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ESSAYS ON TRADE AND PRODUCTIVITY: CASE STUDIES OF MANUFACTURING IN CHILE AND KENYA

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Abstract

This thesis deals with various aspects of the relationship between trade and productivity in developing countries. It contains of a general introduction and four separate essays. The essays consist of case studies of the manufacturing sector in Chile and Kenya.

The export promotion hypothesis suggests that exports and export policy play a crucial role in stimulating growth. The role of import competition in providing similar benefits has to a large extent been absent in the literature. Essay I contributes to the ongoing debate on trade and productivity growth by examining the existence of a causal relation running from trade and domestic competition to productivity growth in Chilean manufacturing. The results suggest that the Chilean productivity growth during the period 1980 to 1991 was import-led rather than export-led.

Essay II examines whether the higher productive efficiency among exporting plants in Chilean manufacturing is a result of learning or self-selection. A method to calculate deviations from potential productivity, referred to as total factor efficiency, using a translog production function is proposed. We found no significant differences in total factor efficiency, technical efficiency or scale efficiency between plants with either a long or a short export history. Plants just prior to the start of exporting are significantly more productive than plants that remain out of the export market. This suggests that relatively efficient firms self-select into the export market.

Essay III investigates the link between efficiency and exports in Kenyan manufacturing. Like many similar studies we find that exporters are more efficient than non-exporters. The analysis supports that relatively efficient firms self-select into exports activities, but we also find some evidence in favour of learning from exports. Our results provide no evidence for the hypothesis that trade direction influences either the export effect on technical efficiency or the efficiency effect on exports. However, while the probability to export to other African countries increases with physical and human capital intensity, firm size appears more important for export activities outside Africa.

Essay IV investigates the technical efficiency of foreign- and domestic-owned plants in the chemical sector in Chile. The model combines a stochastic frontier production function in which technical inefficiency effects are modelled in terms of ownership and input level. The results indicate that the higher average inefficiency observed among domestic-owned plants stems partly from the inefficient use of capital. Increased use of labour inputs improves technical efficiency for domestic-owned plants, while increased uses of capital reduce efficiency. Thus, the shift towards more capital-intensive production techniques in Chile, following the trade liberalization, may have brought adjustment costs in the form of reduced technical efficiency.

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Introduction

1 Background

From the early 1950s, through the late 1970s, industrialisation policies in developing were generally based on limiting international openness. These policies, which came to be known as "import substitution" strategies, had their origins in the thinking of Prebisch (1950) and Singer (1950). Developing countries dependence on the export markets of industrialised countries, it was thought, would lead them to concentrate on primary commodities in their own exports. This, as a consequence, would retard industrialisation. Furthermore, deterioration in the price of raw materials and primary commodities was anticipated. In the absence of industrialisation this would contribute to an ever-widening gap between rich and poor countries. In order to industrialise, it was argued, the emerging manufacturing sector in developing countries would require temporary assistance in the form of protection from foreign competition.

In the 1980s the majority of economists instead began to recommend development strategies based on market-oriented reforms that included the reduction of trade barriers and the opening of international trade to foreign competition. One major reason for this shift in viewpoint among mainstream economists and in the public policy debate was the growing awareness that the poor performance of Latin American countries, most of which had followed the dictates of import substitution, stood in high contrast to the performance of rapidly growing East Asian countries which had implemented outward-oriented strategies. Due partly to pressure from the World Bank and the International Monetary Fund, several developing countries, in the 1980s and the beginning of 1990s, abandoned their inward-looking strategies in favor of drastic trade liberalisation programmes.

Despite voluminous empirical research on the impact of trade liberalisation on economic growth, controversies still remain about whether trade liberalisation has played an important role in the performance of outward-oriented economies. While cross-country studies have generally found a positive association between growth and outward-looking policies, recent criticism of these studies has called their conclusion into question (see Edwards, 1993; Rodriguez and Rodrik, 1999; Giles and Williams, 2001). One source of criticism is the difficulty of separating out the effects of trade liberalisation from the effects of other government policies and various macroeconomic variables. For instance, Rodrik (1997) concludes that "it is at least plausible" that East Asian outward orientation was the consequence – rather than the cause – of an increased investment demand.

A common conclusion in the critical studies of empirical work done by Edwards (1993) and Rodriguez and Rodrik (1999) is that there is much to be learned from micro-economic analysis of plant-level data sets. Recent research by, for instance, Roberts and Tybout (1997), Clerides, Lach and Tybout (1998) and Bernard and Jensen (1999) has shed new light on the relationship between trade and firm performance. These papers find little evidence that firms derive technological benefits from exporting per se. However, to able to draw more definite conclusions about the effect of increased trade on firm performance, there is need for more theoretical and empirical research at the micro level.

The four essays in this thesis deal with topics related to the effects of trade on technical efficiency and productivity growth in the manufacturing sector in developing countries. A common purpose of the essays is to contribute to the existing literature with further micro-evidence on the relation between outward orientation and productivity. The essays consist of case studies of the manufacturing sector in Chile and Kenya. Three of the essays deal with the relationship between trade and productivity growth or technical efficiency. The last essay investigates the technical efficiency of foreign- and domestic-owned plants in the chemical sector in Chile.

In analysing the relationship between trade and productivity, Chile provides an interesting example. Rightly or wrongly, Chile has been perceived as a shining example of the success that awaits countries that abandon import substitution and introduce market reforms. In late 1973, Chile initiated a comprehensive trade liberalisation programme, together with privatisation of state-owned firms and market deregulation. Following a balance-of-payment crisis that hit the country in 1982, the tariff rate was raised again. One of the main aims of the second trade liberalization programme in the mid 1980s was to expand non-traditional exports through a devaluation of the exchange rate and assistance to export producers. At the same time tariffs were reduced gradually to a uniform rate of 10 percent. After the implementation of the structural adjustment programme in the mid 1980s, Chile experienced a rapid GDP growth. The role of increased exports in the overall growth of the Chilean economy is debated. Studies by Jung and Marshall (1985) and Dodaro (1993) found evidence for growth-led exports in Chile. On the other hand, Agosin (1999) found results to indicate export-led growth. In any event, the most common view among economists seems to be that the Chilean growth during the latest 15 years has been export-led (Ffrench-Davis, 2000).

As in Chile, Kenya followed an import substitution industrialisation strategy that placed quantitative restrictions on imports and high and variable tariffs.[1] In 1980s there was a shift in trade policy towards openness. The reform had two major components: export promotion and import liberalisation. The former mainly comprised measures to improve support to the exporters and, largely by means of liberalising and streamlining the export licensing process. There was also increased direct support to exporters by establishing schemes for ensuring duty-free access to imported inputs and by providing subsidies for technical assistance. The import liberalisation aspect of reform started with the replacement of quotas by tariff-equivalents and was followed by a reduction of tariffs. Import licenses, however, remained a requirement. Since the mid 1980s there has been a remarkable increase in manufacturing exports. The latter part of the 1980s also saw a fairly stable economic development with GDP growing by about five percent per year. It seemed as if the shift in policy in a somewhat more liberal direction was beginning pay off. However, with the exception of a short recovery period between 1994 and 1996, economic growth in Kenya has been poor since 1992.

2. Outline and Main Results of the Thesis

The export promotion hypothesis suggests that exports and export policy play a crucial role in stimulating growth. The role of import competition in providing similar growth benefits has to a large extent been neglected in the literature. The *first essay* in this thesis contributes to the ongoing debate about trade and growth by examining whether there is a causal effect from the level of international trade and domestic competition to productivity growth and by attempting to distinguish the respective effects of exports and imports. Total factor productivity growth is estimated for 30 industries in the Chilean

[1] This description of the Kenyan trade liberalisation draws heavily from Granér and Isaksson (2001) and Bigsten (2001).

manufacturing sector using plant-level data covering the period 1979 to 1991. Using dynamic panel data methods, the determinants of Chilean productivity growth are estimated at the sectoral level.

The results in first essay suggest that import competition rather than exports was the important conduit of productivity growth in Chilean manufacturing during the period 1980 to 1991. This challenges the export promotion hypothesis, which suggests that exports and export policy plays a crucial role in stimulating growth. Conversely, the results indicate a negative impact of exports on Total Factor Productivity (TFP) growth at the industry level.

