Technical Efficiency in the Chilean Agribusiness Sector – a Stochastic Meta-Frontier Approach

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Abstract:

The Chilean economy is strongly export-oriented, which is also true for the Chilean agribusiness industry. This paper investigates the technical efficiency of the Chilean food processing industry between 2001 and 2007. We use a data-set from the 2,471 of firms in food processing industry. The observations are from the 'Annual National Industrial Survey'. A stochastic meta-frontier approach is used in order to analyse the drivers of technical efficiency. We include variables capturing the effects of labour-quality, the extent of export orientation and the impact of paid subsidies to the agribusiness firms. Raw materials and labour have to largest impact on the output, but with a different input-intensity for the different agribusiness sectors. We could show that technical efficiency is different in the different agribusiness sectors and that some sectors (the bakery and the grain & mill sector) are using a more productive technology than the other sectors. Potential impacts on structural change in the Chilean food processing industry are discussed. The paper also shows, that exporting firms in the agribusiness industries can be described as more dynamic, achieving either a higher technical efficiency or a higher technological change.

Keywords: Technical Efficiency, Stochastic Meta-Frontier Analysis, Food Processing Industry, Chile

JEL codes: D24, G14, F14

1 Introduction

Chile, one of the strong emerging economies in Latin America, has a long tradition of liberal trade policies. Chile has free trade agreements with other countries, regions and free-trade areas[2], documenting a strong trade orientation of Chiles economic policy. Between 2000 and 2010 Chile has increased the volume of export by on average 4,9 % per year and the value of exports by on average 26,9 % per year (WORLDBANK 2012), still with a strong focus on the mining industries.

During the last 12 years, the food processing industry has successfully overcome different challenges. As result, this industry has constantly increased its exports with the exception of 2009. In 2009, the world economic crisis reached the Chilean economy, affecting mainly the fruit and vegetable sector. Nevertheless, the whole food processing industry managed to duplicate its value of total exports in the last 12 years (CHILEALIMENTOS 2012). The following Table 1 is presenting the actual level and increase of exports of the agribusiness industries:

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[1] A preliminary version of the paper has been presented at the IAMO-Forum 2011.

[2] European Union, Mexico, Canada, South-Korea, EFTA, Central America, the Mercosur-states, Singapore, Japan, China, India, New Zealand, Colombia, Venezuela, Ecuador, Bolivia, Peru, and the US.

Table 1: Exports of food and processed food 2011 and 2012 (in Mio. US $)

Sector	2011	2012	Variation
Processed food	3,147	3,196	2 %
Fresh fruit	3,398	3,177	- 6 %
Salmon and trout	2,917	3,089	6 %
Wines	1,721	1,809	5 %
Meat and cured meat	1,146	1,208	5 %
Others	2,477	2,643	7 %
Total	**14,807**	**15,122**	**2 %**

Source: CHILEALIMENTOS 2012

The figures indicate, that the food processing industries is increasing, except for the sector of fresh fruits, and also the growth rates are different among the sectors.

Following the classical trade-theory, we might expect that the Chilean agribusiness and food industries to be competitive and export-oriented. In 2004, the Chilean government announced a new strategy for the agricultural and trade policy called 'Potencia Alimentaria' ('Global and Agricultural Food Power'). The objective of this policy is to enforce Chiles export potential in the area of agriculture and agribusiness and to enter the top ten of the worlds export nations (ECHEVERRÍA and GOPINATH 2010).

The objective of this paper is to investigate technical efficiency of the Chilean agribusiness and food processing industry. By analysing firm efficiency we will show how the different production structures, factor endowment and export-orientation lead to technical inefficiency. Finally we will compare the efficiency of the different agribusiness sectors in Chile.

2 Background and theory

Trade liberalisation is the process when the restrictions to the free international movement of goods and services are abolished (DIJKSTRA 2000). Trade liberalisation affects positively economic development, poverty reduction (BOUET 2008), and even to more political stability and democratic development of a country (ACEMOGLU & ROBISON 2012). Likewise, firms and consumers benefit from freer trade because of the realization of static welfare gains, as well as from higher quality of goods and services. In addition to this, firms can diversify risks and channel resources to where returns are higher, i.e., structural changes lead to improved productivity. Furthermore, openness means more competition, putting bounds on price mark-ups resulting from market power, higher investment, productivity growth, and also improved exploitation of economies of scale, at least if appropriate domestic policies accompany the liberalisation (PAVCNIK 2002, OECD 2010).

- A comprehensive trade liberalisation strategy can be expected to have effects on economic development and poverty reduction in multiple ways which extend well beyond the standard (static) gains from trade, i.e., the gains in welfare from adjustments in the structure of consumption and production in response to international price ratios. For the production, these occur as one-time adjustments in the output of industries whose prices change due to trade liberalization, i.e., output allocative efficiency gains. The fruits from these static effects might already have been reaped since Chile started its free-trade agenda some decades ago. Hence, the dynamic effects of freer trade on efficiency and productivity are likely to be more important. RODRIK (1995) and PAVCNIK (2002) list a number of potentially important channels through which trade liberalisation might improve sectoral performance permanently, reflected in higher industry growth rates. All these channels start from the assumption that the sector is characterized by substantial heterogeneity prior to trade liberalization. Learning by doing, in particular 'learning by exporting' might contribute both to higher rates of adoption of new technologies, and to better utilization of the potential of the existing technology (gains in technical efficiency).
- Stronger competition, caused both by external competitors, and by price pressures in those domestic industries which had enjoyed some extent of protection prior to liberalization, might affect sectoral output by pushing firms to exert higher efforts (i.e., gains in technical efficiency). The Hicksian 'quiet life' of the monopolist is difficult to imagine in the presence of global competition.
- In the same vein, increases in competitive pressures can be expected to increase the rate of structural change within the industry so that the more productive firms will grow at the expense of less productive firms. The effect of this structural change will be an improvement in sector productivity, even if the more productive firm stagnate in their level of technical efficiency.
- We might on the other hand, observe different kinds of technological spill-overs from exporting industries or firms to non exporting firms via the labour markets. We might also observe the same on the product market: For the case of the agricultural sector in Chile, FLEMING & ABLER (2013) show technological spill-overs from non-traditional crops, that are mainly exported, to the traditional crops, which are consumed on the domestic market.
- Firms acting in a globalized market might better be able to exploit increasing returns to scale, if these do play a role in the industry at hand, or might be able to better utilize their installed capacities. The relatively low degree of processing in the food and agribusiness sector, however, suggests that the impact of scale improvements on sectoral growth could be rather limited; typically, economies of scale increase with the degree of processing.

