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Resumen

La economía chilena experimentó un profundo cambio estructural a mediados de los setenta, debido a varias reformas económicas. De todas ellas la más profunda fue la liberalización del comercio internacional. Este proceso causó una serie de quiebras en la industria manufacturera y una reducción en la participación de este sector en el PIB, lo cual ha llevado a algunos autores a pensar que Chile se ha convertido en un país menos industrializados. Este artículo describe los principales cambios de política que son relevantes para entender la evolución de la productividad usando datos a nivel de plantas. Nuestros resultados desafían la hipótesis de que la liberalización comercial ahogó al sector manufacturero y que habría empujado a la economía hacia la exportación de materias primas. También, nuestros resultados muestran que la industria chilena, después de las reformas económicas, llego a ser más eficiente y competitiva.

Abstract

The Chilean economy underwent a deep structural change in the mid-seventies, through several economic reforms. Among these, the most impressive one was trade liberalization. This process caused a string of bankruptcies in the manufacturing industry and a reduction in the share of this sector in GDP, which some authors have used to imply that Chile has become a less industrialized economy. This paper describes the main policy changes that are relevant to understand the evolution of the manufacturing industry in Chile after the reforms, and analyzes the evolution of productivity using plant-level data. Our findings challenge the hypothesis that trade liberalization stifled the manufacturing sector and pushed the economy toward exporting raw materials. Also, our results show that the Chilean industry, after these economic reforms, became more efficient and competitive.

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1. Introduction and motivation

The big changes in both political spectrum and economic conception experienced by the Chilean economy in the seventies and eighties have attracted the interest of both economists and political scientists. From the purely economic point of view, after the Great Depression of the thirties, and following the strategy of most countries in the world, the Chilean economy became less outward oriented implementing several barriers to international trade. This gathered even more strength after Prebich's ideas about economic development and international trade in the fifties.

These policies reached their peak in the early seventies under the government of President Salvador Allende, who was supported by a coalition of left political parties. Under his administration from 1970 to 1973, not only did the economy become almost closed, but also the very idea of resource allocation by the market was derided. Most private firms were either nationalized or driven out of business, through price and interest rate controls (see Edwards and Edwards, 1987).

After the military coup in 1973, the new team reversed several of these measures in almost six years, introducing what may be the largest structural change in the Chilean economic history. The actions taken by the military administration were severely criticized by politicians and economists that opposed the new government. Criticism was based on the idea that the new model of development would push the economy toward becoming a primary product exporter, thus very vulnerable to international market fluctuations. Also, it was argued that the new policies would undermine the industrial sector and therefore the Chilean economy would never be able to join the group of more developed countries.

Regarding the Chilean industry, several articles[1] have explored the impact of trade liberalization on productivity growth, but methodological problems leave open the question of whether outward orientation has a positive impact on productivity. The theoretical trade literature provides conflicting predictions about the impact of liberalization on productivity. Both groups, inward and outward oriented policy advocates, expected higher rates of productivity growth in manufacturing as a result of their respective opposite policies (Pack, 1988). Much of the empirical evidence has focused on this topic for developing countries, but the evidence is not yet conclusive.[2]

The purpose of this paper is to present a different look at the large structural changes to the Chilean economy in the 70s and their effects on the manufacturing sector, from a long-term perspective. The hypothesis is that Chile had comparative advantages in natural resource intensive commodities and, as trade liberalization came forward, a large shift in the resources' allocation should take place. In this process, the share of manufacturing industry on total GDP would decrease and therefore Chile would become less industrialized. Some authors gave a negative connotation to this process since industrialization was used as signal of development.[3] Our approach is to analyze how the manufacturing industry performed during and after the reforms, and what were the losses and gains of the process.

[1] See Corbo and Sánchez (1985), Tybout, De Melo, and Corbo (1991), Agacino, Rivas, and Roman (1991), Marshall (1992), Fuentes (1995) and Pavcnik (2002).
[2] For an excelent survey of theoretical arguments and empirical evidence, see Rodrick (1995).
[3] See, for example, Ffrench-Davis and Saez (1995).

Is this a story of just losses? Do we have a weak industrial sector? Today we have a long-run perspective that can provide additional insight on this topic.

The methodology used is the following. First, a number of articles are reviewed that address the relationship between trade and productivity in the Chilean manufacturing industry. Second, we provide our own estimates of technological progress and technical efficiency indices. The difference with previous studies is that now we can assess the effect of trade liberalization on both variables over a longer time span. Third, we analyze changes in productivity over time and across sectors, and its link to trade liberalization.

Our main findings are that 1) Chile did not become a less industrialized economy, using the share of manufacturing industry value added over GDP and the share of exported manufactured products over total exports as measures of industrialization. 2) However, accordingly with the comparative advantage hypothesis, the composition of the manufacturing industry changed in favor of sectors more intensive in natural resources. 3) The Chilean industrial sector showed higher overall efficiency in 1994 compared with 1979, when the trade reform was completed. Combining this finding with the increase in the share of manufactured over total exports, we can conclude that this sector has become a more competitive one.

The paper continues as follows. Next section describes in more detail the structural changes concerning the trade reform in the Chilean economy during the 70s and 80s. The trade reform and the exchange rate policy of the late seventies had the greatest impact on the manufacturing sector. Using this as background, the third section looks at the figures of the manufacturing industry to have an idea of the magnitude of these changes. The fourth section offers a brief review of the empirical studies concerning the relationship between trade liberalization and manufacturing industry performance. Then, the fifth section, using plant-level data, estimates productivity changes in the post trade liberalization period. The paper ends with concluding remarks.

2. The trade policies of the seventies and eighties

The reforms of the seventies and eighties have been the object of numerous studies. Among the most comprehensive ones it is worth singling out Edwards and Edwards (1987) and the book edited by Bosworth, Dornbusch and Labán (1993). These reforms were deep and drastic. They meant a big shift in the development strategy that had prevailed in Chile since the 1940s.

Chile did not escape the ideas of inward oriented development that were common around the world after the Great Depression.[4] This inward oriented strategy was accompanied by proactive industrial policies and an increasing share of the Government in the economy, through the creation of state owned enterprises. The manufacturing industry was protected with high tariffs, non-tariff barriers and multiple exchange rates. All this happened between 1940 and 1970, with three failed attempts to reverse this trend during the 1956-58 1959-1961 and 1965-1970 periods. In the late 60s, the Chilean government introduced some reforms to the external sector that simplified the international trade regime (Berhman, 1976), reduced some of the import substitution effect, but according to Cortés, Butelman and Videla (1981) protectionism still survived after the reform.

In 1970, a newly elected government deepened the inward oriented policy and government intervention. Before the military coup of 1973, the Chilean economy could be characterized as a closed economy (high barriers to trade and capital movements)[5] with strong government intervention, price and interest rate controls, a large fiscal deficit and high inflation. Moreover, during the 1970-1973 period the Government expropriated an important number of private companies (Edwards and Edwards, 1987).

Among the trade protection measures, it is worth mentioning that in 1973 there was a high dispersion in import tariffs, ranging from 0% to 750%, with an average nominal tariff equal to 105% and a mode of 90%. Half the tariffs were above 80% and only 4% of the tariff positions had rates below 25% (Corbo, 1985). There was also import prohibition for 187 tariff positions, a 90-day import deposit requirement of 10,000% over the CIF value, plus some other discretionary actions that could be taken by the Central Bank.