The *second essay* uses a census-based plant-level dataset for the Chilean manufacturing sector covering the period 1989-1991 to analyse the link between productive efficiency and exports. A method to calculate the degree of deviation from potential productivity, referred to as Total Factor Efficiency, from a translog production function, is proposed. To be able to separate the effect of exports on technological capabilities from its effect on economies of scale, total factor efficiency is decomposed into the components, technical efficiency and scale efficiency.

Micro-data in developing countries often show exporting firms to be more efficient than non-exporting firms. The comparisons of efficiency between exporting and inward-oriented plants in the Chilean manufacturing sector in this essay confirm that pattern, as well as indicate that superior scale efficiency among exporters is more significant than the difference in technical efficiency. There is however no evidence for a positive relation between the level of exports and plant performance.

The second essay also addresses the question whether the higher productive efficiency among exporting plants in Chilean manufacturing is a result of learning or self-selection. The results give no support for the hypothesis that export activities precede efficiency change. Thus, we find no evidence that exporting plants increase productive inefficiency through learning-by-exporting. Instead, the results suggest that plants just prior to the start of exporting are significantly more productive than plants that remain out of the export market. This suggests that relatively efficient firms self-select into the export market.

The third essay is co-authored by Anders Isaksson. This paper investigates the link between technical efficiency and exports in Kenyan manufacturing. As in many similar studies, we find that technical efficiency is higher among exporters than among non-exporters. Kenyan exporters are also larger in size and relatively more intense in their use of physical and human capital. The analysis supports that relatively efficient firms self-select into export activities, but we also find weak evidence in favour of learning from exports. Besides technical efficiency, firm size and foreign ownership emerge as important determinants of the export decision.

The third essay also addresses the importance of direction of trade. We explore the question of whether Kenyan exports to other African countries (i.e. to other developing countries) have the same determinants and efficiency-effects as trade outside Africa (mainly to industrial countries). Our results provide no evidence for the notion that trade direction influences either the export effect on technical efficiency or the efficiency effect on exports. However, direction matters for the effect from other determinants on the export decision. Firm size has a positive effect on the decision to export outside Africa, while we found no evidence that firm size influences the decision to export within Africa. This result may be explained by higher costs of penetrating North markets than for South markets. Another interesting result is that high physical and human capital intensity increases the probability to export within Africa, while factor proportions have no explanatory power on export activities outside Africa. These findings might lead one to speculate that Kenyan firms have a comparative advantage in production intensive in its use of those factors of production for exports destined to other African countries.

The last essay in this thesis investigates the technical efficiency of foreign- and domestic-owned plants in the chemical sector in Chile. One of the arguments for trade liberalisation in developing countries is that a more rational market structure will attract foreign investors and thus promote the adoption of new and superior technologies. However, foreign-owned firms may be inefficient when they operate in an unfamiliar environment. Two related hypotheses are tested in this essay: First, that because of the low labour cost in developing countries, the cost-minimising foreign firms adopt unfamiliar labour-intensive techniques that negatively affect technical efficiency; Second, that because of the fall in the price of capital relative to labour costs following a trade liberalisation, domestic firms may adopt an unfamiliar capital-intensive technology, with resulting inefficiency.

The econometric model combines a stochastic frontier production function in which technical inefficiency effects are modelled in terms of ownership and input level. By including inputs as determinants of inefficiencies, the conventional restriction in stochastic frontier models that technical efficiency is independent of the factors of production is dropped. The non-neutral shifts of the production function obtained from this specification make it possible to test the hypothesis that inefficient foreign firms are relatively more inefficient in labour than in capital, while inefficient domestic firms are more inefficient in capital.

Average technical efficiency is higher among domestic small and medium-sized plants compared with foreign-owned plants belonging to the same size groups, while large foreign-owned plants are, on average, more efficient than domestic-owned large plants. This result may be explained by the fact that capital-intensity typically increases with plant size in Chile's chemical industry. The results suggest that increased use of labour inputs improves technical efficiency for domestic-owned plants, while increased uses of capital reduce efficiency. For foreign-owned plants, however, there is no significant relationship between input levels and technical efficiency. Thus, the shift towards more capital-intensive production techniques in Chile, following the trade liberalisation, may have brought adjustment costs in the form of reduced technical efficiency.

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Export-led or Import-led Productivity Growth?
A Dynamic Panel Study of Chilean Manufacturing

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Abstract: The export promotion hypothesis suggests that exports and export policy play a crucial role in stimulating growth. The role of import competition in providing similar benefits has to a large extent been absent in the literature. This paper contributes to the ongoing debate on trade and productivity growth by examining the existence of a causal relation running from trade and domestic competition to productivity growth in Chilean manufacturing. The results suggest that the Chilean productivity growth during the period 1980 to 1991 was import-led rather than export-led.

Keywords: Trade liberalisation, competition, productivity growth, Chile, manufacturing

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E-mail: Mats.Graner@industry.ministry.se. The author wishes to express his gratitude for valuable advice from Måns Söderbom, Anders Isaksson and Arne Bigsten.

1 Introduction

Competition and exposure to superior foreign firms may have long-lasting effects on firm performance by speeding up technological acquisition which, in turn, leads to faster productivity growth. Proponents of export-led growth strategies have long argued that exports and export policies play a crucial role in stimulating growth since exporting is an effective means of introducing new technologies to the exporting firms as well as to the rest of the economy.[2] Recently, endogenous growth-trade theorists have formulated a range of formal models in which trade contributes to economic growth by, among other things, increasing the diffusion of knowledge and technology, facilitating learning-by-doing, providing imported inputs, and increasing the size of the markets.[3] These models predict that trade liberalization contributes to productivity growth.

While the role of exports in promoting productivity has been extensively explored, the import part of the trade and productivity relationship is not as well investigated. The same arguments that are made for export-promotion may also be valid as arguments for a link from imports to productivity growth. Stronger exposure to international competition from foreign exporters may increase the pressure on export firms to keep costs low and provide incentives to reduce productive inefficiency. Productive efficiency may also be positively related to imports because domestic firms learn by examining products imported from abroad or because foreign competition from technologically superior developed countries spurs innovation. In addition, access to higher quality foreign intermediates may be important for productivity growth. As the bulk of research and development (R&D) is oriented towards the creation and improvements of new products, spillover from improved inputs is also presumably of great importance (Grossman and Helpman, 1991). Since R&D is largely carried on outside developing countries, productivity gains in developing countries from imports of input goods may be especially high.

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[2] See e.g. Feder (1983), Corbo, Krueger and Ossa (1985), and World Bank (1993).
[3] See e.g. Young (1991), Grossman and Helpman (1991), and Romer (1994).

Throughout the last decade The World Bank has emphasised the importance of manufactured goods exports. In its study of the East Asian Miracle (World Bank, 1993) it suggests that exports and export policies played a crucial role in stimulating growth. The study advocates government support for exports as an effective way of boosting productivity and output growth. A shortcoming in the bank study was that, while it emphasised exports as a channel for growth through learning and technological transfer, it did not include a discussion of the role of imports in providing similar benefits.

The World Bank emphasis on manufactured exports as an instrument of growth is apparently supported by a large number of macro studies which found that export growth and export levels were highly correlated with GNP growth at the macro level.[4] In macro level studies, however, it is not possible to distinguish between the importance of exports and imports respectively. Empirical macro level studies with results apparently supporting export-led growth may actually be results generated from import-led growth. Thus, results at the macro-level provide no evidence that export-promotion has positive effects on productivity levels and/or productivity growth for the firm or sector that is promoted.

