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Technical Efficiency in the Chilean Agribusiness Sector

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Abstract

The reform-process towards a higher world-market orientation has a long tradition in Chile, with all its strengths and weaknesses. The food processing industry is highly competitive on the world-market. The following paper investigates the technical efficiency of the Chilean food processing industry between 2001 and 2007. We used a data-set from the 5,941 of firms in food processing industry. The observations are taken of the 'Annual National Industrial Survey'. The method of stochastic frontier analysis is applied; the heteroscedasticity-model is used in order to analyze the determinants of technical efficiency. We included variables capturing different effects before and after the introduction of a liberalization policy in 2004. Raw materials and labor have to largest impact on the output. We could show that technical efficiency is different in the periods before and after 2004. The region with the highest level of efficiency is the metropolitan region around Santiago de Chile.

Keywords: Technical Efficiency, Food Processing Industry, Chile

JEL codes (if available)

1 INTRODUCTION

Reforms towards more trade liberalization reform were one of the most important aspects of trade policy in many developing countries between the 1970s and early 1990s, especially in Latin-American countries. These countries have embarked on programs of external economic liberalization through sometimes drastic strategies. It was hoped that, among other objectives, productivity increases in domestic industries would materialise. Chile was one the first countries which implemented this new trade policy, between 1974 and 1978. Because of that, Chile has developed an international strategy, part of its new development strategy based on complete liberalization and deregulation of the economy to foreign trade and the reordering of productive activity. Nowadays, Chile has free trade agreements with many countries and regions, such as the 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. There are ongoing negotiations on agreements with Malaysia and Thailand. As of 2003, Chile has improved market-access to economies all over the world, representing about 60 % of the world population and 85 % of world's GDP (SICE 2003).

The result of this new trade policy has been the transformation of the export sector, which increasingly acts as the engine of Chilean economic growth. During the last 15 years, Chilean exports have been increasing 11% in average per year (PRO CHILE 2010). However, there is a still clear dominance of the mining sector, specifically of copper exports. The manufacturing sector is the second biggest exporting sector, from which agro processed food is the dominant industry. Over the last 15 years, this industry has represented around 35 % of total manufacturing exports, and it seems to be in the future the new national development girder (CHILEALIMENTOS 2008).

The most important products involved in the processed food industry are: sea products (fish meal, salmon, shells and canned fish); fruits and vegetables (dehydrated fruits, tomato purée, frozen and canned fruits, juices, frozen and dehydrated vegetables); pork meat and others (BANCO CENTRAL DE CHILE 2010). In 2009, sea products, fruits and vegetables and pork meat represented 73 % of total exports from the processed food industry, i.e. around US$ 4.5 billion, from which US $ 1 billion corresponds to exports of processed fruit and vegetables, however, this amount was lower than the previous year when the exports of these products were almost US$ 2 billion. As result of this, Chile is today the top southern hemisphere exporter of frozen raspberries and strawberries, apple juice, canned peaches, dehydrated apples and tomato paste, as well as the 2nd most important southern hemisphere exporter of grape juice (CHILEALIMENTOS 2008).

In 2004, Chile established as its new agricultural and trade policy to be a 'Potencia Alimentaria' (Global and Agricultural Food power). This policy aims to consolidate and to strengthen Chile's agricultural and food exports in order to place Chile between the world's top ten food and agricultural products exporters by 2015 (ECHEVERRÍA and GOPINATH 2010). To achieve the long-term objective, it was created in 2007 the Chile Food Power Council. The aim of this public-private organization is to coordinate and to unify all food producers and exporters jointly with the public sector in the generation of a regulatory frame and an operative environment necessary to achieve the new Chilean goal (CHILEALIMENTOS 2008). According to the Chile Food Power Council, the result of Chile as Global and Agricultural Food power would be around 50.000 new jobs per year, plus additional effects on national income, demography and revitalization of rural areas, and national markets as well. Moreover, these effects would contribute to a more equilibrated social and geographical development (CONSEJO CHILE POTENCIA ALIMENTARIA 2006).

Public and private sector have noticed that the new development strategy for agro export sector must be based on sector's competitive advantages instead comparative advantages, since the first ones are more dynamics and unlimited, based on high price products, e.g. differentiated food by quality. The

main comparative advantages of Chile are its climate and its condition of 'Ecological Island'. Chile, together with California, South Africa, Australia and Europe, has the so-called Mediterranean climate (between latitude 30° and 35°, west of the continents), which has big thermal variation between day and night, and also a minimum incidence of plagues and pest. Moreover, this climate favours the accumulation of natural sugars in fruit and vegetables, giving them very distinguishing tastes, aromas and colours. The result of that is healthier and abundant food, for instance, berries with high levels of antioxidants (CHILEALIMENTOS, 2008). Furthermore, Chile is an 'Ecological Island' due to its geography. In the north is the Atacama Desert, the Los Andes mountain range on the east, the Pacific Ocean on the west and the Antarctic's eternal snow on the south. This peculiar geography provides Chile with extraordinary phytosanitary conditions due to its natural protection against exotic plagues and pests. Thus, Chilean food products are characterized by its highly safe and quality (CHILEALIMENTOS, 2008).