- Finally, resource use efficiency might improve because of liberalisation frequently lowers the (expected) returns to rent-seeking activities. However, existing rent-seeking activities, even if they were targeted, e.g., at obtaining export licences, might not completely vanish but re-emerge in different areas (e.g., public procurement). The share of resources devoted to such wasteful activities will be more strongly influenced by the general level of governance in a country (DIJKSTRA 2000); since Chile, in almost all quantification attempts, shows a relatively low level of corruption, red tape, etc., the impact of this last channel is likely rather limited.

Hence, most of the dynamic effects are likely to materialize in the form of efficiency improvements. Therefore, this paper investigates the effects of trade liberalisation on the technical efficiency of the Chilean food industry, and the determinants of this efficiency.

A number of studies in the existing literature analyses the nexus between trade liberalisation and efficiency / productivity improvements. We first start with a brief overview of selected general results, before summarize the few studies which analyse specifically manufacturing in Chile.

SEMENICK ALAM and MORRISON (2000) analysed the effects of trade reform on technical efficiency in the Peruvian manufacturing industries. They considered the period between 1988 and 1992 – two years before and two years after the trade reform of 1990. To measure technical efficiency in Peruvian industries was used the linear programming method of Data Development Analysis (DEA). In addition, the authors explore possible determinants of technical efficiency, specifically commercial policy (measured by rates of effective protection), and industrial structure (measured by Herfindahl index of industrial concentration). Their results show that out of 20 industries, 15 increased their average levels of technical efficiency during the period 1988 to 1992[3]. Likewise, they found that commercial policy and industrial structure affects the levels of technical efficiency in the Peruvian manufacturing industries. Thus, if there is high level of rate of protection, there will be lower levels of technical efficiency, the same for the degree of industrial concentration.

HOSSAIN and KARUNARATNE (2004) investigated the effects of trade liberalisation on the technical efficiency of the Bangladesh manufacturing sector by estimating a combined stochastic frontier-inefficiency model using panel data for the period 1978 to 1994 represented by a Cobb Douglas production technology. They estimated the impact of the trade policy reforms on technical efficiency of manufacturing industries of Bangladesh using as proxy variables, the export orientation and capital deepening. Their results show that a Translog production function is more accurate for representing the production technology. Further, their results show that

[3] The model is estimated due to un-weighted and weighted average technical efficiency level. However, the industries with lowest and higher levels of technical efficiency were similar in both methods (see SEMENICK ALAM & MORRISON 2000: 318).

overall technical efficiency of the manufacturing sector has increased over time from 34.2 % (average) in 1978 to 68.2 % (average) in 1994[4], and that trade liberalization; represented by the proxy variables; has had positive and significant impact on the reduction of the overall technical inefficiency. In addition to this, their results show that the degree of technical efficiency is the same or has increased over time for export-oriented industries. In the same way, import-substituting industries have benefited significantly from trade liberalization.

SALIM and HOSSAIN (2006) analysed the impact of trade liberalisation and of market deregulation on the performance of agriculture of Bangladesh. They estimated a random coefficient frontier production function assuming a Cobb-Douglas technology. As relevant factors of technical efficiency, they considered farm size (in term of hectare), tenancy (proportion of rented-in land cultivated by the farm household), crop diversification index, average level of education, index of underdevelopment infrastructure, effective rate of assistance (both trade and domestic assistance policies which affect prices of factors, material inputs, products, assistance in the form of price and quantity controls, import bans, and subsides), non-agricultural income share, extension services received by household farm (dummy variable). The authors used three approaches: pooled regression with no control for farm or time effects, fixed effects, and random effects models. They found as expected that the variables farm size, tenancy, crop diversification index and rate of assistance, affect negatively the farm-specific technical efficiency. Likewise, the variables related to education, infrastructure and non-agricultural incomes had a positive effect on farm-specific technical efficiency. Their results show also that there was an increase in the average farm-specific efficiency from 0.56 in 1977 to 0.64 in 1997 i.e. technical efficiency increased by 8 % from pre- to post-reform period partly attributable to market and trade policy reform. SALIM and HOSSAIN (2006), state that probably the trade liberalisation reform removed some distortions from the agricultural input and output markets. This increases farmer's accessibility to new seed varieties, modern technology, market information and education, which results at the end in higher efficiency levels in crop production.

SASIDARAN and SHANMUGAM (2008) analyse the impact of trade liberalisation on the efficiency of Indian's textile industry during 1993-94 to 2005-06. They estimate a Cobb-Douglas production-function with stochastic and efficiency effects for panel data using the Generalized Least Square (GLS) approach. The authors also estimate the firm specific and time specific technical efficiency using the two-stage procedure. As determinants of firm specific technical efficiency over time they considered firm size (measured by real sales), export intensity of the firm (ratio of exports to sales value), raw material import intensity (ratio of the value of import of raw material to the total raw material used in production) and time specific (structural shift)

[4] The authors estimated also the weighted average of technical efficiency for the manufacturing sector as a whole (see HOSSAIN & KARUNARATNE 2004: 112).

dummies to account for the phasing out of quotas. The authors found declining technical efficiency from 0.60 to around 0.54 of the Indian's textile industry over the years considered in their study. Likewise, they found that firm size has a negative and significant impact on efficiency, which indicates higher efficiency in small firms than large ones. Furthermore, the export intensity influence positively on efficiency. Also, the raw material intensity variable has a negative impact on efficiency which is a signal that firm with higher proportion of imported raw materials are less efficient. Finally, the dummies variables considered in the study in order to capture the impact of trade liberalisation through phasing out quotas restrictions have a negative coefficient which imply that the removal of quota restriction had negative effects on the technical efficiency of Indian's textile industry.

CAVALCANTI & ROSSI (2003) investigated the effect of trade liberalisation on productivity growth from the Brazilian manufacturing industries in the period 1985-97. In order to estimate the effects of trade liberalisation on productivity growth were considered the following variables: industry specific fixed-effect which represents different unobserved industry specific factors, a vector of dummy variables which capture the effect of common industrial and macroeconomic factors that affect productivity growth, and a group variables used as proxy for trade liberalisation (tariffs, effective rate of protection, and import ratio). Their results indicate that trade liberalisation started in 1988-90, has had a positive effect on productivity growth of Brazilian manufacturing industries, concluding that there is a significant and robust relation between the factors investigated. Hence, trade liberalisation had a significant effect on industrial performance. There was an increased around 6 % in total factor productivity growth rate and labour productivity.