After the military coup, Chile moved toward a market economy. The most relevant policies were price liberalization (including interest rates), the abrupt reduction of the fiscal deficit through reduced government spending and the privatization of state-owned enterprises.

[4] It is worth noticing that Chile was one of the economies that suffered the most during the Great Depression. In fact, per capita GDP fell by 47% and exports by 79% (see Lüders, 1988). This event triggered the inward oriented type of policies.
[5] Chile was one of the countries with the highest degree of trade distortions in the world. See Edwards (1994) and the references therein.

Among the reforms of the first ten years of the military administration it is worth mentioning trade and financial liberalization, and the new pension fund system that is the heart of the Chilean capital market.

Perhaps the deepest reform conducted over that period was trade liberalization. In less than six years almost all the trade restrictions were lifted.[6] By June 1979 all the non-tariff barriers (NTBs) were eliminated and an across the board 10% tariff was imposed. The following table shows the evolution of the effective rate of protection (ERP) during that period.

[6] See Cauas and De la Cuadra (1981) for a detailed description of the process of trade liberalization.

Table 2.1. Effective Rate of Protection 1974-1979

Sectors	1974	1975	1976	1977	1978	1979
Food	161	105	48	28	16	12
Beverages	203	119	47	32	19	13
Tobacco	114	68	29	19	11	11
Textile	239	138	74	49	28	14
Apparel and Footwear	264	164	71	48	27	14
Leather	181	98	46	36	21	13
Wood Products	157	93	45	28	16	15
Furniture, except Metal	95	58	28	17	11	11
Paper and Pulp	184	114	62	37	22	17
Printing	140	75	40	32	20	12
Chemical Products	80	53	45	24	16	13
Plastic	80	53	45	24	16	13
Petroleum and Coal	265	101	17	0	12	13
Glass, Pottery and Non Metallic Minerals	128	87	55	32	20	14
Basic Metals	127	86	64	38	25	17
Metallic Products	147	101	77	52	27	15
Electrical and Non Electrical Machinery	96	72	58	35	19	13
Manufacturing Industry (Average ERP)	156.5	93.2	50.1	31.2	19.2	13.5
Agriculture	30	27	19	11	10	10
Mining	7	18	24	17	13	14
Non Tradable	-30	-19	-11	-7	-4	-3

Source: Aedo and Lagos (1984)

Two features are worth highlighting from table 2.1. The first one is the high ERP enjoyed by the manufacturing industry in 1974, compared to other sectors in the economy. Thus, trade liberalization introduced a big change in relative prices in favor of agriculture, mining and non-tradable goods. The second important characteristic concerns the high ERP dispersion across the manufacturing sectors at the beginning of the period and the almost no differences at the end of it. These big changes in relative prices affected the allocation of resources within the economy.

In addition to the relative price shifts described above, the exchange rate policy played a significant role in resource allocation. In an effort to control inflation, in June 1979 the economic authority decided to peg the exchange rate, which coincided with the completion of the first trade liberalization process. However the low speed of convergence between domestic and international inflation rates (because of wage indexation) and capital inflows (as a result of the external financial liberalization) the peso experienced a large real appreciation.[7] This, combined with wage indexation based on past inflation, introduces an even larger loss in competitiveness to the tradable sector. Corbo and Sánchez (1985) called this episode a "second and more intensive trade liberalization."

External and internal factors induced in 1982 the deepest recession since the Great Depression. Among them, one can mention the lack of external funding and the low world economic growth rates. Domestically, wage rigidities, that hindered the necessary adjustments in the labor market to realign the real exchange rate, plus a weak banking system, further propagated the external shocks on the economy. At last the Government decided to devaluate the peso in 1982, after two years of fixed exchange rate. After several devaluations and a short episode of flexible exchange rate, Chile adopted a crawling peg system.

Given the situation at the time, the Government decided to modify the trade policy by increasing tariffs from 10% to 20% in 1983 and to 35% in 1984 (always across the board). Additional tariffs were imposed for electronic goods and automobiles, and a price band for certain crops (i.e. wheat, sugar and oil seed).

[7] See Edwards (1989) and Le Fort (1988) for empirical evidence on the real exchange's rate behavior over that period.

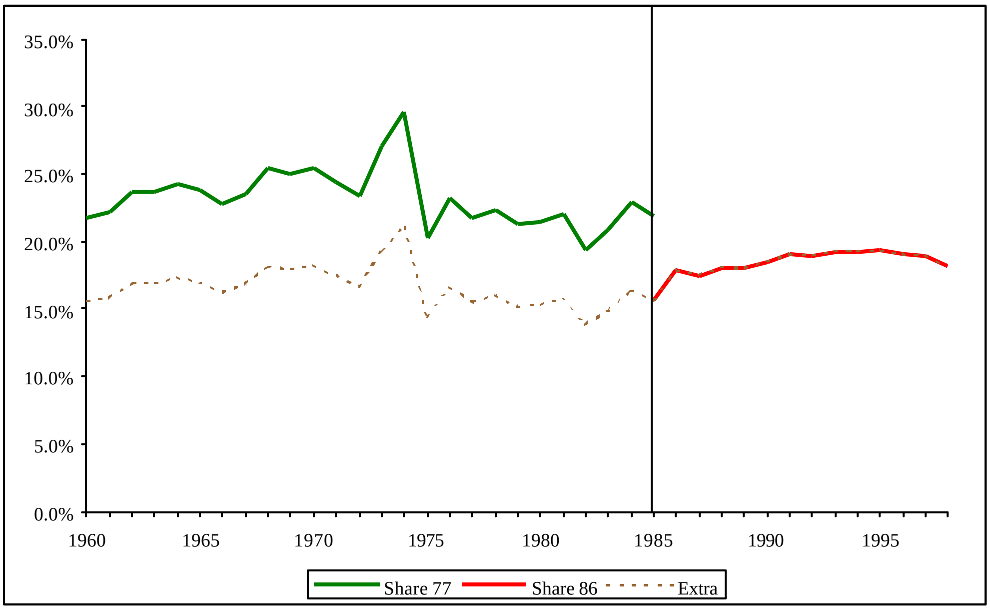
In 1985, a second trade liberalization process was implemented. Tariffs were reduced from 35% to 20% in 1986 and to 15% in 1988. In 1991 a newly elected Government reduced tariffs further to 11% and established free trade agreements with several countries, whereby tariff differences were again introduced according to origin and type of good, but now at a much lower level.

3. The history of the manufacturing industry in numbers

As stated above, the large changes in relative prices introduced important shifts in resource allocation across sectors. The share of the manufacturing industry in GDP diminished, but less dramatically than many authors has argued.[8] The base year of the national accounts was changed in 1986, making it difficult to compare figures before and after that year, even in current prices. For instance, in 1985 (a year that is common to both national accounts systems) there is a difference of 5.2 percentage points between the 1977 series and the 1986 one. Figure 3.1 shows the shares of manufacturing industry over GDP using the national accounts based on 1977 (Share 77) and 1986 prices (Share 86). To construct a more consistent series of manufacturing valued added over GDP we extrapolated the Share 86 series using the nominal series of manufacturing value added and GDP from the national accounts system based on 1977.[9] The new series appears in Figure 3.1 as a dashed line.

[8] For instance, Ffrench-Davis and Saez (1995) mentioned that the share of the manufacturing industry in 1989 was way below the 1960-1969 average. This conclusion cannot be drawn from figure 3.1, below.
[9] We did the same exercise using the 1986 nominal series to extrapolate the Share 77, and the conclusion does not change. What changes is the level of the share but in all periods. We agree that this is not a first best methodology, but it is more accurate than compared shares in nominal terms under different national accounts systems.