Nonetheless, the new strategy must be based on Chile's competitive advantages, for instance, Chile's internal stability, continuous signature of trade agreements, the strong public and private organizations that promote investments, and food safe and quality. Due to trade agreements, Chile has today favoured and privileged access to countries and blocks of countries, which represent around 4,000 million of people (85% of world's GDP). In addition, Chile has today one of the lower risk indexes in the region. By end 2009, and according to JP Morgan Bank information, Chile has an index of 132 points. However, food safe and quality is the most important competitive advantage of Chile. This is the result of the condition of 'ecological island' plus the high standards and controls that today has been implementing in the whole agro food industry. This interest in quality includes raw materials agricultural producers who receive training in hygiene and safety requirements. Likewise, the promotion of good agricultural practices (GAP), good manufacturing practices (GMP) and international certifications like Hazard Analysis and Critical Control Points (HACCP) (CHILEALIMENTOS, 2008).

To hold and improve these advantages, in 2005 Chilean government published the *Pro-Competitiveness Agenda for the period 2006-2015* developed by the Chilean food power council. The main objectives of this agenda are to remove all structural, institutional, commercial and technological, and any other obstacles that hinder to Chile be a Global and Agricultural food power. This agenda involves six lines of actions: to promote development strategies, to further competitive strategies for incorporation into international markets, to promote innovation and technological development in the agro food industry, to modernize sector's institutions, to promote the effect of food on health and nutrition, and finally, to disseminate the strategy 'Chile, global and agricultural food power' (CONSEJO CHILE POTENCIA ALIMENTARIA 2006).

Thus, this paper extends and updates previous research on the impact of trade liberalization on productivity in the Chilean manufacturing industry from the time before the introduction of the new policy (e.g. PAVCNIK 2002). Since Chile is nowadays a emerging economy, the application of such a policy and the impact of such policy might be also of interest for other transformation countries not only in Latinamerica, but also in Eastern Europe and in Asia. We use a firm-level data-set from 2001 to 2007 with survey data on the Chilean food industry. We combine this with secondary data on trade and geographical variables. Technical efficiency model is estimated based on stochastic production frontier approach, using the specification of BATTESE and COELLI (1995) and the heteroscedasticity-model of CAUDILL et al. (1995) in order to model the impact of various covariates on the level of technical effiency

2 THEORY AND LITERATURE SURVEY

2.1 *The impacts of trade liberalisation on efficiency*

Trade liberalization is the process when the restrictions to the free international movement of goods and services are abolished (DIJKSTRA 2000). Trade liberalization affects positively economic development and poverty reduction (BOUET 2008). 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 markups resulting from market power, higher investment, productivity growth, and also improved exploitation of economiesof scale , at least if appropriate domestic policies accompany the liberalization (Pavcnik 2002, OECD 2010).

- A comprehensive trade liberalization 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 liberalization 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.
- 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 liberalization 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 reemerge 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 liberalization on the technical efficiency of the Chilean food industry, and the potential determinants of this efficiency.

A number of studies in the existing literature analyses the nexus between trade liberalization 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) analyzed 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[1]. 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 1978–94 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 overall technical efficiency of the manufacturing sector has increased over time from 34.2 % (average) in 1978 to 68.2 % (average) in 1994[2], 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) analyzed the impact of trade liberalization 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,

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[1] 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 and MORRISON 2000: 318).

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

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 liberalization 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) analyze the impact of trade liberalization 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) 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 liberalization 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 and ROSSI (2003) investigated the effect of trade liberalization on productivity growth from the Brazilian manufacturing industries in the period 1985-1997. In order to estimate the effects of trade liberalization 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 liberalization (tariffs, effective rate of protection, and import ratio). Their results indicate that trade liberalization 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 liberalization 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) analyzed 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[3].

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

PAVCNIK (2002) investigated the effects of trade liberalization on plant productivity of Chilean manufacturing industries during the period 1979 to 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 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 liberalization 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.

3 METHODS AND DATA

Technical efficiency analysis can provide valuable for the creation of policies to improve the performance of a sector (LOVELL 1993), or to design programs in order to restructure inefficient firms (O'DONNELL *et al.* 2008). In this paper, we use a stochastic frontier analysis approach in order to model the production frontier and the determinants of efficiency in the Chilean food processing industry. The pioneers of stochastic frontier analysis (SFA) were AIGNER *et al.* (1977) and MEEUSEN and VAN DEN BROECK (1977) who suggested a stochastic frontier production function along the lines of equation (1):

$$q_{it} = f(x_{jit}, \beta_i) * exp\{w_{it}\} \qquad with \; w_{it} = v_{it} - u_{it} \qquad (1)$$

$$q_{it} = f(x_{jit}, \beta) * exp\{v_{it} - u_{it}\} \qquad (2)$$

Where output q_{it} is turnover of the firm and *j*=4 inputs are defined as:

x_1 = Total of labor (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, $time \; \epsilon \; \{1,2,...,7\}$.

The functional form $f(\cdot)$ is specified as a translog function. Thus, β represents the 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 component u_i is a systematic and *nonnegative* random variable associated with specific factors that are under firm's control. This error term is accounting for the inefficiency of the *i*-th firm (SCHMIDT and SICKLES 1984). Furthermore, u_i is assumed to be distributed independently from v_i. In order to estimate the frontier model by maximum likelihood, a specific distribution has to be assumed. The literature suggests, inter alia, a half-normal[4], exponential, truncated normal or a gamma distribu-

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

tion (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[5]. 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 and 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. Thus, the inefficiency term would vary according to the size of the firm; large firms might have more variation than small firms, associated to the input endowment (LAKNER and BRÜMMER 2008). Since the data vary substantially, it might make sense to use the heteroscedasticity-model specification proposed by WANG and SCHMIDT (2002) for a production frontier framework.

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

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).