Firm-level or sectoral level data provides better opportunities to distinguish between the respective effects of exports and imports. There is however only minimal micro-economic research on the productivity effects of import competition. Some empirical studies have examined the evidence on technology diffusion and productivity growth through imported intermediates. These studies generally report a positive correlation between access to imported intermediate goods and performance (Handoussa, Nishimizu and Page, 1986; Tybout and Westbrook, 1995; Iscan, 1998; Sjöholm, 1999). The findings of Lawrence and Weinstein (1999) on Japan suggest a beneficial impact of manufacturing imports on Total Factor Productivity (TFP) growth during the period 1964 to 1973. Further, their results suggest that the positive contribution made by imports on TFP growth stems more from their contribution to competitive pressure and learning than from intermediate inputs. Macdonald (1994) found that increased import competition in the U.S. led to large increases in labour productivity growth in highly concentrated industries during the period from 1975 through 1987.

Why it is then important to distinguish between the effects of exports and imports on productivity growth? Even if growth is import- rather than export-led, a country's export-promotion policy may be quite valuable in supplying foreign exchange, which relieves import shortages. The distinction is, however, not purely of an academic interest, but also has policy implications. If, for instance, the political target is to improve productivity in the manufacturing sector, promoting manufactured exports may be an effective policy option if productivity is export-led. On the other hand, in the case of import-led productivity growth, a general government support for exports accompanied by a removal of import barriers may be the most effective policy.

This paper contributes to the ongoing debate on trade and productivity growth by examining the possible existence of a causal relation running from the level of international trade and domestic competition to productivity growth in Chilean manufacturing, using data covering the period 1979 to 1991. TFP growth is estimated for each sector using plant-level data. Using dynamic panel data methods, the determinants of Chilean productivity growth are estimated at the sectoral level. The results give no support for the hypothesis that export per se was a conduit of Chilean productivity growth in the manufacturing sector. On the contrary, we found a significant negative link from exports to productivity growth. However, the results suggest that the import of goods produced in the foreign sector stimulated productivity growth in the corresponding domestic sector.

In analysing the relationship between trade and productivity, Chile provides an interesting example. In late 1973, Chile initiated a comprehensive trade liberalisation programme, together with privatisation of state-owned firms and market deregulation. Following a balance-of-payment crisis that hit the country in 1982, the tariff rate was raised again. One of the main aims of the second trade liberalisation programme in the mid 1980s was to expand non-traditional exports through a devaluation of the exchange rate and assistance to export producers. At the same time, tariffs were reduced gradually to a uniform rate of 10 percent. Following the implementation of the structural adjustment programme in the mid 1980s, Chile experienced a rapid GDP growth. The role of exports in Chilean growth is debated. However, the most common view among

[4] See Giles and Williams (2000) for a comprehensive survey of applied research on export-led growth.

economists seems to be that the Chilean growth rate during the past 15 years has been export-led (Agosin, 1999; Ffrench-Davis, 2000).

The remainder of this paper is organized as follows. Section 2 briefly discusses the trade reform in Chile. Section 3 presents the methodology used to estimate productivity growth and the impact of trade and competition on productivity growth. Section 4 presents results. Conclusions are drawn in the final section.

2 The Chilean Trade Liberalisation

As in much of Latin America during the 1960s, Chile pursued a strategy of inward-oriented development. In late 1973, before the introduction of reforms, Chilean foreign trade was subject to a great deal of government control: nominal tariffs averaged 94 percent and ranged from 0 to 750 percent; 50 percent of all imports had to be authorised by the Central Bank; countless non-tariff barriers were in place, including the requirement of large advance deposits for imports, and; a complicated multi-rate exchange system (Agosin and Ffrensch-Davis, 1993). The Augusto Pinochet government that took control in 1973 implemented radical changes in policy. In less than four years (1975-1979) Chile eliminated all quantitative restrictions and exchange controls, and reduced tariffs to a uniform 10 percent (Edwards, 1998).

The first trade liberalisation program was not the success that the neo-liberalists had anticipated. During the first two years, the real depreciation of the government-controlled exchange rate offset the reduction in the average level of the protection. This gave a strong boost to exports and offered some protection for the import-substituting activities. The trade volume as a share of GDP tripled between 1973 and 1975. The export boom was most significant in the manufacturing sector. In 1976 the Chilean peso started to appreciate. When the first liberalisation program was completed in 1979, the real exchange rate was at almost the same level as it had been at the start of the liberalisation process. The main reason for the appreciation of the currency was the acceleration in capital inflows. The currency appreciation had a severe dampening effect on the production of tradable goods and hence, on the growth of exports. During the period 1974-1981, the economy underwent a rapid de-industrialization, as evidenced by the more than seven percent points drop on the manufacturing share of GDP. Many potentially strong manufacturing enterprises went bankrupt as a consequence of the particular combination of trade exchange policies. The mean annual GDP-growth during the period was 3.8 percent, which was lower than for the period 1962-1969 (see Table 1). Unemployment increased from 4.7 percent in 1973 to 13.6 percent in 1979.

A balance-of-payment crisis hit the country in 1982. As a consequence, monetary and trade policy became more flexible. A number of separate devaluations was instituted beginning in 1982 and the tariff rate was raised in stages up to a level of 35 percent in September 1984. In 1984 the Chilean government implemented a new "structural adjustment program", with the support of the IMF and the World Bank. The aim of the program was to expand non-traditional exports through a devaluation of the exchange rate and assistance to export producers, the encouragement of public savings and private investments, a strengthening of the regulations of the financial systems and a reduction of external debt. The main components of the program included: (i) export promotion through devaluation of the exchange rate; (ii) regulatory redesign for the financial sector in order to re-establish its role in savings mobilization and investment, (iii) fiscal actions to raise taxes and reduce expenditures; and (iv) reopening of the economy through tariff reductions (Ritter, 1992). As the structural adjustment program gathered strength, the average tariff rate was gradually scaled down to 11 percent in 1991.

Following the implementation of the structural adjustment programme in the mid 1980s, Chile experienced a rapid GDP growth (see Table 1). The economic growth rate was accompanied by a substantial increase in the volume of foreign trade. Even though manufacturing exports as a share of GDP increased during the 1990s, they did not increase with the same speed as did manufactured imports. Despite the success of the second liberalisation program the de-industrialization process set in motion by the first has not been reversed. However, the relative share of products with a larger share of value added has been expanding; investments have continued to increase; and the creation of new product capacity has begun to increase at a sustainable pace. The Chilean industry is now widely believed to be one of the most competitive in Latin America.

Table 1. GDP per capita, GDP growth, manufacturing value added, trade openness and manufacturing trade in Chile 1962-1997.

	1962-69	1970-73	1974-81	1982-84	1985-89	1990-97
GDP per capita[a]	2201	2412	2358	2391	2849	4184
GDP growth[b]	4.44	1.22	3.83	-2.33	7.42	7.73
Manufacturing value added, % of GDP[c]	24.2	25.3	23.0	21.3	18.2	18.8
Trade, % of GDP[d]	11.1	9.0	17.9	17.4	23.8	24.2
Manufacturing Exports, % of GDP[e]	0.8	0.9	4.0	4.0	5.4	5.8
Manufacturing Imports, of GDP[e]	7.9	6.3	11.2	9.5	15.1	18.9
Manufacturing exports, % of total exports[e]	6.7	9.9	22.3	23.1	20.5	24.6
Manufacturing imports, % of total imports[e]	75.4	72.8	61.9	56.1	70.0	76.4

[a] Constant 1995 US$, source: World Bank Development Indicators (WDBI).
[b] CAGR, source: WDBI.
[c] Current US$, source: WDBI.
[d] (Imports+exports)/2xGDP, source: UN trade statistics.
[e] Exclusive copper, source: Authors calculations based on UN trade statistics.

3 The Model and Data

The modelling strategy employed in this paper to estimate the effect of foreign trade on productivity is a two-step approach. First, TFP growth is estimated for each of the 30 sectors for the period 1979 to 1991 using plant-level data. Second, the impact of trade and competition on TFP growth is estimated with a dynamic panel data model.