TYBOUT *et al.* (1990) analysed the effects of trade liberalization, comparing the year 1967 and 1979, on scale and technical efficiency of the Chilean manufacturing sector. They considered on the study industries which higher reduction on levels of protection and industries in which there was a small one. They represented the production technology through a Cobb Douglas production function where were included the as exogenous variables: capital, Labour, and type of ownership. Their results show an increase in the output level, which was similar in industries with significant reductions in level of protection; however, there was no proof of improvements on technical efficiency[5].

PAVCNIK (2002) investigated the effects of trade liberalisation on plant productivity of Chilean manufacturing industries during the period 1979-1986, a period of significant adjustment in the Chilean trade policy. In order to obtain a measure of plant productivity, the author estimated a technology production function represented by a Cobb Douglas production function which includes plant exit in the estimation for correcting the selection problem associated with liquidated plants. In addition, the author identified the impact of trade on plant productivity

[5] It is important to mention that the average technical efficiency is represented in the model by the intercept.

through the estimation of a second regression model, which allows variation in productivity over time and across trade and non-trade goods sectors. As proxies of trade, were considered as variables: real exchange rate, tariff, and the ratio import/output. The results indicate that trade liberalisation has had impact on plant productivity for plant in the import-competing sector which increase between 3 % and 10 % (average) more than the productivity of plants in the non-traded goods sectors. This improvement in plant productivity has as source the shift of resources from less to more efficient producers. The aggregate productivity grew by 25.4 % and 31.9 % in the export-oriented and import competing sectors over seven years, respectively. The non-traded goods sectors increased its productivity around 6 %. Finally, the results show that the Chilean manufacturing sector grew at an average annual rate of 2.8 % after trade liberalization.

A very recent study investigates the relation between trade orientation and productivity of the agricultural sector in Chile (FLEMING & ABLER 2013). The study is focused on tradable non-traditional products and traditional products, which are consumed on the domestic market. Their results find trade exposure positively correlated with yield suggesting that trade has positiv impact on farm productivity. The authors conclude, that these productivity gains might lead to spill-overs even to traditional crops, which are not typically traded.

3 Methods and data

3.1 The stochastic frontier model

We use a stochastic frontier analysis approach to model the production frontier and the determinants of technical efficiency in the Chilean agribusiness industry. According to AIGNER *et al.* (1977) and MEEUSEN & VAN DEN BROECK (1977) we can set up a stochastic frontier model along the lines of equation (1):

$$y_{it} = f\left(x_{jit}, \beta_i\right) * exp\{w_{it}\} \qquad with\, w_{it} = v_{it} - u_{it} \tag{1}$$

$$y_{it} = f\left(x_{jit}, \beta\right) * exp\{v_{it} - u_{it}\}\,, \tag{2}$$

where output y_{it} is the sum of revenues of a *firm i* and *j = 4 inputs x* are defined as:

x_1 = total of labour (L),
x_2 = total cost of raw materials (RMAT),
x_3 = total cost of energy (OC) sources used in the production process (water, combustible and electricity),
x_4 = capital, measured as nominal stock at end of each year (K) and
t = period of time, $time \in \{1,2,\dots,7\}$.

The functional form $f(\cdot)$ is specified as a translog function. Thus, β represents a vector of coefficients for the translog specification, whereas w_{it} is the composed error, $w_{it} = v_{it} - u_{it}$. The first component v_i is defined as a pure random error (white noise) independently and identically distributed as $N(0,\sigma_v^2)$ (AIGNER *et al.* 1977). The second error-term u_i is a systematic and *nonnegative* random variable, which is assumed to be under the firm's control. This error term accounts for the inefficiency of the *i*-th firm (SCHMIDT & SICKLES 1984). We assume a half normal distribution for the inefficiency term, thus $u_i \sim N^+(0,\sigma_u)$.

The literature suggests, inter alia, a half-normal[6], exponential, truncated normal or a gamma distribution (MURILLO-ZAMORANO 2004). We assume a half normal distribution for the inefficiency term, thus $u_i \sim N^+(0,\sigma_u)$.

The inference of the parameters under stochastic frontier model can be based on maximum-likelihood estimates which are obtained in terms of the parameterization of $\sigma_v^2 + \sigma_u^2 \equiv \sigma^2$ and $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$, where γ lies between zero and one. Thus, if $\gamma = 0$ all deviations are due to noise, while $\gamma = 1$ means all deviations are due to technical inefficiency[7]. Hence, the output-oriented measure of technical efficiency *(TE)* for any individual firm *i*, will be reflected by the ratio given by:

$$TE = \frac{q_i}{q_i^*} = \frac{f(x_{ik};\beta)\exp(v_i - u_i)}{f(x_{ik};\beta)\exp(v_i)} = \exp(-u_i) \in [0,1]. \qquad (2)$$

An important advantage of SFA methods is that it allows inference regarding to returns to scale, choice of inputs, structure of technology and also the significance of technical efficiency (HOSSAIN & KARUNARATNE 2004, BRÜMMER 2010).

The estimation of the equation (1) depends on the assumption that both error components are homoscedastic. However, it is possible that both errors are affected by *heteroscedasticity* (see CAUDILL *et al.* 1995). Thus, the inefficiency term would vary according to the size of the firm; larger firms might have more variation than small firms (LAKNER & BRÜMMER 2008), associated to the input endowment. Since the data show a large variation, we are using the 'heteroscedasticity-model' developed by WANG & SCHMIDT (2002) for a production frontier framework. The main estimation of the heteroscedasticity model is described as follows:

$$\sigma_{u_{it}} = exp\{z_{it}\rho_j\} \qquad (3)$$

where z_{it} is a matrix of *j* explanatory variables of the variance of inefficiency term $\sigma_{u_{it}}$ for firm *i* in period *t;* ρ is a vector of length *j* of parameters to be estimated, reflecting the impact of the variable z_{it} on technical inefficiency. A positive (*negative*) estimate of ρ indicates that the corresponding variable leads to a larger (*smaller*) variance of the inefficiency term, i.e. a smaller (*larger*) technical efficiency. We started with the translog specification as a functional form, later also testing for Cobb-Douglas as a functional form. The model was estimated by means of Maximum-Likelihood (see COELLI *et al.* 2005).

[6] In the literature u_i was typically specified by a half-normal distribution $u_i \sim N^+(0,\sigma_u^2)$.