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), which contains accounting information from firms located between 4th and 8th region, part of the manufacturing sector. However, there were firms that did not have complete information, for instance, no capital, no workers and no raw materials. These companies were deleted from the original panel data, thus the final used panel data set had 5,941 observations. The available variables are described in Table 6. In order to capture the policy change introduced in 2004, we included a Dummy (*PDum*) for the years 2001-2003, i.e. before the introduction of the policy. We also introduced interaction terms with the variable PDum into the model, in order to see the effects of certain subgroups in the period 2001-2003. The interpretation of the interaction-terms (e.g. *PDum* NPL*) is such, that we have to add the coefficients of NPL *and* PDum*NPL in order to get the total effect in the Period 2001-2003.

We derived some additional variables like OC (Operation Cost), which is the sum of the expenses for fuel, water and electricity. 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

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[5] 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.

indices. Energy was deflated by the '*Wholesale Price Index (IPM)*', the output (revenue from 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. The accounting variables used are summarized in Table 1:

Table 1: **Description of the Variables in the Dataset**

Variable		Unit	Min	Mean	Max	Std. Dev.
Turnover	Y	CL$ 1,000	1,731.80	1,135,200.0	3,230,800.0	2,191,200.0
Labor	X_1	Persons	1.00	41.6	2,825.0	85.6
Raw Materials	X_2	CL$ 1,000	93.00	645,370.0	11,624,000.0	1,398,300.0
Operation Costs	X_3	CL$ 1,000	3.61	42,295.0	1,002,200.0	83,207.0
Capital	X_4	CL$ 1,000	1.85	441,840.0	15,446,000.0	1,135,900.0

Source: Own Calculations

The variables considered as determinants for technical efficiency were used on the heteroscedasticity model (Table 2).

Table 2: **Variables used on the Heteroskedasticity Model**

Variable		Unit	Min.	Mean	Max.	Std. Dev.
a.) Firm specific Variables						
Dummy for the period before 2004	PDum	0/1	0	0.433	1	
Non-Production Labor	NPL	%	0	0.415	1	0.235
Non-Production Labor 2001-2003	PDum*NPL	0/1	0	0.177	1	
Percentage Export of the production	pexp	%	0	0.045	1	0.178
Percentage Export 2001-2003	PDum*pexp	0/1	0	0.017	1	
Firms receiving Subsidies	SUB	0/1	0	0.048	1	
Firms receiving Subsidies 2001-2003	PDum*SUB	0/1	0	0.022	1	
Firms in foreign Property	PROP	0/1	0	0.005	1	
b.) Region-Dummies						
Fourth Region	REG4	0/1	0	0.052	1	
Fifth Region	REG5	0/1	0	0.159	1	
Sixth Region	REG6	0/1	0	0.056	1	
Seventh Region	REG7	0/1	0	0.087	1	
Eight Region	REG8	0/1	0	0.166	1	
c.) Industry-Dummies						
Meat Industry	I1	0/1	0	0.055	1	
Meat Industry 2001-2003	PDum*I1	0/1	0	0.021	1	
Fish Industry	I2	0/1	0	0.048	1	
Fish Industry 2001-2003	PDum*I2	0/1	0	0.020	1	
Fruits & Vegetables Industry	I3	0/1	0	0.082	1	
Fruits & Vegetables Industry 2001-2003	PDum*I3	0/1	0	0.031	1	
Vegetable & animal oils & fats	I4	0/1	0	0.015	1	
Vegetable & animal oils & fats 2001-2003	PDum*I4	0/1	0	0.008	1	
Dairy Products	I5	0/1	0	0.043	1	
Dairy Products 2001-2003	PDum*I5	0/1	0	0.018	1	
Grain, starch & animal feeds	I6	0/1	0	0.067	1	
Grain, starch & animal feeds 2001-2003	PDum*I6	0/1	0	0.029	1	

Source: Own Calculations

The variable K (capital) comprises Land, vehicles, machinery and buildings. Likewise, the variable RMAT (raw materials) involves also the value of bought products to be processed, for instances, fruits, vegetables, milk. The dummy variable I_i is used to identify to which industry the firm belongs. Each industry is identified on the panel data base by its 'International Standard Industry Classification (ISIC)' Rev 3. Code provided by 'United Nations Statistical Division'. Since I_i is a dummy variable, to obtain firms from the bakery products industry (I_7), I_1 to I_6 must have value 0. The dummy variable REG_i is used to identify in which region the firm is located. The variables REG_4 to REG_8 identify regions 4th to 8th. If variables REG_4 to REG_8 have value 0, we obtain the information from the metropolitan region around Santiago de Chile (RM).

4   RESULTS AND DISCUSSION

The Table 3 shows the parameter estimates of the frontier model:

**Table 3:   Estimated Parameters of the Stochastic Frontier
for the Chilean Agro Processed Food Industry**

Parameter	Coefficient	t-value	Parameter	Coefficient	t-value
β_0	0.022	0.92	β_{22}	0.295	14.30
β_1 (Labor)	0.362	17.20	β_{33}	0.033	4.77
β_2 (Raw Materials)	0.461	24.50	β_{44}	0.010	2.96
β_3 (Operation Costs)	0.130	13.00	β_{tt}	0.019	1.83
β_4 (Capital)	0.059	6.77	β_{12}	- 0.206	- 10.60
β_t (trend)	- 0.022	- 1.05	β_{13}	- 0.003	- 0.29
$\beta_{2001-2003}$	0.023	1.04	β_{14}	0.018	1.88
$\beta_{2001-2003*t}$	0.091	2.44	β_{1t}	- 0.010	- 2.07
β_{I1}	0.185	4.68	β_{23}	- 0.039	- 4.42
β_{I2}	0.093	3.02	β_{24}	- 0.037	- 4.91
β_{I3}	0.068	2.22	β_{2t}	0.008	1.92
β_{I4}	0.205	3.24	β_{34}	0.013	3.18
β_{I5}	0.066	2.11	β_{3t}	0.006	2.24
β_{I6}	0.108	2.75	β_{4t}	- 0.006	- 3.27
β_{11}	0.141	6.68	$\ln \sigma_v$	- 1.210	- 44.10