3.1 Modelling Productivity Growth

The data used in the estimation of TFP growth is based on plant-level survey data collected by Statistics Chile. The original sample includes all plants in the manufacturing sector with more than ten employees, and covers the period 1979 to 1991. Unfortunately, data on capital stock was reported only in 1980 and 1981. Therefore, capital-stock variables, derived from the perpetual inventory method, could not be constructed for entrants after 1981.[5] Therefore, only plants observed for the whole sample period are included in the estimation of TFP growth. The attrition in the data set may lead to a bias of estimated TFP growth, since it does not take into account the effect on TFP growth from entering plants. TFP growth estimated in this paper should, as a consequence, not be interpreted as TFP growth for the entire industry, but as TFP growth for surviving plants during the period 1979 to 1991. Thus, industry rationalisation originating from exit and entry is not taken into account in this paper. The balanced panel consists of 10 816 observations of 832 plants in 30 industries at the four-digit level of the International Standard Industrial Classification (ISIC, rev 2).

To allow for heterogeneity we use plant-level data to estimate one production function for each of our 30 industries. The production technology for a plant *i* in industry *j* at time *t* is approximated as

$$Y_{jit} = \alpha_{ji}\delta_{jt}F(K_{jit}, L_{jit}, M_{jit})e^{\varepsilon_{jit}} \tag{1}$$

where Y_{jit} is the output for plant *i* at time *t* in industry *j*, α_{ji} is the intercept for plant *i* in industry *j*, δ_{jt} is the time-specific intercept term, and ε_{jit} is the stochastic error term. Output is a function of capital (*K*), labour (*L*), and material (*M*). Output is measured by sales adjusted for changes in inventories. Capital is defined as the book value of machines and equipment, corrected for the number of operating days. Data on investments and book value depreciations for the years after 1981 were used to construct the capital-stock variable. Labour input is defined in efficiency units, where the number of employees is computed in blue-collar workers' equivalents.[6] Material is defined as the cost of raw materials, energy inputs, goods purchased for resale, and contract work. All variables are deflated to 1986 prices using four-digit sector-specific price indices. Output price deflators were constructed directly from average-price indices obtained from Statistics Chile. Deflators for capital and raw materials were constructed from sectoral output prices using the 1986 Chilean input-output table.

[5] If all plants entered in the panel were new establishments, investment data could be used to calculate the capital-stock. However, since our data only cover plants with 10 or more workers, entry may also reflect an increase in labor over the cut-off point. Since we cannot identify the reason for entering the panel, all entering plants are excluded.

TFP growth ($\dot{TFP}$) for plant *i* is expressed as the ratio between output year t and the input aggregation function year t divided by the corresponding ratio for year t-1. In the case of constant returns to scale, F(·) fulfils all desired properties of an input aggregation function.[7] TFP growth may be calculated as

$$\dot{TFP}_{jit,t-1} = \frac{\hat{Y}_{jit} \big/ F(K_{jit}, L_{jit}, M_{jit})}{\hat{Y}_{ji,t-1} \big/ F(K_{ji,t-1}, L_{ji,t-1}, M_{ji,t-1})} = \frac{\delta_{jt}}{\delta_{j,t-1}}, \tag{2}$$

where $\dot{TFP}$ denotes TFP growth and $\widehat{Y}$ denotes estimated output level. This specification allows the level of total factor productivity to be plant-specific, while TFP growth is restricted to be identical across all plants in an industry. Thus, this specification can be used to estimate mean TFP growth in an industry, but is too restricted to provide information on TFP growth for individual plants.

Equation (1) is approximated with a translog production function and estimated as a two-way fixed effect model as follows:[8]

$$\ln Y_{it} = \alpha_i + \delta_t + \sum_{j=1}^{3} \beta_j \ln X_{jit} + \frac{1}{2} \sum_{j=1}^{3} \sum_{k=1}^{3} \beta_{jk} \ln X_{jit} \ln X_{kit} + \varepsilon_{it}. \tag{3}$$

The inputs X_1, X_2, and X_3 stand for capital, labour, and material respectively.

As mentioned, constant returns to scale technology is a condition for TFP growth to be expressed as in Equation (2). There are some suggestions in the literature on how to approximate TFP growth without any restrictions on returns to scale.[9] In practice, however, deviations from constant returns to scale are hard to pick up econometrically.[10] We choose to restrict the technology to constant returns, even though formal testing rejects this hypothesis in the majority of industries.[11] Unconstrained estimates generally

[6] See Granér (2002)
[7] See Diewert (1976) for a discussion of the properties of an input aggregation function.
[8] For convenience, the industry-subscripts are omitted.
[9] See e.g. Bjurek (1996).
[10] See Westbrook and Tybout (1993) and (1996).
[11] Test for linearly homogeneity was rejected in 23 of 30 industries.

exhibit decreasing returns.[12] This implausible result is most likely due to measurement error and, following Liu and Tybout (1996), we adopt the constant returns restriction.[13]

3.2 Modelling the Effect of Trade and Competition

For each industry, the shares of exports and imports as a share of total sales from domestic production, the price-cost margin and the Herfindahl index were calculated. Exports and imports at the industry level were estimated by converting the United Nations commodity trade statistics at the five digit levels of the Standard International Trade Classification (SITC) to the ISIC four digit levels. The price-cost margin is calculated as the value of sector output minus expenditures on labour and materials over the value of output. This is equivalent to economic profits plus payments to fixed factors (capital) as a proportion of industrial level revenue. Thus, the price-cost margin varies across industries with variations in capital intensity and economic profit. Since capital stocks change slowly over time, temporal variations in the margin are likely to reflect mostly variations in economic profit (Roberts and Tybout, 1996). The rationale for inclusion of the price-cost margin in the regressions is that variations in the margin reflect variations in economic profit, which, in turn, reflects the competitive environment. The lower the margin, the stiffer the competition in the sector. However, the excess profits may result from differences in productive efficiency across plants instead of non-competitive behaviour.[14] The weaknesses of the price-cost margin as a measure of domestic competition motivate an alternative measure – the Herfindahl index for industry level concentration. The Herfindahl index is equal to the sum of the square of the market shares of firms in each sector.[15] The index varies between zero and one. The higher the value, the higher is the concentration in the sector. High concentration is thought to indicate weak competition. Means of TFP growth and the explanatory variables by sector are given in Appendix 1.

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[12] Returns to scale evaluated at means were decreasing in 25 of 30 industries.

[13] Measurement errors is thought to bias output elasticities downward. See Westbrook and Tybout (1993) for an analysis of measurement error bias in production function estimation.

[14] On the other hand, variations in productive efficiency across establishment may be an indication of loose competition since competitive pressure force inefficient plants to exit.

[15] The price-cost margin and the Herfindahl index are calculated from a dataset including all plants in the manufacturing sector with at least ten employees.

The main model used to estimate the effect of trade and competition on productivity growth is formulated as follows:

$$\ln T\dot{F}P_{it} = \sum_{j=1}^{p} \alpha_j T\dot{F}P_{t-j} + \sum_{k=1}^{n} \left[\beta_{1k} MS_{t-k} + \beta_{2k} XS_{t-k} + \beta_{3k} \ln PCM_{t-k} + \beta_{4k} HF_{t-k\,it}\right] + \left(\eta_i + \nu_{it}\right) \qquad (4)$$

where $\ln T\dot{F}P$ is the log of growth rate of total factor productivity, *MS* is the import share, *XS* the export share, ln *PCM* is the log of the price-cost margin, and *HF* is the Herfindahl index. The residuals, η_i and ν_{it}, are the usual "fixed effects" decomposition of the error term. In the econometric model, current TFP growth is specified to depend only on past values of the independent variables. This prevents the interpretation of causality running from TFP growth to the independent variables and mitigates endogeneity bias. Moreover, it seems to be a plausible assumption that the effect on TFP growth from variations in the explanatory variables is not instantaneous, but that there is a time lag before changes in trade volumes or domestic competition affect productivity growth.

In panel data models substantial complications arise in the estimation of such dynamic models. Since TFP_{it} is a function of η_i, TFP_{t-j} is also a function of η_i. This renders the OLS estimator to be biased. Within transformation wipes out the time invariant error term, but with fixed T, the within-transformed lagged dependent variable will still be correlated with the within-transformed error term. Therefore, the within estimator will be biased and its consistency depends upon T being large. The same problem occurs with the random effects GLS estimator.[16]

Anderson and Hsiao (1981) suggested first differencing the model to get rid of individual effect and then using $\Delta y_{i,t-2}$ (where y is the dependent variable) or $y_{i,t-2}$ as an instrument for $\Delta y_{i,t-1}$ to avoid correlation with the residual disturbances, $\Delta \nu_{it}$. Arellano (1989) recommends instruments in level, as opposed to instruments in differences, since level instruments have no singularities and much smaller variances. This instrumental variable estimation method leads to consistent but not necessarily efficient estimates.[17]

[16] See chapter 8 in Baltagi (1995).
[17] See Ahn and Schmidt (1995).