Figure 3.1 Share of the manufacturing sector in GDP

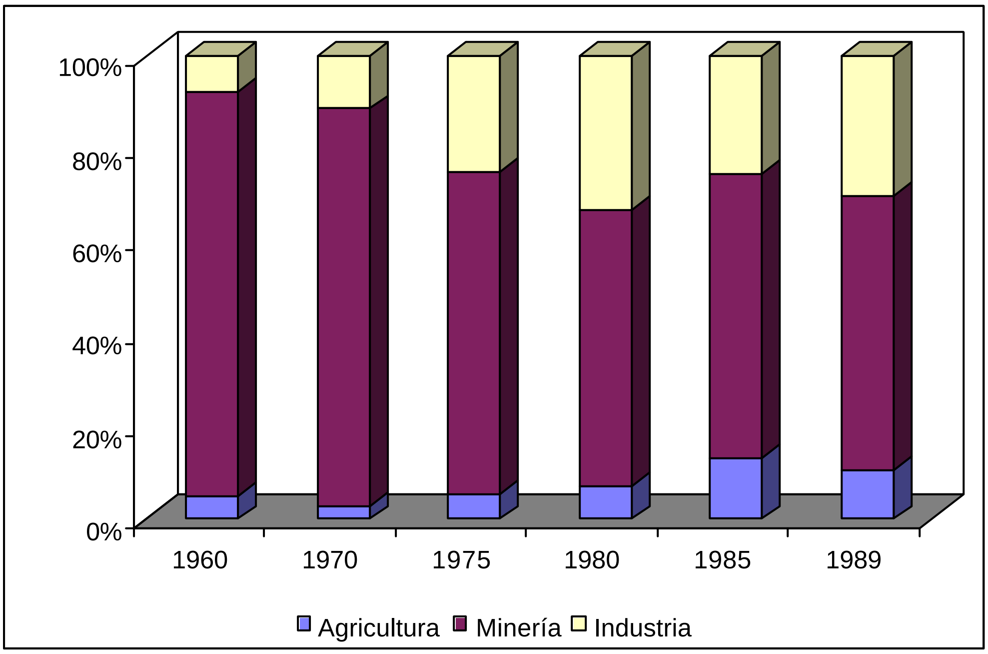


Source: Central Bank of Chile; authors' calculations

In the sixties, the average share was equal to 17.0%, while in the 1975-1985 period the figure was only 15.4%. After 1987, the manufacturing sector increased very fast, mainly due to a higher real exchange rate. Although the real exchange rate peaked in 1990, and declined after that, the manufacturing sector still grew faster than the rest of the economy. As section 5 of the paper will show, this growth was driven mainly by productivity increases. Moreover, the 1986-1999 average is similar to the sixties', but with a more competitive industry and a different composition of sectors, as will be seen below.

In exports, the manufacturing sector also shows an interesting behavior. In 1970, Chile was mainly a copper exporter, and to this day it is by far its most important exported product. But the weight of copper in total exports has decreased, while manufacturing exports have increased as a share of total exports. By the late nineties, the share of manufacturing in total exports was almost three times as high as in 1970, and almost four times with respect to 1960 (see Figure 3.2). It is important to consider that between 1960 and 1989 total exports went from 490 million to 8.19 billion US dollars.

Figure 3.2 Exports by sectors over total exports 1960-1989



Unfortunately, because of an export classification problem, the figures after 1990 are not strictly comparable with those in the figure above. That comparison is shown in a different graph below. As can be seen, the significance of the manufacturing industry increases even further, outperforming the mining sector in 1999.

In light of the evidence presented herein, the so-called deindustrialization process is doubtful, to say the least. However, there are still arguments in favor of the deindustrialization process, based on the idea that the manufacturing industry is intensive in natural resources. But, considering the standard Heckscher-Ohlin-Vaneck model of international trade, a country that opens to trade would tend to specialize in those goods that use the most abundant factor more intensively, which is the case of Chile with natural resources.

Nevertheless, it is important to point out that the evidence concerning natural resource abundance, as a barrier for growth is not over yet. In a seminal paper, Sachs and Warner (1995) argue that economies with abundance of natural resources grow slower than the rest of the world. However, Leite and Weidmann (1999) and Lederman and Maloney (2002) have challenged this idea using different types of arguments. The former paper argues that natural resources may be a good measure of the level of corruption; in general, economies that are rich in natural resources tend to have property right problems and large incentives for corruption. The latter paper criticizes the econometric methodology used by Sachs and Warner; using GMM that deals with unobserved heterogeneity and endogenous explanatory variables, Lederman and Maloney show that there is no such thing as a negative relation between natural resource abundance and growth.

Figure 3.3 Exports by sectors over total exports 1990-1999

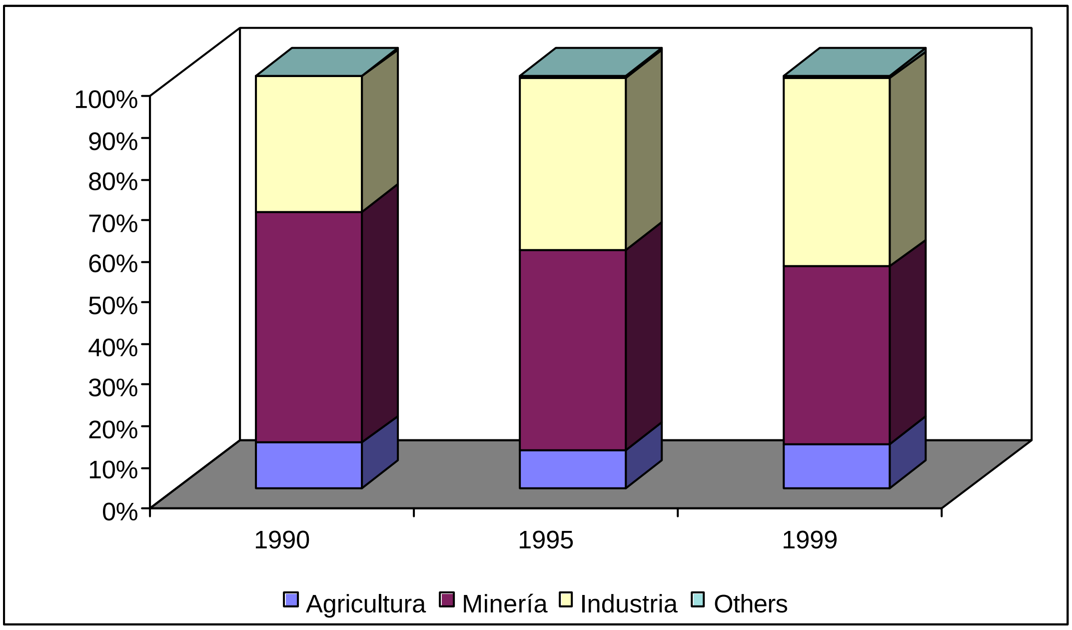


Table 3.2 below shows the value-added distribution across sectors of the manufacturing industry. It clearly shows how sectors more closely associated to natural resources and labor intensive increase their importance, in terms of total value added, in the manufacturing industry. Conversely, those sectors more capital intensive account for one fourth of total value added, which is lower than their share in 1974. This evidence considers the important change in resource allocation after the trade reform. It is no surprise, however, considering that in 1972 Chile could be classified as relatively abundant in minerals, land and literate non professional workers, and relatively scarce in capital and illiterate workers (Leamer, 1984). On top of this, Chile exhibited highly distorted relative prices, as shown above.