<u>**Source**</u>: own calculation

Most of the estimated coefficients are significantly different from zero at the 5 % error level. The first order estimates β_j in a normalised translog model can be interpreted as elasticities at the point of normalisation, in our case at the sample mean. Raw materials shows the largest partial production elasticity (0.46), followed by labor (0.36), operation costs (0.13), and finally capital (0.06). E.g., if raw materials are increased by 1 per cent, turnover grows by 0.46 per cent. Under the assumption of profit maximization, the cost share for raw materials at the sample mean should be equal to output-elasticity. Therefore, raw materials should have the largest cost-share for the production of processed food.

The elasticity of labor (0.36) is higher than some other estimates reported in the literature (e.g., for the Bangladesh manufacturing sector in HOSAIN and KARUNARATNE (2004), or for the Chilean processed food industry in PAVCNIK (2002))[6], but on the other hand lower than the labor elasticity obtained by TYBOUT *et al.* (1990) for the Chilean processed food industry. This might indicate that our estimate lies within a reasonable range. The elasticity of capital (0.05) is similar to the elasticity of capital ob-

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[6] Agro/ processed food industry is part of the manufacturing sector.

tained by PAVCNIK (2002), who found a point estimate of 0.079 in the Chilean processed food industry. The sum of the first order coefficients of the inputs suggests the existence of slightly increasing returns to scale at the sample mean in the processed food sector of 1.013.

Before discussing the parameter estimates for the inefficiency model, we performed some tests on model quality, which are described in Table 4:

Table 4:   Results for different tests of model quality

Test		Null-Hypothesis	Test-Value	Critical Value	Result
H^1:	No inefficiency*	$\rho_j = 0, j = 0,1, \dots ,29$	856.99	44.41	Rejected
H^2:	CD-production function	$\beta_{tt} = \beta_{jj} = \beta_{jk} = 0$	1201.68	25.00	Rejected
H^3:	Linear homogeneity	$\sum \beta_j = 1;$ $\sum \beta_{jk} = 0 \ for \ j = 1,2,3,4$	28.53	11.07	Rejected
H^{3a}:	constant returns to scale at sample mean	$\sum \beta_j = 1$	2.31	*3.84*	Not rejected
H^4:	No heteroscedasticity	$\rho_j = 0, j = 1,2, \dots ,19$	994.66	43.77	rejected
H^5:	No influence of export	$\rho_8 = \rho_9 = 0$	7.95	5.99	rejected
H^6	No regional influence	$\rho_{13} = \rho_{14} = \rho_{15} = \rho_{16} = \rho_{17} = 0$	51.87	11.07	Rejected
H^7:	No industrial influence	$\rho_j = 0, j = 18,19, \dots ,29$	40.27	21.03	rejected

*: Critical Value according to KODDE and PALM (1986), the other critical values are taken from the Chi-sqared-distribution

Source: own calculations

H^1 tests for the absence of inefficiency, and was rejected. We also reject the more restrictive Cobb-Douglas as a functional form (H^2). The hypothesis of globally constant returns to scale (i.e., linear homogeneity, H^3) is rejected, but we were not able to reject constant returns to scale at the sample mean (H^{3a}). Omission of the heteroscedasticity-related variables, equivalent to the absence of determinants of technical efficiency (H^4) could be rejected, which confirms the necessity to integrate variables as drivers of efficiency differences. Finally, we tested if the export-variables could be omitted (H^5), and whether the industry (H^6) and regional (H^7) dummies could be omitted; all null hypotheses could be rejected.

The results indicate overall that the *translog functional form* (TL) is an adequate representation of the production technology function for the firms considered on the sample. Hence, we proceed with Table 5 which shows the results of the inefficiency model.

Table 5: **Estimated parameters for the inefficiency model**

Parameter		Coefficient	t-value
a.) Firm specific variables			
Constant	ρ_0	- 2.372	- 20.20
Labor	ρ_1	0.466	5.90
Raw Materials	ρ_2	- 0.856	- 15.40
Operation Costs	ρ_3	- 0.043	- 0.89
Capital	ρ_4	0.175	5.29
D 2001-2003	ρ_5	- 0.119	- 1.11
Non-Production Labor (NPL)	ρ_6	- 0.683	- 4.62
Non-Production Labor *D 2001-2003	ρ_7	0.356	1.96
Percentage Export of the production (pexp)	ρ_8	0.581	3.73
Percentage Export *D 2001-2003	ρ_9	- 0.534	- 2.12
Paid Subsidy (SUB)	ρ_{10}	- 0.263	- 2.24
Paid Subsidy *D 2001-2003	ρ_{11}	0.254	1.27
Firm in foreign Property (PROP)	ρ_{12}	0.687	3.43
b.) Regional variables			
Fourth Region	ρ_{13}	0.448	5.63
Fifth Region	ρ_{14}	0.300	5.12
Sixth Region	ρ_{15}	0.436	5.54
Seventh Region	ρ_{16}	0.437	5.98
Eight Region	ρ_{17}	0.329	5.78
c.) Industry specific variables			
Meat Industry (I_1)	ρ_{18}	- 0.351	-1.19
Meat Industry *D 2001-2003	ρ_{19}	0.385	1.01
Fish Industry (I_2)	ρ_{20}	0.419	4.12
Fish Industry * D 2001-2003	ρ_{21}	- 0.102	- 0.72
Fruits & Vegetables Industry (I_3)	ρ_{22}	0.200	1.43
Fruits & Vegetables Industry D* 2001-2003	ρ_{23}	0.249	1.52
Vegetable & animal oils & fats (I_4)	ρ_{24}	0.473	2.72
Vegetable & animal oils & fats D*2001-2003	ρ_{25}	- 0.153	- 0.74
Dairy Products (I_5)	ρ_{26}	0.511	3.56
Dairy Products D*2001-2003	ρ_{27}	0.088	0.58
Grain, starch & animal feeds (I_6)	ρ_{28}	- 0.167	- 0.55
Grain, starch & animal feeds D*2001-2003	ρ_{29}	- 0.090	- 0.30