Arellano and Bond (1991) suggest a linear generalised method of moments (GMM) estimator with ($y_{i1},y_{i2},\ldots,y_{i,T-2}$) as the set of valid instruments.

The linear GMM estimator obtained after first differencing has sometimes been found to have large finite sample bias and poor precision in simulation studies.[18] The poor precision is mainly because lagged levels of the series provide weak instruments for first differences. Blundell and Bond (1998) suggest an alternative estimator with an extended linear GMM estimator that uses lagged differences of y_{it} as instruments for equations in levels in addition to lagged levels of y_{it} as instruments for equations in first differences. Monte-Carlo simulations show that this estimator offers notable efficiency gains in the situations where the first–differenced GMM estimator performs poorly.

In the estimation of equation (4), the system GMM-estimator proposed by Blundell and Bond (1998) is used.[19] All explanatory variables are treated as endogenous. The instruments used in differenced equations are $\{TFP_{t-2}, TFP_{t-3},\ldots, TFP_{t-7}; MS_{t-2}, MS_{t-3},\ldots, MS_{t-7}; XS_{t-2}, XS_{t-3},\ldots,XS_{t-7}; PCM_{t-2}, PCM_{t-3},\ldots, PCM_{t-7}; HF_{t-2}, HF_{t-3},\ldots,HF_{t-7}\}$. The instruments used in level equations are $\{\Delta TFP_{t-1}, \Delta MS_{t-1}, \Delta XS_{t-1}, \Delta PCM_{t-1}, \Delta HF_{t-1}\}$.

4 Results

A look at the simple correlation coefficients between the variables in the econometric analysis gives a better knowledge of the data and helps one understand the regression results. The only variables significantly correlated with TFP growth are the import share and the Herfindahl index, but only at the ten percent level. Export share is negatively correlated with the price-cost margin and the Herfindahl index. Hence, export-intensive industries appear to have a higher degree of competition than more inward-oriented industries. Import share is negatively correlated with price-cost and positively correlated with the Herfindahl index. This makes sense since increased competitive pressure from foreign competitors is expected to lower the price-cost margin while competition from abroad increases concentration by reducing the number of domestic firms. The price-cost

[18] See Alonso-Borrego and Arellano (1996).

[19] The one-step estimator is chosen here. In Blundell and Bond (1998) it is found that while asymptotic *t*-tests based on the one step estimator are found to have correct empirical level in Monte Carlo simulations,

margin is positively correlated with the Herfindahl index. This suggests that increased concentration results in lower competitive pressure and higher profits.

Table 2. Pearsons correlation between TFP-growth, export share, import share, price-cost margin, and Herfindahl index.

	ln TFP-growth	Export share	Import share	*ln* Price-cost margin	Herfindahl index
ln TFP growth	1	-0.07	0.09^{*}	0.03	0.09^{*}
Export share	-0.07	1	-0.06	-0.09^{*}	-0.09^{**}
Import share	0.09^{*}	-0.06	1	-0.17^{***}	0.13^{**}
ln Price-cost margin	0.03	-0.09^{*}	-0.17^{***}	1	0.29^{***}
Herfindahl	0.09^{*}	-0.09^{**}	0.13^{**}	0.29^{***}	1

Note: * Indicates that the correlation is statistically significant different from zero at the ten percent level, ** at the five percent level, ***at the one percent level.

The lag length for the dependent variable, the natural logarithm of TFP growth, was set to three. A shorter lag length resulted in second order serial correlation. To avoid a too severe loss of degrees of freedom, a longer lag length than three was not considered. The parameters of the dependent variables were estimated with a lag length of one, two and three. Parameter estimates and hypotheses tests of all models are given in Appendix 2. The long-run marginal effects of the explanatory variables calculated from the GMM estimates of the productivity growth equation are presented in Table 2.

Granger causality tests are typically based on an information set of only two variables. Therefore, it is of interest to compare the results from the bivariate models with multivariate models. Models 1 to 4 give the long run marginal effects from bivariate estimations of the natural logarithm of TFP growth on lags of import share, export share, price-cost margin, and the Herfindahl index respectively. The only significant variable in the bivariate regressions is the Herfindahl index, with a positive long run marginal effect.

In model 5, the TFP growth is regressed against import share and export share, without controlling for domestic competition. Since one of the main arguments for a growth-effect from trade is that it increases competition, the effect from trade when domestic competition is controlled for may be underestimated. When the import share is controlled for, the export share shows a significant negative long run marginal effect on

the asymptotic *t*-tests based on the two-step GMM-estimator can be "seriously misleading", and tend to reject too frequently.

TFP growth. However, this result is only significant at the ten percent level for the specifications with one respectively two lags.

When the price-cost margin is added as an explanatory variable together with the import share and the export share the significance of the trade variables improves dramatically (model 6). Both import share and export share come out with significant long-run marginal effects, independently of lag length. The results from this model suggest that imports have a positive effect on TFP growth, while exports still have a negative effect. With a lag length of three years, the price-cost margin comes out with a positive and highly significant long run marginal effect.

In model 7, the price-cost margin is replaced with the alternative measure of the competitive environment in an industry - the Herfindahl index. As in the bivariate model, the long-run marginal effect of the Herfindahl index on TFP growth is significant at the five percent level with two lags. The long run effect of both the import and export shares are insignificant in this model.

Table 3. Long run marginal effects on *ln* TFP growth with respect to imports share, export share, *ln* price-cost margin and the Herfindahl index.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
One lag								
Import share	0.018		--	--	0.017	0.019**	0.014	0.016*
Export share	--	-0.044	--	--	-0.043*	-0.044**	-0.039	-0.040*
*ln*Price-cost margin	--	--	0.010		--	0.016	--	0.015
Herfindahl	--	--	--	0.148*	--	--	0.117	0.111
Two lags								
Import share	0.021	--	--	--	0.019	0.025**	0.015	0.020*
Export share	--	-0.042	--	--	-0.040*	-0.042***	-0.037	-0.040**
*ln*Price-cost margin	--	--	0.023	--	--	0.032*	--	0.029
Herfindahl	--	--	--	0.219**	--	--	0.185**	0.174**
Three lags								
Import share	0.028	--	--	--	0.027	0.036***	0.021	0.031***
Export share	--	-0.043	--	--	-0.039**	-0.037***	-0.037*	-0.035**
*Ln*Price-cost margin	--	--	0.032	--	--	0.046***	--	0.043**
Herfindahl	--	--	--	0.212**	--	--	0.170*	0.146

Note: * Indicates that the long run marginal effect is statistically significant different from zero at the ten percent level, ** at the five percent level, *** at the one percent level.

Finally, model 8 gives the long run marginal effects when all the explanatory variables are included in the regression. With a lag length of one year, the long run marginal effects are significant for import share and export share, but only at the ten percent level. With a two year lag the negative marginal effect from export share becomes significant at the five percent level and the Herfindahl index shows a positive effect at the same significance level. The Herfindahl index becomes insignificant when a third lag is added to the model. However, the estimates still suggest that stiffer competition have a negative effect on TFP growth since the price-cost margin shows a positive long-run marginal effect. The addition of a third lag also results in a positive and strongly significant effect from import share on TFP growth.

5 Conclusions

The results in this paper suggest that import competition rather than exports was the important conduit of productivity growth in Chilean manufacturing during the period 1980 to 1991. This is in line with estimates for Japan in Lawrence and Weinstein (1999). This challenges the export promotion hypothesis, which suggests that exports and export policy plays a crucial role in stimulating growth. Conversely, the results in this paper indicate a negative impact of exports on Total Factor Productivity (TFP) growth at the industry level.