Table 3.2 Value Added Distribution Across Sectors

Sectors	1974	1979	1982	1986	1990	1994
Natural Resources Intensive	**52.31%**	**49.99%**	**57.66%**	**58.60%**	**59.10%**	**56.40%**
Food	11.66%	18.04%	19.66%	18.93%	18.54%	20.93%
Tobacco	3.01%	3.80%	4.77%	4.32%	3.25%	3.54%
Wood products	1.37%	3.68%	2.91%	2.58%	3.18%	3.82%
Furniture, except metal	0.27%	0.76%	0.70%	0.58%	0.70%	1.00%
Paper products	3.10%	4.54%	4.53%	6.88%	6.20%	7.49%
Petroleum and coal	3.61%	4.09%	5.76%	4.06%	5.15%	6.23%
Non-metallic minerals	1.31%	2.30%	2.48%	2.86%	2.53%	3.70%
Non-ferrous metals	27.98%	12.79%	16.86%	18.41%	19.55%	9.68%
Capital Intensive	**36.19%**	**31.34%**	**25.46%**	**25.97%**	**25.91%**	**25.16%**
Textile	5.73%	5.39%	3.79%	4.82%	4.21%	3.19%
Chemical products	3.25%	3.48%	1.90%	2.33%	3.24%	3.77%
Other chemicals	4.39%	6.22%	7.77%	6.23%	6.94%	7.66%
Iron and steel	8.38%	4.03%	3.96%	4.79%	3.29%	2.55%
Metal products	3.85%	4.38%	3.74%	3.67%	4.46%	4.45%
Non-electrical machinery	2.21%	2.18%	1.75%	1.56%	0.53%	0.63%
Electrical machinery	3.58%	2.28%	1.20%	1.48%	1.45%	1.23%
Transport equipment	4.80%	3.38%	1.36%	1.08%	1.80%	1.69%
Labor Intensive	**11.49%**	**18.67%**	**16.88%**	**15.43%**	**14.99%**	**18.44%**
Beverages	3.37%	5.19%	5.77%	4.26%	4.15%	5.15%
Clothing and footwear	2.68%	4.42%	3.82%	3.30%	3.55%	4.19%
Leather	0.75%	0.78%	0.50%	1.62%	0.52%	0.47%
Printing	1.49%	3.95%	3.74%	2.49%	2.92%	3.47%
Rubber products	1.31%	1.35%	0.98%	1.05%	0.86%	1.10%
Plastic products	0.81%	1.70%	1.44%	1.80%	2.27%	3.16%
Pottery	0.48%	0.46%	0.11%	0.21%	0.11%	0.16%
Glass	0.60%	0.81%	0.52%	0.70%	0.60%	0.73%

Sources: Fuentes (1995) and authors' calculations.

4. Previous studies in productivity and efficiency in the Chilean manufacturing industry

Several empirical studies have focused on the link between trade liberalization and productivity growth in the Chilean economy. It has been argued that higher productivity growth is expected when the economy reduces its trade barriers. Arguments have been provided to explain this positive link between trade liberalization and productivity growth. The first one concerns the expected increases in technical efficiency once the domestic industry is forced to compete in the international markets. In protected sectors, the absence of competition discourages efficient production because firms can enjoy monopolistic power. Hence, trade liberalization is assumed to contribute to increase efficiency.

Other authors contend that in developing countries, trade liberalization would increase the rate of technological progress mainly for two reasons. First, more integrated developing economies have advantages to absorb technological innovations generated in the advanced nations.[10] The second reason stems from the literature on foreign exchange constraints and focuses on the evidence that developing countries import capital and intermediate goods that are not very substitutable by domestic ones because of embodied technological progress. Thus, trade liberalization would allow importing these more technologically advanced goods, increasing the technological progress embodied in imported goods. The empirical evidence in Lee (1995) supports the idea that imported capital goods contribute positively to economic growth, particularly in developing countries.

Corbo and Sánchez (1985) carried out one of the first empirical studies in this area, using a special survey on manufacturing firms after trade liberalization. They found that, due to increasing import competition, the surveyed firms closed down their inefficient plants and reduced production lines. They also struggled to increase efficiency by expanding investment and reducing their labor force.

In a more systematic approach, Tybout, De Melo and Corbo (1991) analyzed the hypotheses related to the link between trade liberalization and efficiency. Using cross-sectional data for the manufacturing industry, they estimated industry-specific technical efficiency indices for 1967, when the economy was highly protected, and for 1979, when trade had been liberalized. Their findings reveal little evidence about efficiency improvements between pre and post liberalization years. Of the 21 sectors analyzed, only 9 showed an increment in technical efficiency, and barely 10 had improved their scale efficiency. Although overall industry efficiency did not improve significantly between the two periods, industries with larger reductions in protection were found to achieve the highest increments in efficiency.

Two similar papers have studied the same issue, but over a longer time span. Marshall (1992) estimated industry-specific efficiency indices for the 1979-1986 period. She found that efficiency and productivity tended to increase between 1974 and 1979, but to decrease between 1979 and 1986. This behavior would be strongly related to changes in tariffs occurred in both periods. In fact, between 1974 and 1979 the average tariff was reduced from 57 to 10%, but between 1979 and 1986 it was raised to 20%.[11]

Liu (1993) focused on plant-specific efficiency during the same period. The results in his paper, consistent with Marshall's (1992), suggest a negative relationship between efficiency and protection. A distinctive feature of this article is the evidence it presents on the

[10] A model based on this idea of "learning by looking" is developed by Edwards (1992).
[11] During this second period, the tariff reached a maximum of 35% in 1984

performance of different groups of firms. Liu distinguished among surviving, entering, and exiting plants and he searched for differences in the evolution of efficiency within these three groups. His results indicated that entrants were more efficient than exiting plants, but less so than surviving ones. However, efficiency was almost always increasing in entrants, but slightly decreasing in surviving plants. Then, he concluded that the competitive pressure of trade liberalization forced less efficient producers to shut down, generating positive effects on aggregate efficiency.

Other authors have approached this issue using a different methodology. Fuentes (1995), applying growth accounting methodology to aggregate data at the three-digit level of ISIC, reports changes in productivity growth after trade liberalization in manufacturing sectors. Consistently with the hypotheses mentioned above, his results show that trade liberalization was accompanied by huge increments in labor productivity and total factor productivity in the 1974-1979 period, for almost every sector in the manufacturing industry.

Liu and Tybout (1996) estimate separate total factor productivity and efficiency indices for manufacturing plants. Although their objective is to analyze the role of entry and exit on aggregate productivity, their estimates are highly consistent with the above-cited studies. Between 1979 and 1986, total factor productivity and efficiency were negatively correlated with protection.

More recently, Pavcnik (2002) makes a critical review about the econometric approach used in these studies. Her contribution, using plant-level data for the same period of the other studies, is to correct the estimates of production function parameters by the presence of selection bias and simultaneity, obtaining a more consistent measurement of total factor productivity. After that, she carries out a regression analysis between firm productivity and outward orientation of the industries, separating among non-tradable, exportable, and import-competing sectors. In general, she finds that plants in the exportable and import-competing sectors are more productive than plants in non-tradable sector. The changes over time in productivity are not very consistent with expected results. Although the productivity differentials between firms in the non-tradable and import-competing sectors increased from 1981 through 1986, the same is not valid for plants in the exporting sector.