Source: own calculation

The results for the inefficiency model show that most of the coefficients are statistically significant at the 5% level. Firms with a high endowment of *labor* (ρ_1) or *capital* (ρ_4) exhibit a lower technical efficiency, whereas efficiency improves with higher use of *raw materials*.

Foreign firms (ρ_{12}) have lower technical efficiency levels than firms with national or mixed capitals (national and foreign). From theory, we expect from theory that foreign direct investments to should lead to an improved efficiency due to technology transfer from outside. This was not the case with the food-industry firms, who received foreign investments.

The results indicates that *geographical effect* (REG$_{4-8}$)is relevant on the technical efficiency, since firms located near to the capital Santiago presented higher level of efficiency than firms located in the other regions. This could be justified by lower transactions and transport cost, better infrastructure, bigger pool of labor and outsourcing services. The modeling results indicate, clearly, that the capital region ('Region Metropolitana (RM)', the region of Santiago de Chile, which was used as reference group) is the region with the most efficient firms. This result proves to be constant over time (See Figure 1). The group of firms from RM account for 65 % of all observations. Obviously, the proximity to the biggest regional market in Chile, the capital Santiago de Chile proves to be more important. This region is one the big agglomerations in Latinamerica and with 40% of the population (6.06 Mio inhabitants) and with the respective market and demand. 41.5 % of the gross domestic product is produced in this region. The high level of competition obviously leads to a higher technical efficiency.
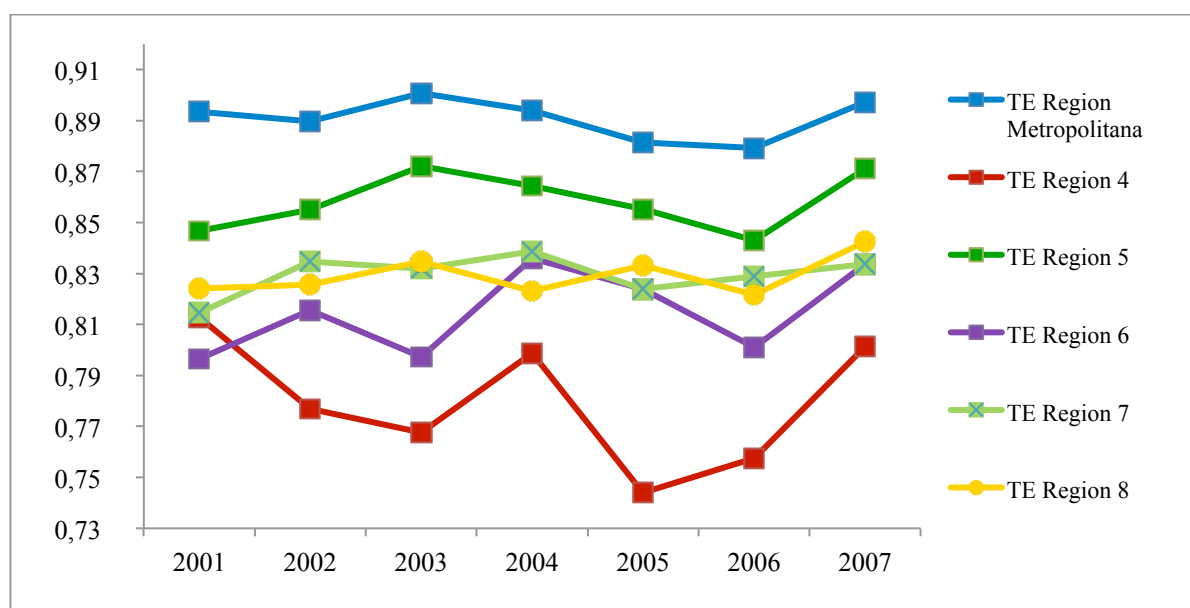

Figure 1:   **Efficiency scores of the food-processing industries in different regions in Chile**
Source: own calculation.

The results confirm the theory of agglomeration and urbanization theory (KRUGMAN 1991, MAIER and TÖDTLING 1995), since obviously the concentration of inhabitants and industry in the region of Santiago de Chile seems to attract efficient firms.

The modeled *policy change* shows that the determinants of technical efficiency are different in the two investigated periods before and after 2004:

- *Non-production labor to total labor (NPL)* variable appears to have a positive effect on technical efficiency throughout the full period, but this effect is substantially lower before 2004 than in the period after 2004. This increase over time could be explained with general higher competitive pressures which accompany the deepened liberalization after 2004. Furthermore, the role of non-production labor, i.e., managers, engineers and R&D personnel, has likely increased with increasing liberalization, since a larger share of this type of labor facilitates better utilization of the existing technological possibilities as well as the adoption of new technologies. In addition, since the Chilean Peso became stronger during the observed period (see Figure 5), we might also conclude that in a difficult export situation with a strong Peso, the management skills in a firm become more important in terms of technical efficiency.