The results provide no evidence for the hypothesis that increased domestic competition fosters productivity growth in Chile. On the contrary, the estimation results suggest that both the price-cost margin and firm concentration in an industry have a positive impact on productivity growth when trade is controlled for. The positive effect of the price-cost margin on TFP may be explained within the context of the endogenous growth theory. High profits increase outlays on research and development as well as innovations.

In the light of the negative effect of domestic competition on productivity growth, the argument that imports increase productivity growth by fostering domestic competition seems to be less valid in the case of Chilean manufacturing sector. Therefore, one may conclude that the positive effect from import competition is simply that the quality of firms in the industry might rise because the added competition from foreign firms. This might occur because domestic firms learn by examining foreign imports or because the foreign competition spurs innovation (Lawrence and Weinstein, 1999).

The evidence for the reverse of “export-led” growth is quite unexpected. Some earlier studies at the industry level, however, have found a negative relation between technical efficiency or productivity growth and exports. Caves and Barton (1990) and Mayes and Green (1992) found a negative relation between the export share and mean technical efficiency in the U.S. and U.K. manufacturing respectively. For Morocco, Haddad, de Melo, and Horton (1996) found a negative impact of export growth on TFP growth in manufacturing. One explanation for the negative sign is that Chilean exporters benefited most in the early stage of the trade liberalisation and that inward-oriented firms were catching up during the period that the data covers. Another possible explanation is that the devaluations in Chile during the 1980s, aimed at promoting exports, resulted in a relaxation of technological and managerial effort in the export sector.

Appendix 1

Table A1.1. Means of TFP growth, export shares, import shares, price-cost margins, and the Herfindahl index by sector, 1980-1985 and 1986-1991.

	TFP growth		Export share		Import Share		Price-cost margin		Herfindahl	
ISIC number	1980-1985	1986-1991	1980-1985	1986-1991	1980-1985	1986-1991	1980-1985	1986-1991	1980-1985	1986-1991
3111	3.6	1.1	2.5	4.1	4.7	1.8	26.6	25.5	5.3	4.4
3112	1.6	-2.1	0.1	0.9	7.6	4.3	26.5	23.9	8.8	9.7
3113	3.4	1.2	15.6	43.9	2.9	1.9	36.3	27.3	8.4	6.3
3114	-1.7	-2.0	91.6	95.7	3.6	1.8	13.5	19.1	5.8	2.2
3115	3.8	-2.1	52.0	53.1	12.3	5.6	20.5	32.2	4.4	3.2
3116	-1.1	1.8	1.1	1.6	2.0	1.6	15.5	17.9	2.3	2.8
3121	-0.5	2.0	0.8	2.1	19.8	14.3	45.0	37.8	11.1	8.5
3132	-5.8	0.2	8.3	19.3	0.4	0.2	38.5	32.2	5.8	8.5
3211	1.9	-0.4	1.0	6.3	33.6	29.9	27.0	29.7	3.0	2.9
3213	2.3	3.3	0.2	3.3	18.1	12.8	27.0	25.4	2.7	2.8
3220	2.4	4.9	0.2	4.4	14.9	7.3	23.6	23.9	1.8	2.3
3231	5.1	0.1	1.0	1.0	5.9	13.0	23.1	22.1	7.8	7.3
3240	8.5	-2.2	0.2	6.4	7.0	3.7	30.6	26.2	6.2	4.0
3311	5.9	0.4	23.6	35.4	0.7	0.5	31.7	27.9	3.6	2.5
3320	1.1	2.0	1.0	8.7	6.9	2.9	27.3	28.1	5.9	5.6
3410	4.9	1.5	39.1	38.6	9.6	9.8	41.9	44.9	11.6	10.4
3420	-6.6	-1.1	1.7	6.2	7.1	5.4	38.2	34.9	10.1	6.9
3511	1.8	9.3	45.3	60.7	125.4	103.9	44.1	39.7	11.5	10.0
3521	7.0	-3.6	0.1	0.6	7.4	8.6	27.3	22.2	10.0	8.6
3522	6.5	-1.2	0.3	1.7	12.3	16.1	43.3	36.7	4.9	5.4
3523	4.0	-2.6	0.1	2.1	9.4	7.0	42.6	39.9	24.9	22.9
3529	4.7	1.3	1.3	2.3	55.2	43.9	38.4	29.8	6.8	7.5
3550	6.9	1.7	3.9	15.5	30.8	51.3	30.9	32.1	18.7	20.6
3620	7.4	-0.8	1.5	2.7	35.5	38.4	43.9	44.6	27.1	26.3
3691	4.2	12.7	0.3	1.4	41.8	32.5	25.5	33.5	22.5	23.2
3811	8.0	8.7	1.4	3.3	114.1	112.7	19.4	31.2	11.4	9.8
3813	-6.5	7.4	0.3	0.2	24.0	15.9	27.1	24.6	3.2	3.9
3819	2.8	3.8	9.8	17.9	53.7	75.4	31.8	30.1	4.1	7.0
3820	1.2	5.4	3.4	3.5	184.7	256.1	11.7	12.1	8.2	6.1
3830	5.1	3.9	3.9	3.7	115.6	124.9	32.5	33.5	8.1	7.3
All sectors	2.7	1.8	10.7	15.2	32.2	33.4	30.4	29.6	9.0	8.0

Appendix 2

Parameter estimates and hypothesis tests

Table A2.1. Parameter estimates and hypotheses tests for the TFP growth equations with one lag.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
TFP_{t-1}	-0.452[c]	-0.464[c]	-0.458[c]	-0.468[c]	-0.462[c]	-0.469[c]	-0.472[c]	-0.479[c]
	(7.75)	(7.87)	(7.66)	(8.16)	(7.86)	(7.80)	(8.20)	(8.06)
TFP_{t-2}	-0.277[c]	-0.285[c]	-0.284[c]	-0.288[c]	-0.285[c]	-0.296[c]	-0.293[c]	-0.303[c]
	(3.55)	(3.52)	(3.57)	(3.72)	(3.53)	(3.64)	(3.70)	(3.78)
TFP_{t-3}	-0.104[b]	-0.119[c]	-0.111[c]	-0.121[c]	-0.115[c]	-0.118[c]	-0.125[c]	-0.127[c]
	(2.50)	(2.73)	(2.74)	(3.25)	(2.61)	(2.75)	(3.11)	(3.23)
MS_{t-1}	0.033	--	--	--	0.032	0.036[b]	0.221	0.031[a]
	(1.64)				(1.64)	(2.19)	(1.32)	(1.78)
XS_{t-1}	--	-0.082	--	--	-0.080[a]	-0.083[b]	-0.074	-0.077[a]
		(1.51)			(1.77)	(2.19)	(1.58)	(1.92)
$lnPCM_{t-1}$	--	--	0.019	--	--	0.030	--	0.028
			(0.67)			(1.01)		(0.94)
HF_{t-1}	--	--	--	0.278[a]	--	--	0.221	0.213
				(1.81)			(1.39)	(1.38)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Hypothesis tests:								
First-order serial corr.	-3.72[30]^{c}	-3.62[30]^{c}	-3.70[30]^{c}	-3.67[30]^{c}	-3.67[30]^{c}	-3.72[30]^{c}	-3.67[30]^{c}	-3.71[30]^{c}
Second-order serial corr.	0.41[30]	0.46[30]	0.53[30]	0.40[30]	0.43[30]	0.58[30]	0.41[30]	0.55[30]
Sargan	21.5[256]	22.4[256]	20.5[256]	21.0[256]	22.0[255]	18.9[254]	20.9[254]	19.2[253]
Joint significance	60.8[4]^{c}	63.6[4]^{c}	60.2[4]^{c}	68.6[5]^{c}	63.0[5]^{c}	63.3[6]^{c}	70.8[6]^{c}	70.3[7]^{c}
Long run marginal effects:								
MS	1.47[1]	--	--	--	2.68[1]	2.68[1]	1.75[1]	3.20[1]^{a}
XS	--	2.51[1]	--	--	3.51[1]^{a}	5.01[1]^{b}	2.60[1]	3.72[1]^{a}
PCM	--		0.46[1]	--	--	4.82[1]^{b}	--	0.89[1]
HF	--		--	3.37[1]^{a}	--	--	1.90[1]	1.92[1]