[7] AIGNER *et al.* (1977) estimate $\lambda^2 = \sigma_u^2/\sigma_v^2 \geq 0$ instead γ. If $\lambda = 0$ then all deviations are due to noise.

3.2 Metafrontier model

The estimation of technical efficiency is usually based on the assumption, that all the firms have access to a homogenous technology. This might not be the case in a rather heterogeneous industry such as the food processing industry in Chile. On the other hand, the different agribusiness sectors are using basically the same inputs, therefore, we might distinguish between the technical efficiency in relation to the specific technology of a single sector of the agribusiness industry and the technical efficiency with respect the industry-wide technology of the agribusiness in Chile. A methodology to address this type of problem is the so-called 'Stochastic Meta-Frontier Model' developed by BATTESE *et al.* (2004) and O'DONNELL *et al.* (2008). The basic idea of the metafrontier is to estimate group-specific frontiers * in the first step and envelope the group-specific frontiers by a metafrontier in the following step. The metafrontier is therefore a deterministic frontier, defined by the condition that it envelops the maximum output predicted from the estimated group-specific frontiers from above. Once a parametric function is assumed for the metafrontier, the metafrontier parameters can be reconstructed by (linear or quadratic) optimization. The basic concept of metafrontier is illustrated in Figure 1:

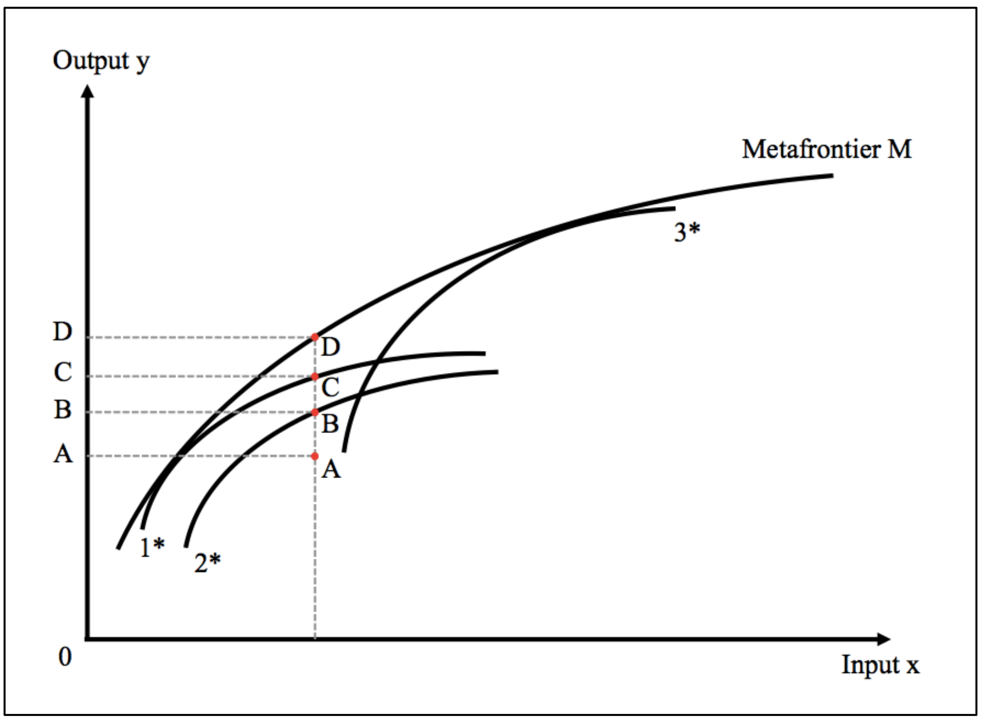

Figure 1: 'Group specific frontiers' for group 1*, 2* and 3* and 'Metafrontier M' for a given set of inputs and different output-levels
Source: own presentation based on O'DONNELL *et al.* 2008: p.236

For a given observation A, we can estimate the technical efficiency for the given group frontier (2*). **Technical efficiency** (*TE*) for a given set of inputs x would be $TE = A0 / B0$. For the same observation A, the total technical efficiency TE^* in relation to the metafrontier would be

$TE^* = A0 / AD$, assuming that the observed firm A could use the joint technology. We can also look at the difference between the group-specific frontier (*2) and the metafrontier *M*. This number is referred to as '**Meta Technology Ratio (*MTR*)**' (O'DONNELL *et al.* 2008). The ratio of the distances between the group-specific frontier *2 and M defines the MTR, so that in the above figure, for observation A or any other firm at the same input use, $MTR = B0 / D0$.

The stochastic metafrontier can be described as:

$$y_{it}(G) = f\left(x_{jit}(G), \beta(G)\right) * exp\{v_{it}(G) - u_{it}(G)\} \tag{4}$$

with a given output *y* and for the inputs *x* $(j=4)$ of firms *i*. The group-specific parameter $\beta(G)$ is estimated for the different groups $G = 1, 2, \ldots, N$.

The metafrontier is then defined such as:

$$y_{it} *= f\left(x_{jit}, \beta *\right) = e^{x_{it,}\beta^*} \tag{5}$$

where $\beta*$ is a parameter for the metafrontier production function, subject to

$$x_{jit}, \beta * \geq \; x_{jit}, \beta_g \; . \tag{6}$$

BATTESE *et al.* (2004) suggest two methods of optimization to derive the deterministic metafrontier, which can be described according the following two objective functions:

$$\min L = \sum_{i=1}^{N} \sum_{t=1}^{T} \left| (\ln f(x_{it}\beta^*) - lnf(x_{it}\widehat{\beta_j}) \right| \tag{7}$$

$$\min L^{**} = \sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it}\beta^* - x_{it}\widehat{\beta_j})^2 \tag{8}.$$

In both models we minimize the deviation of the group-specific frontier from the metafrontier. In the first model (7) the minimal absolute deviation is used for the optimization process, whereas the second model (8) uses the minimum squared deviation (BATTESE *et al.* 2004: 96). The firm individual technical efficiency to the metafrontier $TE*$ is defined as follows:

$$TE_{it}^{\ *} = TE_{it}^{G} \times MTR_{it} \tag{9}.$$

The technical efficiency relative to the group frontier TE^G is multiplied by the meta technology ratio (MTR), which captures the relation of the group-specific technology to the enveloping metafrontier.

The SFA is estimated with the package sfamb for OxMetrics 6.3 (BRÜMMER 2001). In order to assess the precision of the estimated metafrontier parameters, we perform a statistical simulation along the lines of O'DONNELL *et al.* (2008) based on 5,000 random draws from the estimated parameter vectors.