- Before the introduction of the policy change in 2004, the *amount of subsidies (SUB)* virtually[7] did not have any impact on technical efficiency. After the change, firms with a high amount of subsidies performed better than firms without. One possible explanation for this finding is that firms receiving subsidies have better liquidity and improved access to capital markets, and therefore more flexibility in investments. Besides the effect in financial terms, it might be the case, that efficient firms were more successful in the rent seeking process. Therefore the described effect of trade liberalization (see page 4) might be outbalanced.

- The effect of the variable *share of exports (pexp)* is again virtually negligible before 2004, whereas the exporting firms showed a lower technical efficiency after 2004. In this case, we have to take into account the impact of the strong Peso, which makes the exports more difficult, and might lead to a loss in traditional export markets. On the other hand, the effect for import-competing firms (who would face sharper competition on Chilean markets caused by the stronger Peso) might have been partially shielded from foreign completion through high trade costs and imperfect market integration.

- With respect to the different performance of the investigated *sectors of the food industries* (variables I_{1-7}), we found not a single statistically significant estimate for the interaction terms between the industry dummies and the dummy for the first period. Hence, there is no clearly discernible pattern by industries for the difference between periods. The only significant estimates for the second period are found for the meat industry (I_1), the fruits and vegetables industry (I_3), and for the dairy industry (I_5). All these have lower levels of technical efficiency than the mill and flour industry (reference group). It seems, as if policy changes and the macroeconomic situation after 2004 were affecting these three industries in a negative way.

- We could not identify a consistent pattern of any change in *technical efficiency* over time (beyond those patterns explained by changes in the other determinants of technical efficiency. The following Figure 2 shows the development of the efficiency scores from 2001-2007:
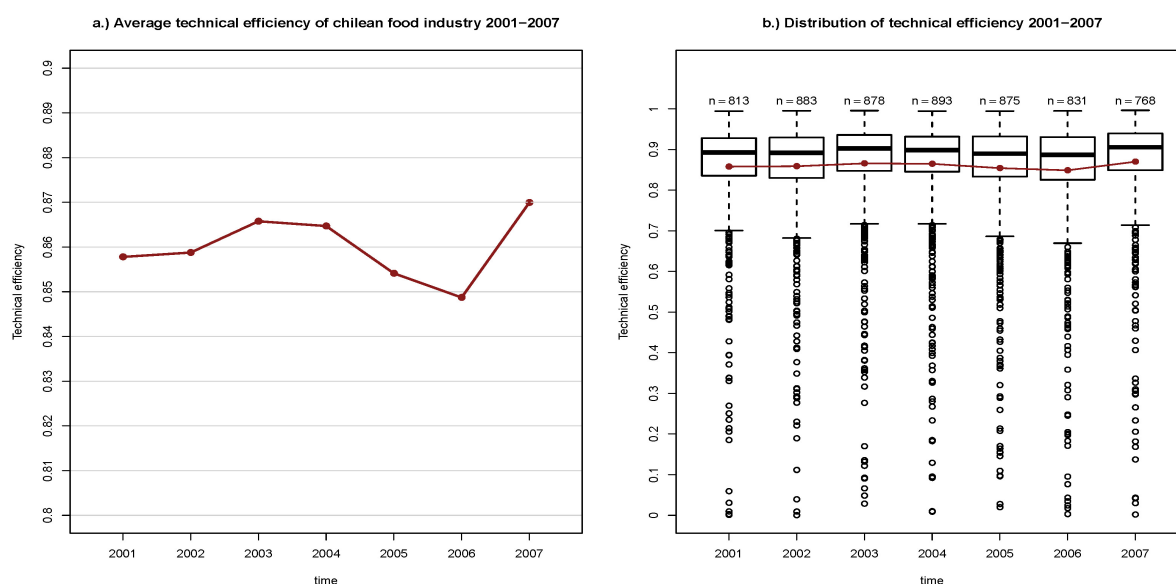

Figure 2: **Development of technical efficiency in the Chilean food industry 2001-2007**
Source: own calculation

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[7] Adding the estimated coefficients oft he interaction term (SUB*PDum) and the variable (SUB).

