.724	0.683	0.707	$y = 0.725 - 0.002t$	0.02
Latvia	0.718	0.741	0.806	0.838	0.818	0.777	0.823	0.856	0.806	NA	$y = 0.742 + 0.011t$	0.46
Netherlands	1.064	1.083	1.101	1.133	1.064	1.061	1.032	0.975	NA	NA	$y = 1.121 - 0.013t$	0.44
Poland	0.871	0.912	0.926	0.941	0.922	0.861	0.862	0.894	0.847	NA	$y = 0.922 - 0.006t$	0.23
Portugal	1.099	1.093	1.092	1.448	1.113	1.087	1.138	1.123	0.919	NA	$y = 1.199 - 0.015t$	0.09
Romania	0.705	0.771	0.821	0.862	0.955	0.918	0.828	0.830	0.759	NA	$y = 0.789 + 0.008t$	0.07
Sweden	1.074	1.083	1.139	1.127	1.041	0.961	1.025	1.072	0.997	1.020	$y = 1.114 - 0.011t$	0.35
Slovenia	0.778	0.744	0.844	0.847	0.771	0.705	0.779	0.816	0.731	NA	$y = 0.799 - 0.004t$	0.05
Slovakia	0.982	0.856	0.969	1.020	0.957	0.852	0.881	0.913	0.766	NA	$y = 0.997 - 0.017t$	0.35
Serbia	NA	0.705	0.688	0.733	0.766	0.783	0.778	0.788	0.774	0.765	$y = 0.702 + 0.010t$	0.61

Source: own calculations

Table 4.36 presents the TFP development. We can observe that a positive trend in TFP was estimated only for Bulgaria, Denmark, Latvia and Serbia. Other countries experienced a rather stochastic development or a decline in TFP. A significant negative trend in TFP was revealed by the estimate primarily in France, Italy, the Netherlands and Slovakia. Thus, we can observe that some countries are catching up and some are falling behind. Compared to the previous sectors, we found smaller differences between old and new member states.

As in the case of previously analysed sectors, Spearman's rank correlation for TFP suggests that the order of food processing companies is stable over time. That is, leapfrogging can be excluded as far as TFP development is considered. Structural change seems to occur in such a way that the most successful producers strengthen their positions. Producers

with poor performance will not be able to catch up with the developments of the sector leaders, and are therefore expected to fall more and more behind.

**Table 4.37 Spearman's rank correlation coefficient of TFP – milling**

EU member country	Spearman's rank correlation coefficients of TFP								
	2004/2003	2005/2004	2006/2005	2007/2006	2008/2007	2009/2008	2010/2009	2011/2010	2012/2011
Austria	NA	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	0.966	0.976	0.988	0.878	0.916	0.851	0.958	0.917	1.000
Bulgaria	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.400	NA
Czech Republic	0.929	0.782	0.951	0.978	0.874	0.682	0.958	0.864	NA
Germany	1.000	0.943	1.000	0.902	0.993	0.923	0.784	0.818	1.000
Denmark	NA	NA	NA	NA	1.000	0.667	0.262	0.607	1.000
Estonia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO
Spain	0.975	0.973	0.979	0.936	0.899	0.904	0.932	0.936	1.000
Finland	1.000	1.000	1.000	1.000	0.500	1.000	0.800	0.600	1.000
France	0.963	0.872	0.986	0.926	0.918	0.980	0.953	0.968	0.986
United Kingdom	0.890	0.556	0.869	0.933	0.923	0.817	0.787	0.836	0.841
Greece	0.937	0.951	0.951	0.510	0.874	0.839	0.785	0.859	0.500
Hungary	NA	NA	LNO	LNO	0.800	0.900	0.930	0.976	NA
Ireland	NA	NA	NA	1.000	0.500	0.500	-0.500	0.800	NA
Italy	0.949	0.915	0.943	0.910	0.870	0.905	0.929	0.962	1.000
Lithuania	-1.000	-1.000	1.000	1.000	-0.500	0.400	1.000	-0.400	LNO
Latvia	1.000	1.000	-1.000	-1.000	1.000	1.000	-1.000	1.000	NA
Netherlands	1.000	0.500	1.000	1.000	0.500	1.000	LNO	NA	NA
Poland	0.801	0.899	0.781	0.930	0.886	0.937	0.892	0.970	NA
Portugal	1.000	1.000	0.400	0.921	0.874	0.901	0.770	0.844	NA
Romania	0.923	0.690	0.476	0.444	0.337	0.425	0.960	0.729	NA
Sweden	0.983	0.929	0.988	0.973	0.972	0.979	0.951	0.956	1.000
Slovenia	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO	LNO
Slovakia	LNO	LNO	0.800	1.000	1.000	1.000	0.900	1.000	NA
Serbia	NA	0.929	0.962	0.862	0.788	0.774	0.953	0.812	0.956