3.3 Data

We use a panel data set from the '*Annual National Industrial Survey (ENIA)*' from the national institute of statistic in Chile, which consists of accounting information from the manufacturing sector. We use the following variables as production inputs or potential determinants for technical inefficiency (Table 2):

Table 2: Description of the variables in the dataset

Variable		Minimum	Mean	Maximum	Std. dev.
a.) Variables for the production frontier					
Turnover (CL$ 1,000)	Y	31,850.0	2,462,100.0	74,875,000.0	6,816,400.0
Labour (Persons)	X_1	4.0	59,597.0	1,638.0	128.0
Raw Materials (CL$ 1,000)	X_2	1,108.4	1,526,300.0	38,004,000.0	4,093,100.0
Operation Costs (CL$ 1,000)	X_3	522.0	74,479.0	3,346,200.0	201,820.0
Capital (CL$ 1,000)	X_4	123.0	1,021,800.0	57,751,000.0	3,600,500.0
Export-Dummy (0/1)	EXP	0.0	0.12	1.0	0.32
b.) Determinants of technical inefficiency					
Non-Production Labour (%)		0.0	0.5	1.0	0.26
Wages paid per person (CL $ 1,000 / Person)		195.9	3,164.3	109,200.0	2,776.9
Dummy for exporting firms (0/1)		0.0	0.12	1.0	0.32
Paid Subsidies for exports (CLP $ 1,000)		0.0	616.2	452,510.0	11,236.0

Source: Own calculations

The original panel data set used in the present study extends from 2001 to 2007. It includes a total of 7,807 observations from the Annual National Industrial Survey (ENIA) developed by the Chile's National Institute of Statistics (INE). This survey contains accounting information from firms from the whole manufacturing sector. For the econometric analysis, we considered only firms that are part of the food processing industry, with special consideration to five sectors: production, processing and preserving of meat and meat products (1), processing and preserving of fruit and vegetables (3), manufacture of dairy products (5), manufacture of grain mill products (6) and manufacture of bakery products (7)[8]. Most firms were located between 4th and 8th region[9], which correspond to the most densely populated areas in Chile. Likewise, on these regions are concentrated the largest firms and exports from the processed food industry and agriculture, being this the main justification to the selection of regions for the analysis. However, some of the firms show inconsistency in their information and, therefore were excluded, for instance some of them did not have capital. As result, we analyse at the end a balance panel data of 2,471 observations (Table 3):

[8] We did not include all agribusiness sectors due to data-constraints.
[9] Chile has 13 geographical and administrative regions.

Table 3: Investigated agribusiness sectors in Chile

Sector	Observation	ID	Description
1	203	1511	Production, processing and preserving of meat and meat products
3	231	1513	Processing and preserving of fruit and vegetables
5	126	1520	Manufacture of dairy products
6	203	1531	Manufacture of grain mill products
7	1,708	1541	Manufacture of bakery products
	2,471		**In total**

Source: own calculation, nomenclature from the Institute of Statistics Chile

The variable **'labour'** represents the number of working units in a firm. The variable **'capital'** comprises the value of fixed assets such as land, vehicles, machinery and buildings. Likewise, the variable **'raw materials'** involves also the value of bought products to be processed, for instances, fruits, vegetables, milk.

We also derived the variable **'operation costs'**, which is the sum of the expenses for fuel, water and electricity used exclusively on the production process. This is especially important, since some firms do not work with electricity from the public grid, but produce their own electricity. These firms should have higher expenses for fuel, but might also have zero expenses for electricity. This new variable represents the direct cost associated with the production process.

The monetary variables are deflated using the respective price indices. Energy was deflated by the '*Wholesale Price Index (IPM)*', the output (revenue from sold processed food) and exports were deflated by the '*Consumer price index (IPC)*' and finally for capital we used the '*Deflator for Fixed Capital (DFC)*', all provided annually by the Central Bank of Chile.

4 Results and Conclusions

The tests for model-quality are presented in the following Table 4:

Table 4: Results for different tests of model quality

Null-hypothesis	Test-value: Meat sector	Fruit & vegetables	Dairy sector	Grain & mill sector	Bakery sector	Critical value
H1: No inefficiency† $\rho_j = 0, j = 0,1,\ldots,29$	161,04 **	54,88**	31,94**	29,02**	312,31**	3,84
H2: CD-production function $\rho_j = 0, j = 0,1,\ldots,29$	532,95**	132,39**	207,49**	61,06**	233,85**	25,00
H3: Linear homogeneity (constant returns to scale) $\sum\beta_j = 1;\ \sum\beta_{jk} = 0\ for\ j = 1,2,3,4$	12,03 **	*10,01*	106,15**	35,86**	58,87**	11,07
H4: No Heteroscedasticity $\rho_j = 0, j = 1,2,\ldots,19$	402,85**	228,98**	72,65**	39,61**	901,26**	15,51

†: Critical Value for H1 according to KODDE and PALM (1986), the other critical values are taken from the Chi-sqared-distribution
* indicates a significance-level of alpha = 0.1, ** indicates a significance-level of alpha = 0.5

Source: own calculations

The results overall show that the model is an appropriate representation of the data. The Hypothesis 1 of not applying the efficiency model, was rejected. The hypothesis 2 (a Cobb-Douglas production function) was also rejected. The Hypothesis 3 were rejected in most cases, but especially in the fruit & vegetable sector, the test of linear homogeneity could not be rejected. (The details of scale elasticity are discussed below.) Hypothesis 4 of not applying the heteroscedasticity model was rejected in all sectors.