Notes:

1. ^{a}Significance at 10% level. ^{b}Significance at 5% level. ^{c}Significance at 1% level.
2. Year dummies are included in all specifications.
3. The absolute values of asymptotic t-ratios, asymptotically robust to heteroskedasticity, are reported in parenthesis.
4. Tests for first-order and second-order serial correlation are asymptotically distributed as N(0,1) under the null of no serial correlation. The tests for serial correlation are on differenced residuals, the disturbances are not correlated if there is evidence of significant negative first order serial correlation and there was no evidence of second order serial correlation. Degrees of freedom are reported in parenthesis.
5. Sargan is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null of instrument validity. Degrees of freedom are reported in parenthesis.
6. Joint significance is a Wald test of all parameters except intercept and the parameters for year dummies.
7. The tests for long run marginal effects are Wald tests of the null that $\beta_k/(1-\Sigma\alpha_k)=0$. Degrees of freedom are reported in parenthesis.
8. The instruments used in differenced equations are $\{TFP_{t-2}, TFP_{t-3}, \ldots, TFP_{t-7}; MS_{t-2}, MS_{t-3}, \ldots, MS_{t-7}; XS_{t-2}, XS_{t-3}, \ldots, XS_{t-7}; PCM_{t-2}, PCM_{t-3}, \ldots, PCM_{t-7}; HF_{t-2}, HF_{t-3}, \ldots, HF_{t-7}\}$. The instruments used in level equations are $\{\Delta TFP_{t-1}, \Delta MS_{t-1}, \Delta XS_{t-1}, \Delta PCM_{t-1}, \Delta HF_{t-1}\}$.

Table A2.2. Parameter estimates and hypotheses tests for the TFP growth equations with two lags.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
TFP_{t-1}	-0.454[c] (7.79)	-0.464[c] (7.94)	-0457[c] (7.44)	-0.478[c] (7.99)	-0.463[c] (7.94)	-0.470[c] (7.62)	-0.484[c] (8.10)	-0.488[c] (7.61)
TFP_{t-2}	-0.279[c] (3.60)	-0.284[c] (3.53)	-0.288[c] (3.69)	-0.299[c] (3.86)	-0.286[c] (3.58)	-0.305[c] (3.89)	-0.305[c] (3.88)	-0.321[c] (4.10)
TFP_{t-3}	-0.108[b] (2.56)	-0.122[c] (2.76)	-0.117[c] (2.90)	-0.128[c] (3.26)	-0.120[c] (2.69)	-0.130[c] (2.98)	-0.135[c] (3.20)	-0.144[c] (3.29)
MS_{t-1}	0.024 (1.15)	--	--	--	0.028 (1.29)	0.031 (1.23)	0.023 (1.06)	0.026 (1.01)
MS_{t-2}	0.015 (0.38)	--	--	--	0.009 (0.22)	0.017 (0.47)	0.005 (0.11)	0.013 (0.32)
XS_{t-1}	--	-0.098 (1.45)	--	--	-0.100 (1.60)	-0.088 (1.75)	-0.094 (1.56)	-0.081 (1.60)
XS_{t-2}	--	0.020 (0.53)	--	--	0.026 (0.63)	0.008 (0.22)	0.022 (0.56)	0.004 (0.10)
$ln PCM_{t-1}$	--	--	0.009 (0.31)	--	--	0.021 (0.77)	--	0.016 (0.57)
$ln PCM_{t-2}$	--	--	0.034 (1.64)	--	--	0.040 (1.88)	--	0.040[c] (1.86)
HF_{t-1}	--	--	--	0.149 (0.57)	--	--	0.088 (0.32)	0.094 (0.36)
HF_{t-2}	--	--	--	0.269 (1.02)	--	--	0.267 (1.04)	0.247 (0.94)

Table A2.2. (cont.)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Hypothesis tests:								
First-order serial corr.	-3.71[30][c]	-3.61[30][c]	-3.61[30][c]	-3.80[30][c]	-3.66[30][c]	-3.58[30][c]	-3.69[30][c]	-3.60[30][c]
Second-order serial corr.	0.41[30]	0.46[30]	0.46[30]	0.24[30]	0.42[30]	0.49[30]	0.24[30]	0.31[30]
Sargan	19.0[255]	21.2[255]	18.2[255]	20.7[255]	16.8[253]	14.4[251]	14.2[251]	11.6[249]
Joint significance	61.2[5][c]	68.2[6][c]	109.4[5][c]	68.8[5][c]	67.5[7][c]	123.1[7][c]	76.7[9][c]	150.0[11][c]
Import share:								
$\beta_{11}=\beta_{12}=0$	3.05[2]	--	--	--	3.32[2]	7.53[2][b]	2.65[2]	5.36[2][a]
$\Sigma\beta_{1k}=0$	1.44[1]	--	--	--	1.32[1]	4.90[1][b]	0.77[1]	2.91[1][a]
$\Sigma\beta_{1k}/(1-\Sigma\alpha_j)=0$	1.47[1]	--	--	--	1.33[1]	4.92[1][b]	0.78[1]	2.98[1][a]
Export share:								
$\beta_{21}=\beta_{22}=0$	--	2.29[2]	--	--	3.03[2]	6.58[2][b]	2.90[2]	5.50[2][a]
$\Sigma\beta_{2k}=0$	--	2.07[1]	--	--	2.74[1][a]	6.57[1][b]	2.65[1]	5.49[1][b]
$\Sigma\beta_{2k}/(1-\Sigma\alpha_j)=0$	--	2.27[1]	--	--	3.00[1][a]	6.74[1][c]	2.80[1][a]	5.44[1][b]
Price-cost margin:								
$\beta_{31}=\beta_{32}=0$	--	--	2.92[2]	--	--	4.25[2]	--	3.69[2]
$\Sigma\beta_{3k}=0$	--	--	1.63[1]	--	--	3.28[1][a]	--	2.36[1]
$\Sigma\beta_{3k}/(1-\Sigma\alpha_j)=0$	--	--	1.62 [1]	--	--	3.19[1][a]	--	2.35[1]
Herfindahl:								
$\beta_{41}=\beta_{42}=0$	--	--	--	6.03[2][b]	--	--	4.76[2][a]	4.23[2]
$\Sigma\beta_{4k}=0$	--	--	--	5.98[1][b]	--	--	4.40[1][b]	4.15[1][b]
$\Sigma\beta_{4k}/(1-\Sigma\alpha_j)=0$	--	--	--	6.38[1][b]	--	--	4.45[1][b]	4.42[1][b]

Notes:
1. [a]Significance at 10% level. [b]Significance at 5% level. [c]Significance at 1% level.
2. Year dummies are included in all specifications.
3. The absolute value of asymptotic t-ratios, asymptotically robust to heteroskedasticity, are reported in parenthesis.
4. Tests for first-order and second-order serial correlation are asymptotically distributed as N(0,1) under the null of no serial correlation. The tests for serial correlation are on differenced residuals, the disturbances are not correlated if there is evidence of significant negative first order serial correlation and there was no evidence of second order serial correlation. Degrees of freedom are reported in parenthesis.
5. Sargan is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null of instrument validity. Degrees of freedom are reported in parenthesis.
6. Joint significance is a Wald test of all parameters except intercept and the parameters for year dummies.
7. The test $\Sigma\beta_k/(1-\Sigma\alpha_j)=0$ is a test of the significance of the long run marginal effect. Degrees of freedom are reported in parenthesis.
8. The instruments used in differenced equations are $\{TFP_{t-2}, TFP_{t-3},\dots, TFP_{t-7}; MS_{t-2}, MS_{t-3},\dots, MS_{t-7}; XS_{t-2}, XS_{t-3},\dots, XS_{t-7}; PCM_{t-2}, PCM_{t-3},\dots, PCM_{t-7}; HF_{t-2}, HF_{t-3},\dots, HF_{t-7}\}$. The instruments used in level equations are $\{\Delta TFP_{t-1}, \Delta MS_{t-1}, \Delta XS_{t-1}, \Delta PCM_{t-1}, \Delta HF_{t-1}\}$.