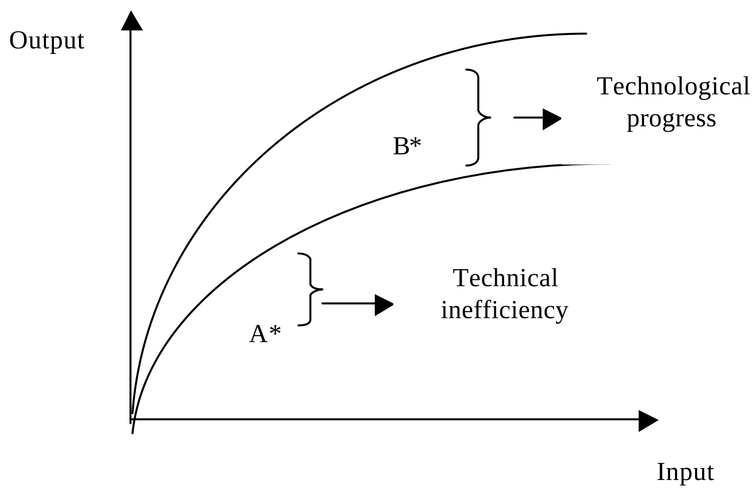
Consistently with the international experience, the evidence on Chile has not been conclusive about the relationship between trade liberalization and productivity (see Deraniyagala and Fine, 2001). There are several shortcomings in the cited studies. First, more often than not, empirical works have studied a relatively short time span. Although a great part of trade liberalization was carried out between 1974 and 1979, this was reversed after the 1982-83 crisis. We believe that a longer time period is needed, to allow for firms to adjust to the new economic conditions. Also, a long-run analysis is preferable, so that our inferences are less distorted by the severe 1982-83 crisis.

Second, to our knowledge, there are no studies about productivity growth in the Chilean manufacturing industry that jointly estimate efficiency and technological progress indices. Past literature has either focused on total factor productivity, or estimated technical efficiency. Theoretically, total factor productivity involves these two elements. Higher production may be achieved by either increasing technical efficiency (reaching the maximum output given the inputs) or improving the production technology (producing more with the same inputs).

Figure 4.1 illustrates both concepts. If attention is focused only on productivity, defined as technological progress, assuming that firms are always efficient, changes in productivity will be equivalent to the vertical distance between two different production functions. On the other hand, if the focus is only on technical efficiency, the correct measure is the distance between an actual production point and the corresponding level of output in the production frontier. Changes in efficiency over time can be seen by looking at how much closer is the firm to the frontier in point A as compared to B. In the empirical analyses carried out in Chile until now, there is no distinction between both elements.

Figure 4.1

Efficiency and Technological Progress



A third shortcoming of these studies, which is also a limitation for this one, concerns the data. Neither of them has a direct measurement of outward orientation at the plant level. Actually, in Pavcnik (2002) the differences in international exposure are determined at the industry level and used in the total factor productivity regressions at the plant level. For example, if there were benefits from competing in international markets, one would expect that in a same sector, exporting firms would be more productive than non-exporters.[12] These productivity differentials have received little attention in Chile.

5. Productivity and Technical Efficiency: Evidence at the Plant Level

The empirical approach in this article contributes to the previous analysis in three ways. First, in the next section, we estimate joint indices of technological progress and technical efficiency. Hence, we can distinguish the effect of trade liberalization on both variables. Second, we have used a longer time period than similar studies. Third, we analyze changes in productivity over time and across sectors, and their link to trade liberalization. The data is obtained on an annual basis from the nationwide survey on manufacturing establishments (ENIA) conducted by the National Institute of Statistics (INE), for the period 1979 to 1994.

[12] Many recent empirical studies document the existence of productivity differentials between exporters and non-exporters. See Bernard and Jensen (1999) for evidence of this in the United States.

5.1 Methodological and Measurement Issues

Following recent developments in the measurement of productivity, a stochastic frontier production function was estimated to decompose total factor productivity into technical progress and changes in technical efficiency.[13] The stochastic frontiers methodology was developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), and it has been used to obtain efficient production frontiers that represent the maximum level of output that can be reached with a specified quantity of inputs. The most efficient firms will be those that are closest to this frontier.

A stochastic frontier production function is defined by:

$$Y_{it} = F(X_{it}; b)\exp(e_{it}) \quad (1)$$

and

$$e_{it} = v_{it} - u_{it} \quad (2)$$

where Y is the output of the i[th] firm (i = 1…n) in the t[th] period of time (t = 1…T); F is the production frontier, and X is a vector of inputs. The error term e_{it} is divided into two random components: v_{it} is the traditional error term, independent and identically distributed as $N(0, s_v^2)$, and u_{it} represents technical inefficiency, which is assumed to be independent and identically distributed as a positive truncated normal.

[13] See Kim and Han (2001) for an application of this methodology in Korea.

We model inefficiency as a function of the degree of protection in the economy. Our hypothesis is that a reduction in trade barriers would be associated to an increment in firms' efficiency. Also, if trade liberalization favors technological absorption from more advanced economies, we expect higher technological progress through this period. The protection level (P_t) is measured at the aggregate level and is time varying, but constant across the different sectors. This is given by:

$$P_t = (1 + a_t)RER_t$$

where RER is the real exchange rate and a is the average tariff.

We estimate two specifications of the production function: Translog and Cobb-Douglas.[14] Then we compute a likelihood ratio test to identify the most appropriate functional form. Every specification is estimated for 21 sectors in the manufacturing industry. In general, these sectors correspond to 3-digit ISIC industries. An exception is Food (ISIC 311). Due to its great size, we have included five industries to 4-digit ISIC; namely sugar products (ISIC 3113), fruits and vegetables (3114), dairy products (ISIC 3115), meat products (ISIC 3116) and bakery products (ISIC 3118).

Output is measured as value added and has been deflated using the 4-digit SIC deflators built by Yagui (1993). These deflators were extended using the same methodology. As for employment, the survey identifies blue-collar (U) and white-collar (S) workers. A simple measurement of total employment would be to add directly both types of workers. However, since both groups have different productivity, we express labor in units of efficiency using the minimum wage as a common measure for low human capital (or productivity). Thus, employment of each type is defined by:

$$U_t^* = \frac{w_t U_t}{w_t^{Min}} \quad \text{and} \quad S_t^* = \frac{w_t S_t}{w_t^{Min}} \qquad (3)$$

where w is mean wage in every category and w^{Min} is minimum wage. Hence, labor used in the estimates is the sum of both categories of workers expressed in the same units.

No direct measure of capital stock for every plant is available from the survey. In addition, investment data, which potentially could be used to estimate capital input, show a very erratic behavior, and not all the plants report this information in the survey. Because of this, electrical power consumption is used as a proxy for capital stock. This proxy has the advantage that it measures the use of capital stock directly and is expected to best capture any changes in capital utilization during business cycles.