The estimation results of the group-specific frontiers and the meta-frontier models are presented in Table 5:

Table 5: Estimated parameter-results of the stochastic frontier model

Parameter	Meat sector (1)	Fruit & vegetables (3)	Dairy sector (5)	Grain & mill sector (6)	Bakery sector (7)	Meta frontier 1	Meta frontier 2
β_0	- 0,0197	0.0965	0.1186**	- 0.062**	0.0489**	0.2490**	0.2416**
β_1 (Labour)	0.5080**	0.2816**	0.2111**	0.232**	0.6194**	0.4728**	0.4763**
β_2 (Raw Materials)	0.4227**	0.5076**	0.4691**	0.777**	0.3057**	0.4367**	0.4050**
β_3 (Operation Costs)	0.1202**	0.3064	0.3225**	0.096**	0.0768**	0.2005**	0.2131**
β_4 (Capital)	0.0715*	0.0444	0.0423	0.027	0.0308**	0.0314	0.0350
β_t (trend)	0.0513**	- 0.0140	- 0.0003	0.020**	0.0223**	0.0158	0.0157
D_{Export}	0.0687	- 0.0264	- 0.1137	- 0.086*	- 0.0086	0.0092	- 0.0192
β_{11}	0.8130**	0.0787	0.2236**	0.127*	0.3762**	0.8777**	0.7683**
β_{22}	0.4780**	0.3080**	0.1493**	0.137**	0.4783**	0.5378**	0.5051**
β_{33}	- 0.0528	0.1844*	0.2584**	0.060**	0.0166	0.1966**	0.1941**
β_{44}	0.0792**	0.0458	- 0.0315	0.002	- 0.0087**	0.0198	0.0466**
β_{tt}	0.0027	0.0210**	0.0058	0.006	0.0026	0.0065	0.0139**
β_{12}	- 0.4206**	- 0.2000**	- 0.0929**	- 0.027	- 0.4302**	- 0.4571**	- 0.4195**
β_{13}	- 0.1358	0.0402	0.0232	- 0.012	- 0.0275	- 0.1907**	- 0.1685**
β_{14}	- 0.1105*	0.0693*	- 0.1151**	0.034	0.0799**	- 0.0311	- 0.0514
β_{1t}	0.0147	- 0.0050	- 0.0297*	0.028	- 0.0106	0.0032	0.0212
β_{23}	- 0.0015	- 0.0802*	- 0.1902**	- 0.048	- 0.0339	- 0.0462*	- 0.0272
β_{24}	- 0.1085**	- 0.0651	0.0640**	- 0.044	- 0.0028	0.0038	- 0.0073
β_{2t}	- 0.0221*	0.0102	0.0208*	- 0.011	0.0278**	0.0356**	0.0278**
β_{34}	0.1295**	- 0.0615	- 0.0118	- 0.018	- 0.0044	0.0054	- 0.0044
β_{3t}	0.0120	- 0.0270	- 0.0243*	- 0.011	0.0001	- 0.0249**	- 0.0317**
β_{4t}	0.0005	0.0042	- 0.0125	- 0.007	- 0.0033	- 0.0033	- 0.0019
ln σ_v	- 2.2773**	- 1.6259**	- 1.9411**	- 1.869**	- 1.5072**	–	–
Gamma	0.9990	0.8097	0.3547	0.2272	0.56	–	–
Log Likelihood	24.02	-10.0	62.57	87.73	-39.11	–	–

* indicates a significance-level of alpha = 0.1, ** indicates a significance-level of alpha = 0.5

Source: own calculation

The estimated gamma shows that the share of inefficiency in the joint error-term is substantially different among the agribusiness sectors, being rather low in the grain & mill sector with 0.23 and very high in the meat sector with 0.99.

The variable **time** can be interpreted as an indicator for average technological change within the different sectors. The results show technological change in three of five sectors in the Chilean agribusiness: We find the highest rate of technological change in the meat-industry with 5.1 % per year, followed by the grain & and mill and the bakery sector with 2.2 % and 2.0 % per year respectively. The **dummy for exports** is capturing the export-activity of a sector. Surprisingly, we can observe some impacts in the grain & and mill sector, where the export-oriented firms show a lower productivity, which is against the general expectations[10].

With respect to factor endowment and it's impacts on outputs, we can observe some differences within the different agribusiness sectors. The first order estimates β_j can be interpreted as partial output elasticities at the sample mean, showing how much the output would increase in percentage terms if the use of the respective input was increased by 1 %. For simplification, we show the partial output elasticities for the five agribusiness sectors in the following Figure 2.

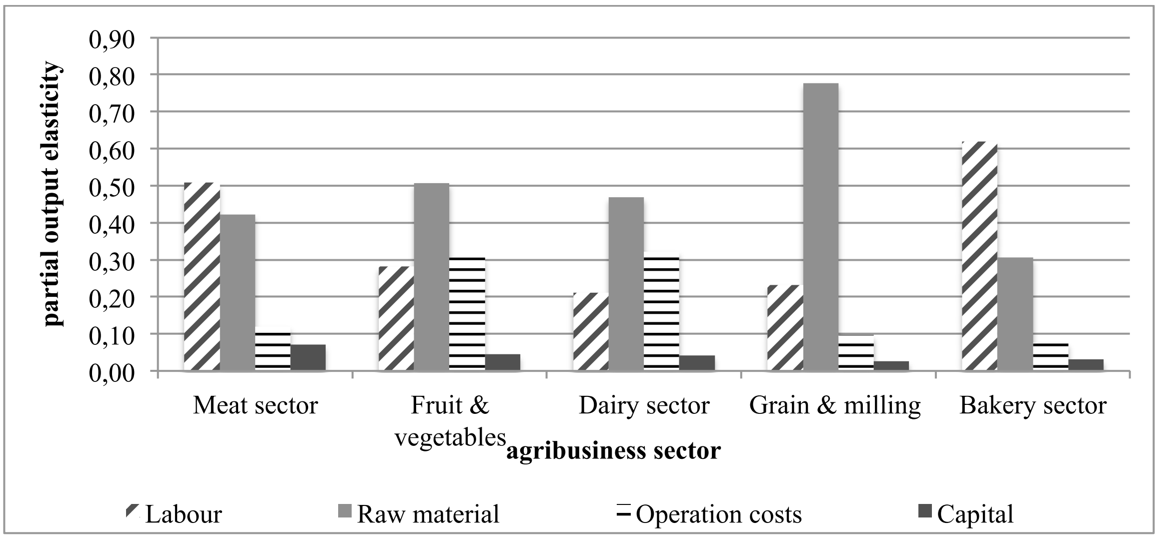

Figure 2: Estimated partial output elasticity of four inputs in the Chilean agribusiness
<u>**Source**</u>: own calculation

The figure clearly indicates, that **capital** contributes just to a small extent to output. The an increase of the capital input by 10 % would increase the output by 0.3 % - 0.7 %, the metafrontier indicates an increase between 0.31 % and 0.35 % respectively. This reflects to some extent the low capital endowment in most firms. **Operation costs** show a high output elasticity in the fruit and vegetable sector and in the dairy sector. The costs of **raw-materials** show a high output elasticity in all sectors, but in the grain & mill sector the increase of raw-materials of e.g. 10 % would increase the output by 7 %, which is high also in comparison to other studies. **Labour** is especially important in the meat processing and the bakery sector, where the output-elasticity is

[10] Deflating the output of exporting firms with a domestic price-index might be one source of potential underestimation of the exports, which can explain a bit of this result. For reasons of data-consistency, we still kept this method of deflation.