Looking at the variable *PEXP*, we can conclude, that a higher share of exports does not lead to a higher efficiency. This result seems to be not in line with the theoretical expectations, that exporting firms have a higher technical efficiency and are therefore able to compete on the world market. The results of this modeling approach must be treated carefully, since the group of exporting firms consists only of 512 observations, which is less than 10% of the sample. The distribution of the technical efficiency scores in both groups is similar and a lot of these firms are highly efficient. Therefore the results might be partly driven by distributional problems (See Figure 3):
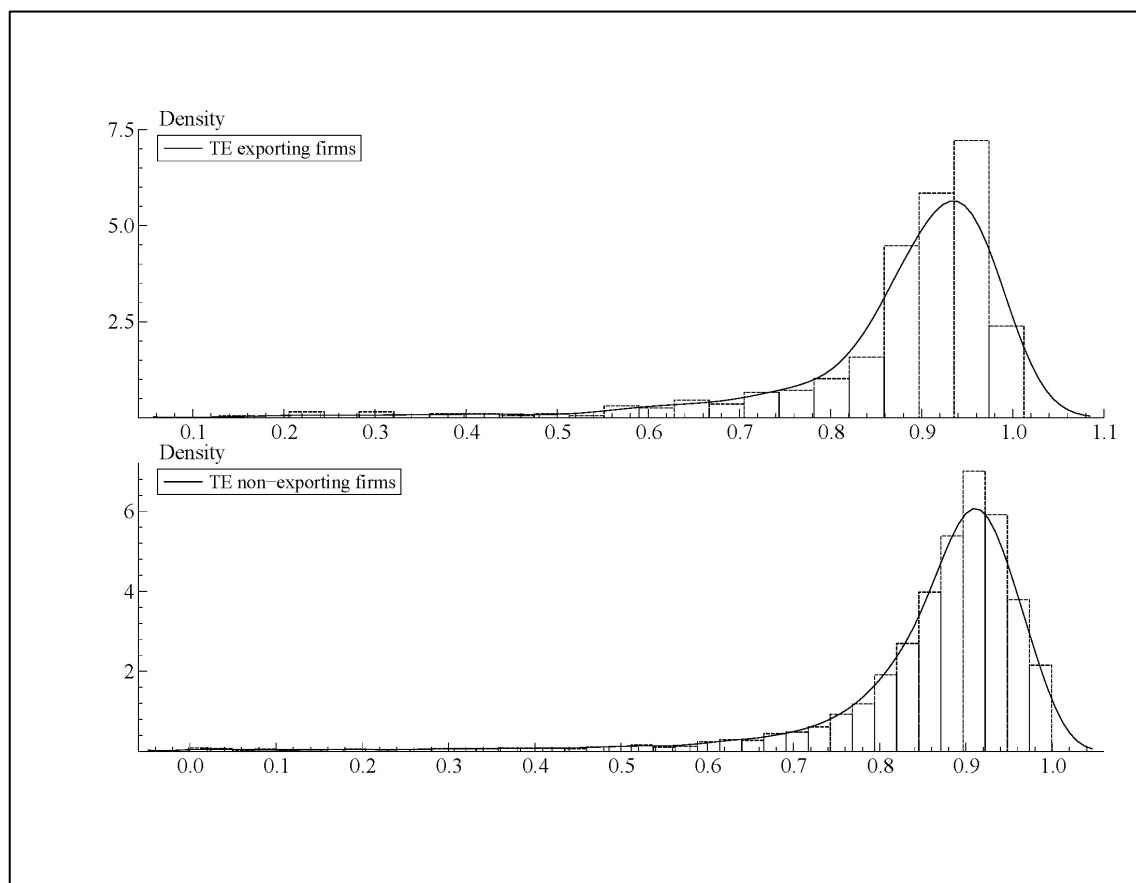

Figure 3: **Distribution of the TE-scores of exporting and non-exporting firms in the sample**
Source: own calculation

5 CONCLUSIONS

The present study has analyzed an unbalanced panel data set to estimate the level of technical efficiency in the Chilean agro-food processing industry. The main objective of the study was to investigate the effects of trade liberalization on the technical efficiency levels of this industry between 2001 and 2007, and to identify the determinants of the technical efficiency for the same industry.

We conclude that there are two effects, which limit the presented model-approach and the interpretation of results:

1. The introduced policy is more focused on other parts of the supply chain, i.e. the primary production. Parts of the policy provide aid for small-holder producer in agriculture and investment aid. The liberalization of Chile's agribusiness sector should be seen as a continuous process. In Figure 4 we can see the average paid subsidies in the years 2001-2007.
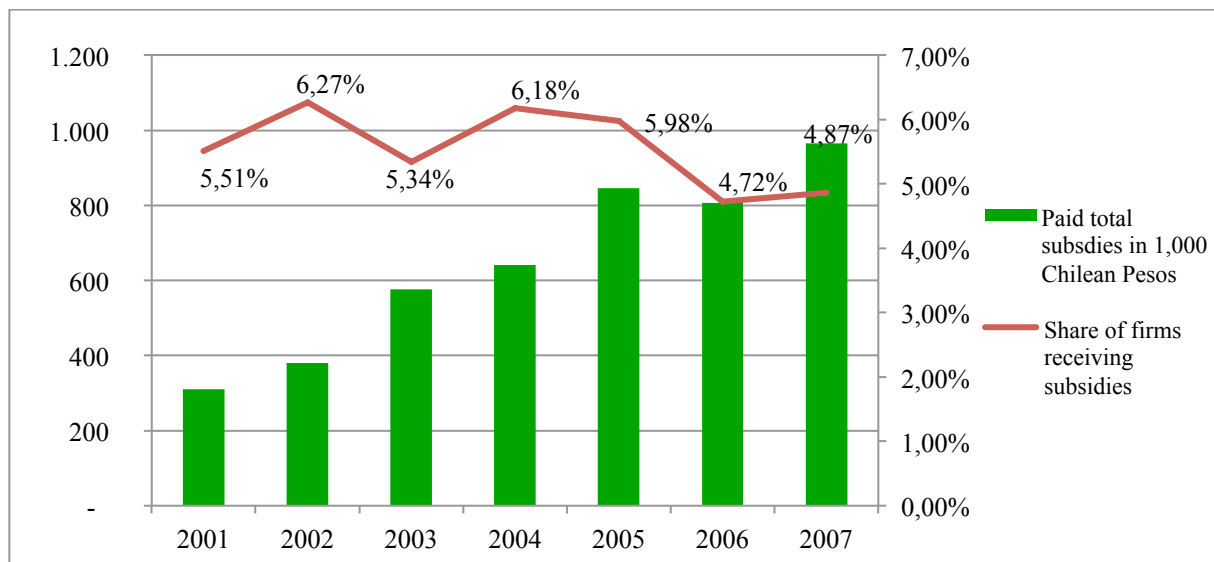
Figure 4: **Average paid subsidies to firms of the Chilean food sector 2001-2007 in 1,000 Chilean Pesos**
Source: own calculation

Figure 4 shows a continuous process of increasing export subsidies. On the other hand, the share of firms receiving subsidies is constantly around 5%.