Costello (1993) mentioned other advantages for using this variable. First, it is a perfectly homogeneous of invariant quality, and lacks the measurement problems that are common to other methods for measuring capital utilization. Second, because electric power cannot be easily stored, its consumption in a productive process corresponds exactly to the quantity used in such process. However, a disadvantage of this variable, especially in long series, is

[14] Specific details about the production function are shown in the annex.

that changes in the relative prices of different types of energy induce changes in relative demand by types of capital.[15] In order to incorporate these substitution possibilities, the relative price between electric power and petroleum is incorporated into the production function regressions.[16]

5.2 Estimation Results

Efficiency

If trade liberalization had some positive effect on efficiency, a higher average efficiency would be expected in 1994 as compared to 1979. Table 5.1 shows the estimated level of efficiency and the difference in the mean between both years. According to these results, almost every sector in the manufacturing industry increased its technical efficiency between 1979 and 1994. The professional and scientific equipment (385), and paper and pulp (341) sectors experienced the greatest increment in efficiency. In these sectors, efficiency increased by approximately 20%. In some other sectors, such as meat products (3116), iron and steel (371), electric machinery (383), chemical products (351) and bakery products (3118), efficiency declined, although these changes are not statistically significant.

Table 5.2 summarizes these results. Out of the 21 industrial sectors analyzed, more than 70% experienced a significant increment in efficiency. In addition, for those industries that

[15] For example, a rise in the cost of electrical energy may provide an incentive for replacing machines and equipment by others that use alternative energy sources, like petroleum.

[16] Technically, assuming a Cobb-Douglas functional form for the capital input, it can be proven that relative price of electricity is an independent variable in production function estimates. See the annex for the final functional form estimated.

experienced a reduction in efficiency, the differences between the two years are not statistically significant. From these estimates, it can be concluded that, along the path toward a more open economy, almost every manufacturing sector has gained in efficiency, which is consistent with the benefits associated to trade liberalization.

Table 5.1: Changes in Efficiency by Sector

ISIC Sector	Description	Efficiency 1979	Efficiency 1994	Change %	t-test	P-Value
3113	Sugar Products	0.56	0.62	11.0	2.69	0.008
3114	Fruits and vegetables	0.61	0.62	0.3	0.08	0.933
3115	Dairy products	0.58	0.61	6.0	0.94	0.351
3116	Meat products	0.69	0.68	-1.4	-0.52	0.604
3118	Bakery products	0.54	0.49	-8.8	-0.31	0.579
313	Beverages	0.53	0.57	8.2	1.65	0.100
321	Textiles	0.65	0.67	2.7	1.84	0.066
322	Apparel	0.67	0.70	4.5	3.40	0.000
331	Wood products	0.58	0.63	8.4	4.26	0.000
332	Furniture, except metal	0.63	0.66	4.7	1.83	0.068
341	Paper and pulp	0.58	0.69	18.7	2.25	0.028
351	Chemical products	0.66	0.63	-4.4	-1.31	0.193
352	Other chemicals	0.55	0.58	5.5	1.52	0.130
356	Plastic products	0.61	0.68	11.5	1.22	0.231
371	Iron and steel	0.65	0.64	-1.4	-0.38	0.705
372	Non-ferrous metals	0.53	0.57	7.5	0.98	0.330
381	Fabricated metal products	0.65	0.69	6.2	4.57	0.000
382	Non-electrical machinery	0.61	0.66	8.7	3.16	0.002
383	Electrical machinery	0.71	0.70	-2.3	-0.95	0.341
384	Transport equipment	0.65	0.67	4.3	1.72	0.086
385	Prof. and scientific equip't	0.49	0.68	38.8	3.14	0.004

Table 5.2: Statistical Test Summary

H_0: Equal Means	Higher Efficiency		Lower Efficiency	
	Sectors	%	Sectors	%
Significant*	11	52.4	0	0.0
Non-significant	5	23.8	5	23.8
Total	16	76.2	5	23.8

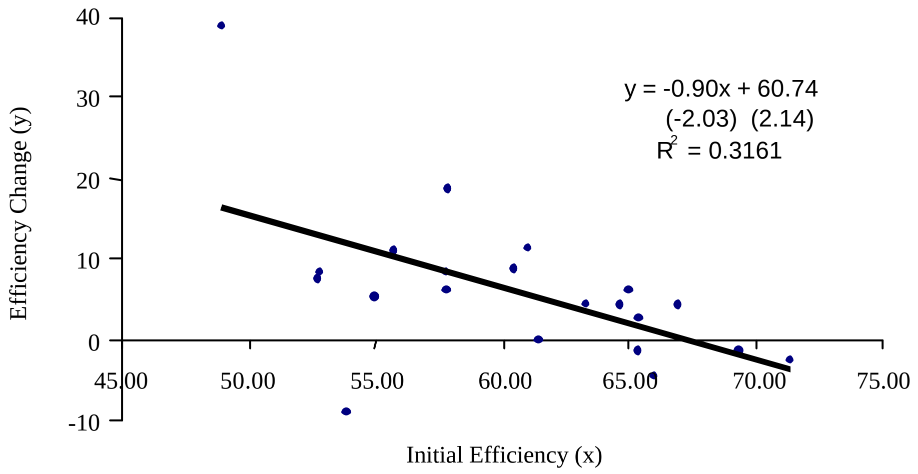
* At 10%.

Convergence in Efficiency

Given the results obtained for average efficiency by sectors, we now look at the question about convergence in efficiency. Industries closest to the efficiency frontier will expectedly experience lower increments in efficiency than those that were less efficient at the beginning of the period. This is similar to the concept of β-convergence in cross-country studies about economic growth. Thus, increments in efficiency should be negatively correlated to initial efficiency.

Our results support this idea. In figure 5.1, we plot changes in efficiency versus the initial efficiency level for every industry in the sample, and a regression line between both variables. The results of this exercise indicate that changes in efficiency are negatively correlated with the initial level of efficiency, suggesting that convergence in efficiency exist across industrial sectors.

Figure 5.1 Convergence in Efficiency



Another interesting analysis is to verify whether there is evidence of dispersion in efficiency diminishing over time across manufacturing sectors (σ-convergence). Table 5.3 shows the results of a statistical test for changes in efficiency dispersion across industrial sectors. The null hypothesis is that variance in 1979 is the same as in 1994 or, in other words, that the variance ratio is equal to 1. It can be appreciated that in most of the manufacturing sector (19 over 21) the efficiency variance in 1994 is smaller than in 1979, although in only eight of these sectors, the reduction in variance is statistically significant. An increment in variance is observed in only two sectors, but this is not significant. These results are summarized in table 5.4.

Table 5.3: Changes in Efficiency Variance by Sector

ISIC Sector	Description	Variance 1979 (1)	Variance 1994 (2)	Variance Ratio (2/1)	P-Value
3113	Sugar products	0.025	0.020	0.788	0.138
3114	Fruits and vegetables	0.021	0.015	0.714	0.045
3115	Dairy products	0.039	0.031	0.791	0.199
3116	Meat products	0.019	0.013	0.683	0.036
3118	Bakery products	0.055	0.097	1.755	0.758
313	Beverages	0.044	0.039	0.888	0.270
321	Textiles	0.020	0.019	0.941	0.271
322	Apparel	0.021	0.014	0.666	0.000
331	Wood products	0.034	0.019	0.552	0.000
332	Furniture, except metal	0.025	0.019	0.766	0.004
341	Paper and pulp	0.019	0.016	0.856	0.333
351	Chemical products	0.017	0.016	0.922	0.371
352	Other chemicals	0.034	0.029	0.874	0.183
356	Plastic products	0.029	0.028	0.944	0.411
371	Iron and steel	0.015	0.012	0.790	0.229
372	Non-ferrous metals	0.022	0.032	1.431	0.842
381	Fabricated metal products	0.025	0.013	0.527	0.000
382	No-electrical machinery	0.032	0.019	0.597	0.000
383	Electrical machinery	0.011	0.010	0.873	0.287
384	Transport equipment	0.020	0.014	0.701	0.022
385	Prof. And scientific equip’t	0.039	0.027	0.695	0.231

Table 5.4: Statistical Test Summary

H_0: Variances ratio = 1	Higher Variance		Lower Variance	
	Sectors	%	Sectors	%
Significant*	0	0.0	8	38.1
Non-significant	2	9.5	11	52.4
Total	2	9.5	19	90.5

* At 10%.