0.51 and 0.61 respectively. The metafrontier 1 and 2 show an output-elasticity of 0.47 and 0.48.

The following **Table 6** shows the estimated parameter-results for the heteroscedasticity-mode:

Table 6: Estimated parameters for the heteroscedasticity model

Parameter		Coefficients Meat sector (1)	Fruit & vegetables (3)	Dairy sector (5)	Grain & mill sector (6)	Bakery sector (7)
Constant	ρ_0	- 1.1182**				- 0,4572**
Lx1a	ρ_1	1.3882**		- 5.3005**	4,1965**	0,2105*
Lx2	ρ_2	- 0.7840**	- 0.5578**		- 2,3253**	- 0,7384**
Lx3	ρ_3			1.4744*		
Lx4	ρ_4		0.3602*	2.6934**		
Wage per person	ρ_5		- 0.0006*	- 0.0009*	- 0,0015**	- 0,0008**
Non production labour	ρ_6		1.0241**	- 7.9056*	- 2,2074**	
Dummy for exporting firms	ρ_7				- 6,2150**	- 0,4877**
Subsidies	ρ_8	- 0.0002**		0.0024**	0,0001**	- 0,0002*

* indicates a significance-level of alpha = 0.1, ** indicates a significance-level of alpha = 0.5
for simplification reason we show only significant results with alpha < 0.1s

Source: own calculation

The results again show substantial differences between the different agribusiness sectors. We used the inputs in the heteroscedasticity model in order to correct for potential size effects. The heteroscedasticity basically shows if a larger factor endowments has an impact efficiency level. A positive (*negative*) coefficient therefore indicates smaller (*larger*) σ_u, i.e. the respective firms is less (*more*) efficient.

The effect of **labour** is different among sectors: A higher labour-intensity leads to lower efficiency levels for the meat, grain & mill and bakery sector, with the larges impact in the grain & mill sector. The impact of high labour intensity is positive in the dairy sector. Overall, the parameter-estimates are rather week, which is due to the scaling in 1,000 $ pesos/person and year. Taking into account this problem,

A larger factor intensity for **raw-materials** leads to a higher efficiency levels in all sectors. Also the **operation costs** is potentially the efficiency in the dairy and bakery sector. The same holds for a high **capital** intensity for three of five sectors.

The parameter estimates for $\rho_5 - \rho_7$ also show interesting impacts on efficiency: The level of the **wages per person** is higher in firms, that are more efficient. This also coincides with the results of the variable **non-production labour**, which describes the share of working units not working in the production process. This variables can be interpreted as an indicator for the management capacity in a firm. The results show, that a large management capacity increases the efficiency in the dairy and grain & mill sector. Both results are intuitive, whereas the results for the fruits & vegetable sector is rather surprising: A high management capacity leads to a lower efficiency in the fruit & vegetables sector. **Exporting firms** achieve a higher efficiency level in the grain & mill and the bakery sector, in the other sectors there is no difference between exporters and non-exporters. The **amount of paid subsidies** has a positive in the meat and bakery sector, and a negative impact in the dairy sector.

The estimated results for technical efficiency and the meta-technology ratio is shown in Table 7:

Table 7: Estimated technical efficiency and meta-technology gap for the six agribusiness sectors in Chile

Agribusiness Sector	Technical efficiency (TE^G)	Meta-technology ratio (MTR)	Technical efficiency to the metafrontier TE*
Production and processing of meat	0.7554	0.6999	0.5290
Processing of fruit & vegetables	0.8256	0.5900	0.4956
Manufacture of dairy products	0.9780	0.5720	0.5545
Manufacture of grain & mill products	0.9850	0.6163	0.6070
Manufacture of bakery products	0.8799	0.9121	0.8021

Source: own calculation

The estimated results show, that the level of technical efficiency within the group-frontier very high: Especially the efficiency level of the dairy (0.98) and grain & mill sector (0.99) is very high, but also the other sector show high average efficiency levels.

This is different for the meta-technology gap, which is rather low for the fruit & vegetable and the dairy and the grain & mill sector. This shows, that the technology

5 Discussion and Conclusions

As already discussed in chapter 4, most of the sectors work with increasing returns to scale. The following table shows the share of firms in each sector, working with scale elasticities smaller than 1.0 (i.e. decreasing returns to scale):

Table 8: Share of firms with decreasing returns to scale (scale-elasticities (SE) < 1.0)

Indicator	Sector1	Sector3	Sector5	Sector6	Sector7	All sectors
Observations with SE < 1.0	8	13	34	33	1,270	1,358
Total observations	203	231	126	203	1,708	2,471
Share of observations with SE < 1.0	3.94 %	5.63 %	26.98 %	16.26 %	74.36 %	54.96 %

Source: own calculation

The tests and the average figures show, that especially bakery sector the larger part of the firms are working with increasing returns to scale. In the other sectors, most of the firms are working with decreasing returns to scale. Aggregating all sectors, we can find that almost half of the firms work with increasing or decreasing returns to scale.

The following figures show the distributions of the scale elasticities of the respective sectors:

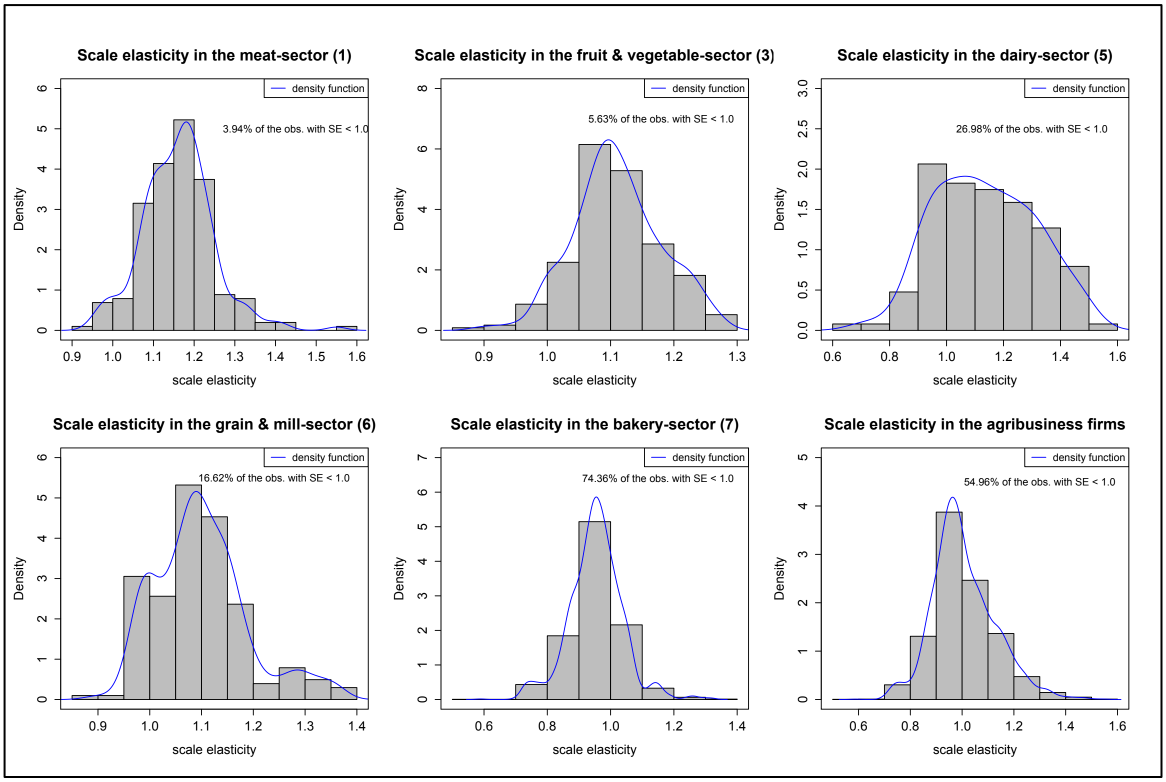

Figure 3: Scale elasticities in the Chilean agribusiness sectors,
Source: own calculations

The increasing returns to scale of e.g. 1.2 (as observed in the meat-processing sector) in the in general, mean that by doubling the firm size, we might observe an increase of 120 %, which will therefore decrease the average costs per unit. Increasing returns to scale can also interpreted as a indicator for a sector with small firms, which is also an incentive for a single firm to grow. This might be done by simply increasing firm size, but also by reorganization and fusions. Based on increasing returns to scale in four of five sectors, we still expect some structural change in the Chilean agribusiness sector (except for the bakery sector). This might a bit reflect the 'structural change' argument for liberal economies (PAVCNIK 2002).

The Chilean agribusiness is one of the exporting sectors. The actual model can show some impacts of stronger export-orientation. About 11.82 % of the firms are actually exporting, but the share of firms in each sector is different (Table 9):

Table 9: Share of exporting firms in the Chilean Agribusiness

	Meat sector	Fruit & vegetables	Dairy sector	Grain & mill	Bakery sector
Share of firms	21,18%	65,80%	15,08%	19,70%	2,22%
number of observations	43	152	19	40	38

Source: own calculation, based on the data-set

The share of exporting firms is highest in the fruit & vegetable sector, whereas the meat, dairy and grain & mill sector are showing rather small shares of exporting firms, and in the bakery sector there are just a few specialists exporting. The results of the heteroscedasticity model show only a higher technical efficiency of exporters in the grain & mill and the bakery sector. In the other three sectors, technical efficiency is not significantly higher in exporting firms.

One effect of export-orientation can be a higher level of technical efficiency, but another dimensions of coping with the international competition can be an increased level of technological change. We therefore calculated the average rate of technological change per year of exporting and non-exporting firms, which is presented in Figure 4:

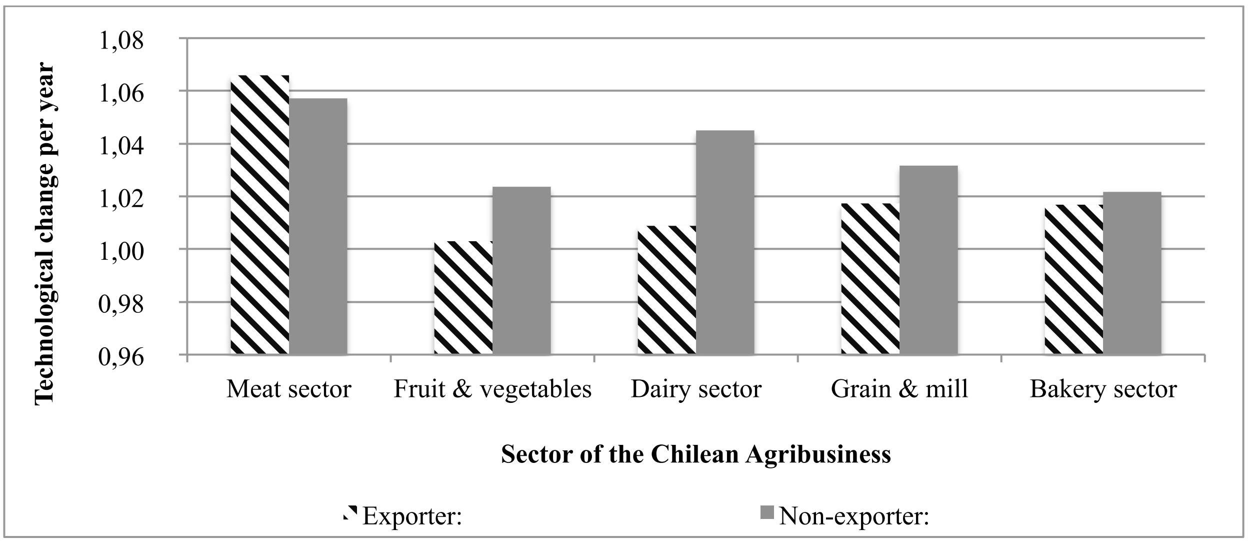

Figure 4: Average technological change per year of exporting and non-exporting firms in the sectors of the Chilean agribusiness
Source: own calculation

The result is once again heterogeneous: The meat sector achieves the highest rate of technological change among the sectors (also confirming the results in Table 5). In this sector, the exporting firms face a higher technological change, whereas in the other sectors, the non-exporting firms have higher rates of technological change.

Linking this with the technical efficiency, we might see exporting firms being either technical efficient with a lower rate of technological change, *or* with a higher technological change and a similar technical efficiency. Therefore, the 'learning by exporting'-argument seems to valid (RODRIK 1995, PAVCNIK 2002), since export orientation might in the long run lead to an increased technical efficiency. But by reaching an increased level of technical efficiency, the firms have to face higher rates of technological change, which can be confirmed by the presented model.

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