2. The impact of the introduced policy changes might be affected by the increase of international commodity prices and the exchange rate of the Chilean Peso. In Figure 5 we can see the Exchange-rate of the Dollar, and specifically in the years 2005 and 2006 the Peso was very strong. This strong Chilean Peso was (driven by other macroeconomic factors) leads to a lower prices for exported goods due to currency effects. Since the output is measured by revenue of the firms, these currency-effects might affect the technical efficiency of exporting firms. This inclusion of this effect is subject to future research.
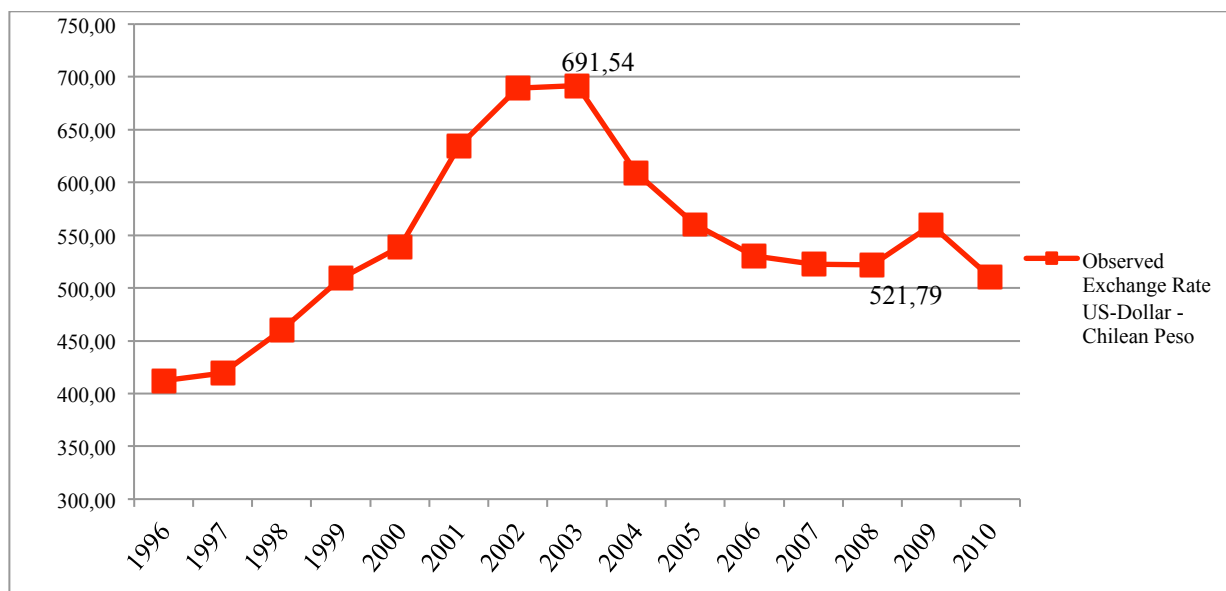

Figure 5: **Observed Dollar Price CL $, 1996 – 2010**
Source: Central Bank of Chile statistics 2011

In the case of a small open economy such as Chile, the effect of trade liberalization on technical efficiency might be affected strongly by the effects of exchange rate changes. In particular, given that Chile's main exports are raw materials (e.g., copper), there might be a Dutch Disease effect which puts additional adjustment pressure on the structure of Chilean labor-intensive sectors. Besides this effect,

it seems obvious that the policy change in Chile was undertaken in a continuous process; therefore the effects can only be seen in the mid-term perspective.

Finally the results show that modelling the different industries by a single common production function might not be fully sufficient in order to adequately capture the different technologies in the respective industries. The meat industry might have a different production function than the milling industry. On the other hand, the driving force behind all these industries is the market for agricultural commodities. Therefore it seems reasonable to opt for a modelling approach, which accounts for technology differences but maintains a common framework for inter-industry comparisons. The 'meta-frontier' approach, which summarizes different technologies in one enveloping function based on technology-specific frontiers, is promising avenue for further research (see BATTESE *et al.* 2004 or DONNELL *et al.* 2008).

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APPENDIX:

Table 6: **Variables in the data-set collected in Annual National Industrial Survey (ENIA)**

Variable	Description
Y	Firm's turnover (thousand of pesos)
L	Total of labor (number of persons)
RMAT	Raw materials (thousand of pesos)
COM	Consumed combustible (thousand of pesos)
WAT	Consumed water (thousand of pesos)
ELECT	Consumed electricity (thousand of pesos)
K	Fixed Capital of the firm, capital stock at end of each year (thousand of pesos)
NPL	Non-production labor (percentage of non-production labor to total labor)
PROP	1 if the company has 100% of foreign capital, 0 otherwise
EXPORT	Exported production (thousand of pesos)
PEXP	Percentage exported production on the total revenue of firm i
REG_i	Region where the firm is located (i=4,5,6,7,8)
I_i	Kind of industry (i=1,2,3,4,5,6)
SUB	1 if the firm receive any kind of subsidy, 0 otherwise
Time	Represent the period between 2001 and 2007 thus time goes from 1 to 7
PDum	Dummy for the period prior the policy introduction of 2004

Source: own elaboration