Technological Progress

The evidence in this paper suggests that during the period when the Chilean economy opened to international trade, the manufacturing industry also experienced increments in technical efficiency. Here, we discuss our results about the technological progress in this period. Table 5.5 shows the annual rates of technological progress for each sector.

The evidence is less conclusive compared to our findings for technical efficiency. The results show that not all the sectors experienced technological progress during the period analyzed. Technological progress growth is positive and statistically significant for only seven sectors in the manufacturing industry.

Table 5.5: Technological Progress by Sector

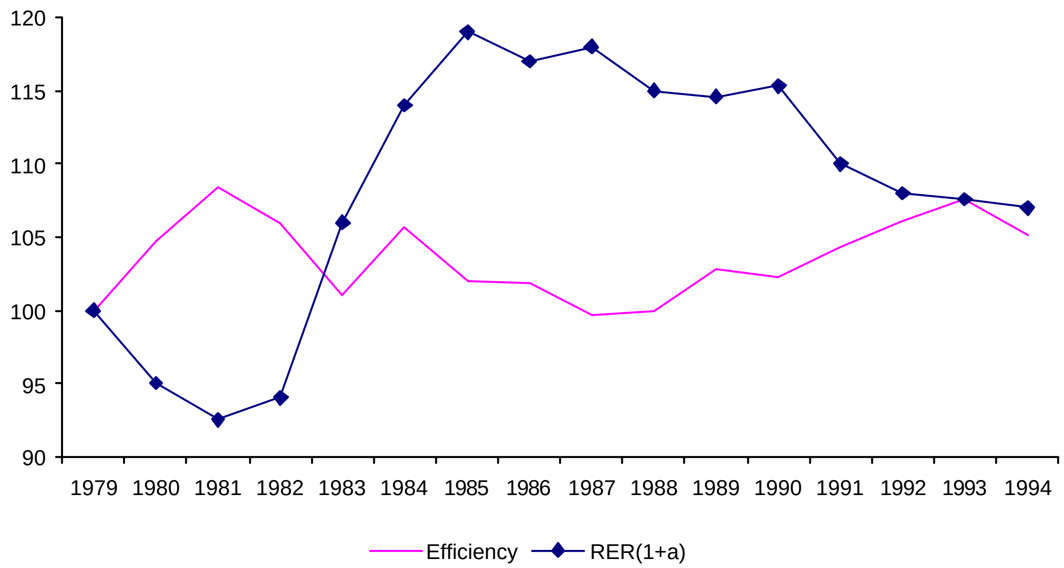
ISIC Sector	Description	Annual growth rate (%	t-test
3113	Sugar products	-1.9	-0.48
3114	Fruits and vegetables	5.3	1.29
3115	Dairy products	5.7	4.04*
3116	Meat products	-3.6	-2.54*
3118	Bakery products	7.5	4.32*
313	Beverages	-2.2	-0.63
321	Textiles	1.4	1.31
322	Apparel	3.9	16.99*
331	Wood products	2.0	0.18
332	Furniture, except metal	0.1	0.13
341	Paper and pulp	-1.2	-1.02
351	Chemical products	4.9	0.78
352	Other chemicals	0.6	1.51
356	Plastic products	2.2	0.33
371	Iron and steel	-0.7	-0.55
372	Non-ferrous metals	5.8	4.72*
381	Fabricated metal products	1.1	4.79*
382	Non-electrical machinery	-0.5	-0.52
383	Electrical machinery	5.5	4.19*
384	Transport equipment	3.6	3.39*
385	Prof. and scientific equip't	-1.3	-1.58

* Significant at 5%

Efficiency and Trade Liberalization

One important question concerns the causality between efficiency and trade liberalization. Although the evidence presented above supports the idea that openness has been associated to greater efficiency, causality has not been discussed. To motivate a more formal approach, consider figure 5.2 that plots average efficiency for the aggregate manufacturing industry and the measurement of protection used (real exchange rate times the average tariff rate). An inverse relation can be observed between these two variables. When protection was increased in the first part of the period, efficiency tended to decrease. During the second part of the period, reduction in protection was followed by an increment in efficiency.[17]