Note: LNO – Low Number of Observations

Source: own calculations

## 5 Conclusions

The stochastic frontier analysis, which uses a derived joint country-specific input distance function, revealed significant differences in technology among the countries. Moreover, heterogeneity among firms, as well as among food processing sectors, was pronounced. That is, we found that intra- and intersectoral differences are important characteristics in EU food processing. This holds for all analysed sectors, i.e. slaughtering, fruits and vegetables, dairy and milling.

As far as scale efficiency is concerned, we derived a model which is based on the assumption that companies maximise their return on capital, instead of on the conventional profits maximisation assumption. Since the dataset predominantly consists of large and mid-sized companies, maximising returns on capital is a more appropriate decision rule in the case of manager-operated but shareholder-owned companies. Using this criterion, it follows that the companies operate with constant returns to scale. Since we did not reject the model specification in our empirical application, we can conclude that there is no indication of economies of scale in the analysed countries.

Technological change made a significant positive contribution to the production possibilities in the majority of countries. Technological change was not pronounced in Spain, Hungary, Ireland and Portugal. Technological regress was exercised in Germany, United Kingdom, Greece and Italy. Moreover, inter- as well as intrasectoral differences in technological progress were revealed by the estimate. Slaughtering experienced higher positive technological change in the majority of countries as compared to other food processing sectors. In the case of the fruits and vegetables sector, the specific technological effect was positive in 6 countries and negative in 5. Technological progress in the dairy sector was, as in the case of slaughtering, higher as compared to other food processing sectors in the majority of EU countries. The milling sector experienced lower technological progress as compared to other food processing sectors. Furthermore, intrasectoral heterogeneity in technology was pronounced in 17 countries; however, the contribution was rather small, except for Bulgaria and Finland. Finally, biased technological change was pronounced for almost all countries. Contrary to our expectations, labour-saving technology was estimated only in Spain, France, Greece, Hungary, Italy and Sweden. On the other hand, materials-saving, biased technological change was estimated for most European countries.

The estimates revealed that efficiency differences among food processors are important reasons for variation in all sectors: slaughtering, fruits and vegetables, dairy and milling. However, the metafrontier analysis shows that the differences in average technical efficiency are not large for all EU member countries, including Serbia, even when there are huge differences between the best and worst producers. High technical efficiency of the top 10 % of food processors is a common feature of all countries in all analysed sectors. The difference between the top and bottom 10 % of companies differs among the countries. Large differences can be found, in particular, in Bulgaria and Romania. The developments in technical efficiency are rather stochastic in many EU member countries. Thus, rather idiosyncratic developments in technical efficiency were observed. However, in general we can conclude that we cannot observe significant changes in technical efficiency. This again holds for all analysed sectors (slaughtering, fruits and vegetables, dairy and milling).

Leapfrogging in TE appears to be a common phenomenon for all member countries in all sectors. However, some exceptions can be found. In the case of slaughtering, we can find groups of producers, especially in the Czech Republic, Germany, Finland, France, United Kingdom, Greece, Italy, Poland, Portugal and Romania, that tend to strengthen their positions. Relatively high and stable values of Spearman's rank correlation coefficient can be found in Belgium, Greece, France, United Kingdom and Italy for the fruits and vegetables sector. In addition, some dairy producers in Belgium, Greece, United Kingdom, Spain and Italy also seem to be strengthening their positions. The same holds true for milling producers in United Kingdom, France and Italy.

On the other hand, leapfrogging can be denied, as far as TFP developments in the slaughtering, fruits and vegetables, dairy and milling sectors are concerned. Structural change seems to occur in such a way that the most successful producers strengthen their positions. Producers with poor performance will not be able to catch up with the developments of the sector leaders, and therefore it is presumed they will fall more and more behind.