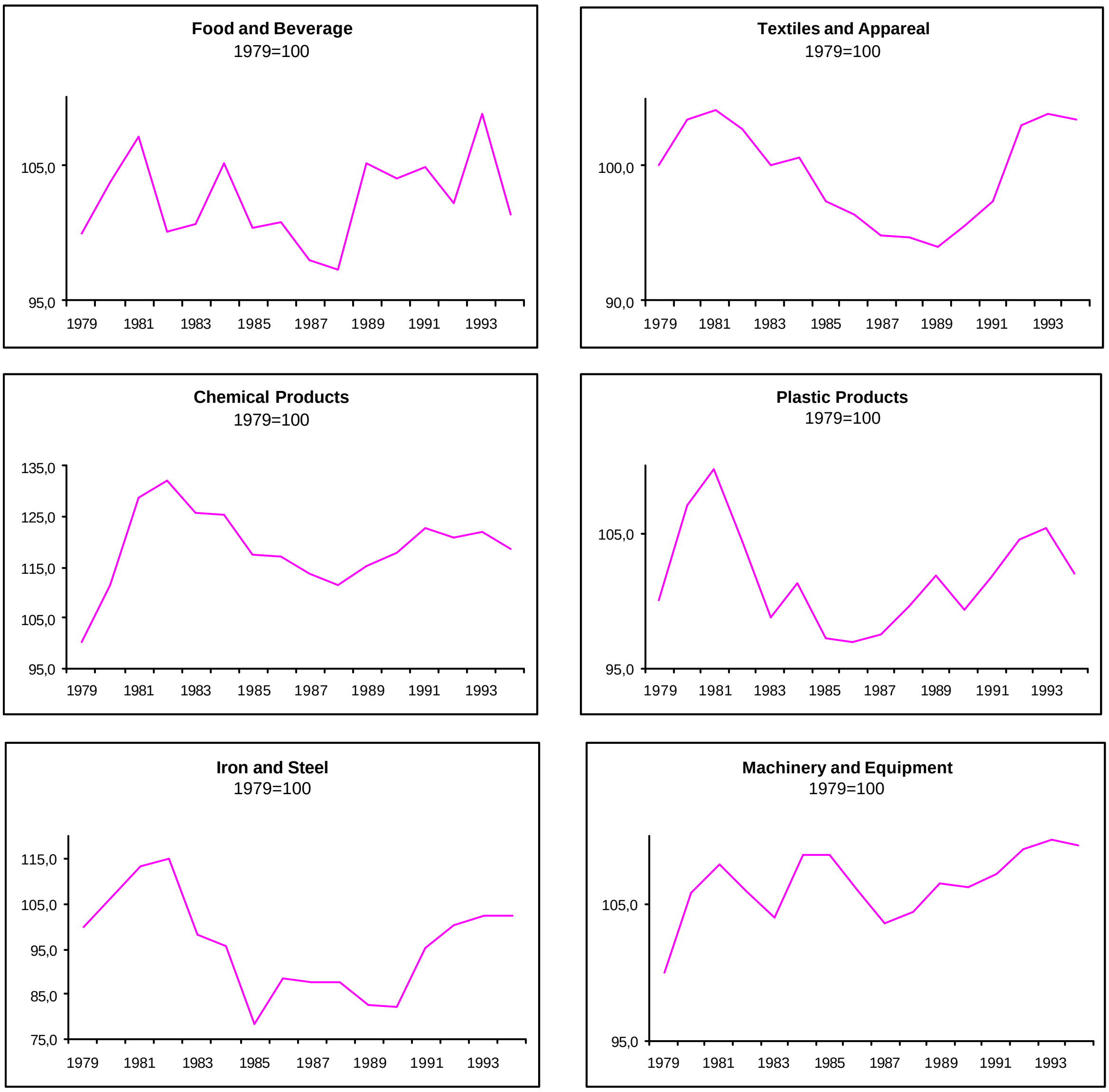
Figure 5.2 Efficiency and Protection



Similar evidence regarding the evolution of technical efficiency by sectors is shown in figure 5.3. In general, in almost all the sectors efficiency increased at the beginning of the period, then declined until the mid 1980's. From there on, efficiency grew slightly up to the end of the period.

[17] Given the huge trade liberalization between both decades, it may be surprising that "protection" is higher in the 90's that it is in the 70's. But this can be because we compute a measure of protection that includes the real exchange rate, and during this period, especially in the 80's, the real exchange rate appreciated enormously.

Figure 5.3 Evolution of Technical Efficiency Across Sectors



A more formal analysis is presented in table 5.6. As explained above, we include protection as an explicative variable in the estimation of inefficiency from the production frontier. The expected value of the parameter associated to protection is positive, under the hypothesis that increases (reductions) in protection generate greater (smaller) inefficiency. Our results show a positive and significant parameter in nine out of 21 sectors. The number of sectors in which the relationship is negative and significant is only six. Then, from this evidence, we can conclude that, although there is not a general case for every manufacturing sector, trade liberalization has had a positive impact on efficiency for an important number of sectors in the Chilean manufacturing industry. Future research should explore these differences in the impact of trade liberalization on technical efficiency.

Table 5.6: Efficiency and Protection by Sector

ISIC Sector	Description	Parameter	t-test
3113	Sugar Products	-22.6	-7.08*
3114	Fruits and vegetables	20.1	2.35*
3115	Dairy products	-10.4	-4.93*
3116	Meat products	21.3	2.84*
3118	Bakery products	-0.5	-1.15
313	Beverages	-23.3	-1.45
321	Textiles	4.5	6.49*
322	Apparel	16.2	3.34*
331	Wood products	-18.4	-4.87*
332	Furniture, except metal	-11.6	-3.36*
341	Paper and pulp	12.1	6.48*
351	Chemical products	24.1	3.17*
352	Other chemicals	-9.9	-5.37*
356	Plastic products	11.9	1.63
371	Iron and steel	34.1	3.79*
372	Non-ferrous metals	5.1	1.25
381	Fabricated metal products	2.5	9.31*
382	Non-electrical machinery	-12.8	-3.15*
383	Electrical machinery	13.4	5.45*
384	Transport equipment	-11.0	-4.1*
385	Prof. and scientific equip't	-19.1	-1.63

* Significant at 5%

6. Concluding remarks

This paper has shown how the trade reforms in the seventies have affected the manufacturing industry. We found no evidence of deindustialization in Chile after the reforms, as defined by the share of the manufacturing industry in GDP and the export of manufactured products. The share of manufacturing sector over GDP actually increased during the nineties, where the average was higher than the sixties. On the other hand, manufacturing exports surpassed mining exports in 1999.

However, a case can be made that the manufacturing sector has developed based on natural resources, and therefore Chile is still exporting primary products. But, this is consistent with having comparative advantage in natural resource intensive industries as predicted by the standard Heckscher-Ohlin-Vaneck model. Nevertheless, it is important to point out that the controversy concerning natural resource abundance, as a barrier for growth, is not over yet. In a seminal paper Sachs and Warner (1995) argue that economies abundant in natural resources grow slower than the rest. However, Leite and Weidmann (1999) and Lederman and Maloney (2002) have challenged this idea using different types of arguments.

Besides the level of the manufacturing sector production, it is important to notice the significant shifts occurred in the structure and level of productivity in the manufacturing industry after the trade liberalization. Specifically, our findings reveal that increases in productivity are closely associated to changes in technical efficiency for the manufacturing industry as a whole and for most manufacturing sectors. On the other hand, we cannot find strong evidence of technological changes in the manufacturing industry. But, given that

Chile has a natural advantage in mining products, the manufacturing sector has to be highly competitive to become as important as mining in terms of exports.

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Annex

Functional Form of the Production Function

Two alternative functional forms of the production function were estimated: (1) Translog, and (2) Cobb-Douglas. These can be expressed, respectively, as:

(1)
$$\log Y_{it} = b_0 + b_1 t + b_2 t^2 + b_3 \log L_{it} + b_4 t \log L_{it} + b_5 \log K_{it} + b_6 t \log K_{it} + b_7 (\log L_{it})^2 + b_8 (\log K_{it})^2 + b_9 \log L_{it} \log K_{it} + e_{it}$$

(2)
$$\log Y_{it} = b_0 + b_1 t + b_2 LogL_{it} + b_3 LogK_{it} + e_{it}$$

where i represents the plant, t is time, Y is value added, L the corrected employment, K capital services, and ε is the error term defined in equation 2, section 5.

We suppose that services of capital (K) can be approximated by a combination of electric power consumption (E) and petroleum (M). Using a Cobb-Douglas function, we can write an expression for capital services as:

(3)
$$K = E^{l} M^{1-l}$$

The first order condition establishes that the firm will combine energy and petroleum equating the ratio of marginal productivity with relative prices of these types of energy.

(4) $$\frac{lM}{(1-l)E} = \frac{P_E}{P_M}$$

Substituting (4) in (3) and taking log, K can be expressed as a function of electric power consumption (E) and price ratio of energy and petroleum ($p = P_E / P_M$). This is:

(5) $$\log K = (1-l)\log\left(\frac{1-l}{l}\right) + \log E + (1-l)\log p$$

Substituting (5) in (1) and (2), both production functions are given by:

Translog:

(6) $$\begin{aligned} \log Y_{it} &= a_0 + a_1 t + a_2 t^2 + a_3 \log L_{it} + a_4 t \log L_{it} + a_5 \log E_{it} + a_6 t \log E_{it} \\ &+ a_7 \log p_t + a_8 t \log p_t + a_9 (\log L_{it})^2 + a_{10} (\log E_{it})^2 + a_{11} (\log p_t)^2 + \\ &a_{12} \log L_{it} \log E_{it} + a_{13} \log L_{it} \log p_t + a_{14} \log E_{it} \log p_t + e_{it} \end{aligned}$$

Cobb-Douglas:

(7) $$\log Y_{it} = a_0 + a_1 t + a_2 LogL_{it} + a_3 LogE_{it} + a_4 Logp_t + a_5 \log E_{it} \log p_t + e_{it}$$

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