The TFP estimates revealed significant differences among EU member countries, including Serbia, in all analysed sectors. In general, the old member states have higher TFP than the new member states.

Slaughtering is characterised by high TFP in Belgium, Germany, Hungary, France, Italy and the Netherlands. On the other hand, the lowest TFP was estimated for the Baltic countries (Estonia, Lithuania and Latvia) and Serbia. Unlike the best-performing countries, where the variation among companies is large, the productivity differences among food processors in the worst-performing countries are quite small. This can lead to substantial sectoral changes, with consequences for the sectoral size if companies lose competitiveness. TFP shows a positive trend in the majority of EU member countries; only Bulgaria and Serbia are exceptions. We can observe that some countries with average or poor performance are catching up. However, countries with high productivity are further improving their performance. In other words, the catching-up processes are not so strong. Moreover, countries that cannot keep pace with competitors are falling more and more behind.

The highest TFP in the fruits and vegetables sector was again estimated for Belgium, Germany, Hungary, France, Italy and the Netherlands, and the lowest for Lithuania, Latvia, Greece, Romania, Slovakia and Serbia. Large spreads between the top and bottom 10 % of companies were found in Belgium, Spain, Finland, Hungary, the Netherlands, Portugal, Romania and Sweden. On the other hand, the differences in productivity among food processors are considerably smaller for the Czech Republic, Estonia, Lithuania and Latvia. This can lead to significant structural changes if the companies have problems with competition on the domestic market.

As far as the dairy sector is concerned, the highest TFP was estimated for old member states (Belgium, Germany, Spain, France, Italy, the Netherlands and Portugal) and Hungary. The lowest TFP can be observed in the Baltic countries, Bulgaria, Romania and Serbia. As in slaughtering and fruits and vegetables, some countries are characterised by large differences in productivity among companies (Belgium, the Czech Republic, Germany,

Spain, France, Hungary, Italy, the Netherlands, Portugal, Romania and Sweden), and there are countries with very small differences in TFP among companies (Austria, Denmark, Estonia, Ireland, Latvia and Slovenia).

The milling sector is the most productive in the following old member states: Belgium, Germany, France, Italy, the Netherlands, Portugal and Sweden. Bulgaria, the Czech Republic and Hungary have the highest TFP of the new member states. On the other hand, the lowest TFP was estimated for Lithuania, Latvia, Slovenia and Serbia, where the variation among food processing companies is quite small.

Finally, technological change was identified as an important factor that contributed predominantly positively to TFP development. This holds true especially for slaughtering and dairy. Moreover, despite the positive TFP development in many countries, we did observe a slow catching-up process from between the countries, but only in some cases. The metafrontier analysis showed that despite a period of almost 10 years after accession, the productivity differences in the food processing sectors, among as well as within (some) countries, are quite substantial.

Since the adoption of innovation is an important factor determining TFP growth, policy makers should focus their attention on supporting the spread of innovation and expertise, in order to support productivity growth in less-productive countries and thereby decrease the differences among countries in terms of productivity.

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## Project information

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- Title:** International comparisons of product supply chains in the agri-food sectors: determinants of their competitiveness and performance on EU and international markets (COMPETE)
- Funding:** Collaborative research project (small or medium-scale focused research project), FP-7-KBBE.2012.1.4-09, total EU contribution is 2,422,725 €
- Duration:** 01/10/2013-30/09/2015 (36 months)
- Objective:** The objective of the COMPETE project is to gain a more comprehensive view on the different elements which contribute to the competitiveness of the European agri-food supply chain in order to provide better targeted and evidence based policies on the EU as well as on the domestic level. The project investigates selected determinants of competitiveness like policy interventions and the business environment, productivity in agriculture and food processing, the functioning of domestic and international markets, the choice of governance structures, and innovative activities in food processing. The research results will enable a congruent, coherent and consistent set of policy recommendations aiming at improving competitiveness of European product supply chain.
- Coordinator:** IAMO, Germany, Prof. Heinrich Hockmann
- Consortium:** 16 Partners from 10 European countries. COMPETE brings together academics, trade bodies, NGOs, agricultural co-operative, industry representative advisory services. In addition, the project is supported by the group of societal actors, incorporating farmer, food processing and consumer associations, providing in-depth knowledge on the agri-food sector and speeding up the achievement of the project goals.
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