Table A2.3. Parameter estimates and hypotheses tests for the TFP growth equations with three lags.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
TFP_{t-1}	-0.459^{c}	-0.465^{c}	-0.464^{c}	-0.477^{c}	-0.469^{c}	-0.488^{c}	-0.487^{c}	-0.502^{c}
	(7.84)	(7.98)	(7.85)	(7.80)	(8.12)	(8.50)	(8.19)	(8.13)
TFP_{t-2}	-0.279^{c}	-0.285^{c}	-0.286^{c}	-0.298^{c}	-0.287^{c}	-0.304^{c}	-0.304^{c}	-0.316^{c}
	(3.59)	(3.52)	(3.67)	(3.82)	(3.59)	(3.90)	(3.90)	(3.97)
TFP_{t-3}	-0.109^{c}	-0.123^{c}	-0.121^{c}	-0.126^{c}	-0.125^{c}	-0.142^{c}	-0.138^{c}	-0.151^{c}
	(2.57)	(2.73)	(3.02)	(3.00)	(2.84)	(3.39)	(3.20)	(3.45)
MS_{t-1}	-0.011	--	--	--	-0.008	-0.006	-0.008	-0.005
	(0.40)				(0.27)	(0.20)	(0.30)	(0.15)
MS_{t-2}	-0.010	--	--	--	-0.019	-0.011	-0.021	-0.014
	(0.26)				(0.46)	(0.33)	(0.47)	(0.36)
MS_{t-3}	0.074^{c}	--	--	--	0.077^{b}	0.088^{c}	0.071^{c}	0.080^{c}
	(2.68)				(2.54)	(3.88)	(3.14)	(5.15)
XS_{t-1}	--	-0.089	--	--	-0.093	-0.080	-0.090	-0.079
		(1.08)			(1.20)	(1.19)	(1.19)	(1.16)
XS_{t-2}	--	0.027	--	--	0.058	0.053	0.051	0.045
		(0.60)			(1.08)	(1.11)	(1.01)	(0.99)
XS_{t-3}	--	-0.018	--	--	-0.038	-0.044	-0.031	-0.034
		(0.27)			(0.53)	(0.66)	(0.45)	(0.53)
$ln PCM_{t-1}$	--	--	0.007	--	--	0.021	--	0.016
			(0.24)			(0.81)		(0.56)
$ln PCM_{t-2}$	--	--	0.030	--	--	0.037^{b}	--	0.038^{b}
			(1.46)			(2.10)		(2.13)
$ln PCM_{t-3}$	--	--	0.023	--	--	0.032	--	0.032
			(1.09)			(1.57)		(1.58)
HF_{t-1}	--	--	--	0.168	--	--	0.093	0.124
				(0.53)			(0.29)	(0.39)
HF_{t-2}	--	--	--	0.285	--	--	0.253	0.248
				(1.06)			(1.00)	(0.99)
HF_{t-3}	--	--	--	-0.051	--	--	-0.018	-0.084
				(0.16)			(0.07)	(0.29)

Table A1.3. (cont.)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Hypothesis tests:								
First-order serial corr.	-3.78[30][c]	-3.62[30][c]	-3.70[30][c]	-3.74[30][c]	-3.74[30][c]	-3.78[30][c]	-3.74[30][c]	-3.69[30][c]
Second-order serial corr.	0.44[30]	0.50[30]	0.26[30]	0.23[30]	0.54[30]	0.38[30]	0.34[30]	0.11[30]
Sargan	19.6[254]	20.2[254]	18.5[254]	18.9[254]	18.6[251]	13.2[248]	12.3[248]	8.21[245]
Joint significance	72.8[6][c]	69.8[6][c]	112.2[6][c]	70.9[6][c]	89.0[9][c]	173.9[12][c]	190.6[12][c]	322.1[15][c]
Import share:								
$\beta_{11}=\beta_{12}=\beta_{13}=0$	9.51[3][b]	--	--	--	8.28[3][b]	26.3[3][c]	11.8[3][c]	33.7[3][c]
$\Sigma\beta_{1k}=0$	2.09[1]	--	--	--	2.01[1]	13.4[1][c]	1.35[1]	9.15[1][c]
$\Sigma\beta_{1k}/(1-\Sigma\alpha_j)=0$	2.14[1]	--	--	--	2.04[1]	13.0[1][c]	1.37[1]	8.87[1][c]
Export share:								
$\beta_{21}=\beta_{22}=\beta_{23}=0$	--	2.83[3]	--	--	7.03[3][a]	10.9[3][b]	6.87[3][a]	8.26[3][b]
$\Sigma\beta_{2k}=0$	--	2.36[1]	--	--	3.48[1][a]	7.51[1][c]	3.29[1][a]	5.54[1][b]
$\Sigma\beta_{2k}/(1-\Sigma\alpha_j)=0$	--	2.61[1]	--	--	3.88[1][b]	6.94[1][c]	3.49[1][a]	5.17[1][b]
Price-cost margin:								
$\beta_{31}=\beta_{32}=\beta_{33}=0$	--	--	3.90[3]	--	--	9.19[3][b]	--	7.83[3][b]
$\Sigma\beta_{3k}=0$	--	--	2.55[1]	--	--	7.32[1][c]	--	5.73[1][b]
$\Sigma\beta_{3k}/(1-\Sigma\alpha_j)=0$	--	--	2.52[1]	--	--	7.04[1][c]	--	5.72[1][b]
Herfindahl:								
$\beta_{41}=\beta_{42}=\beta_{43}=0$	--	--	--	6.10[3]	--	--	4.60[3]	4.82[3]
$\Sigma\beta_{4k}=0$	--	--	--	4.69[1][b]	--	--	3.38[1][a]	2.21[1]
$\Sigma\beta_{4k}/(1-\Sigma\alpha_j)=0$	--	--	--	5.16[1][b]	--	--	3.48[1][a]	2.42[1]

Notes:
1. [a]Significance at 10% level. [b]Significance at 5% level. [c]Significance at 1% level.
2. Year dummies are included in all specifications.
3. The absolute value of asymptotic t-ratios, asymptotically robust to heteroskedasticity, are reported in parenthesis.
4. Tests for first-order and second-order serial correlation are asymptotically distributed as N(0,1) under the null of no serial correlation. The tests for serial correlation are on differenced residuals, the disturbances are not correlated if there is evidence of significant negative first order serial correlation and there was no evidence of second order serial correlation. Degrees of freedom are reported in parenthesis.
5. Sargan is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null of instrument validity. Degrees of freedom are reported in parenthesis.
6. Joint significance is a Wald test of all parameters except intercept and the parameters for year dummies.
7. The test $\Sigma\beta_k/(1-\Sigma\alpha_j)=0$ is a test of the significance of the long run marginal effect. Degrees of freedom are reported in parenthesis.
8. The instruments used in differenced equations are $\{TFP_{t-2}, TFP_{t-3},\ldots, TFP_{t-7}; MS_{t-2}, MS_{t-3},\ldots, MS_{t-7}; XS_{t-2}, XS_{t-3},\ldots, XS_{t-7}; PCM_{t-2}, PCM_{t-3},\ldots, PCM_{t-7}; HF_{t-2}, HF_{t-3},\ldots, HF_{t-7}\}$. The instruments used in level equations are $\{\Delta TFP_{t-1}, \Delta MS_{t-1}, \Delta XS_{t-1}, \Delta PCM_{t-1}, \Delta HF_{t-1}\}$.

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Export-led Efficiency or Efficiency-led Exports? Evidence from the Chilean Manufacturing Sector

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Abstract: This paper examines whether the higher productive efficiency among exporting plants in Chilean manufacturing is a result of learning or self-selection. A method to calculate deviations from potential productivity, referred to as Total Factor Efficiency, using a translog production function is proposed. We found no significant differences in total factor efficiency, technical efficiency or scale efficiency between plants with either a long or a short export history. Plants just prior to the start of exporting are significantly more productive than plants that remain out of the export market. This suggests that relatively efficient firms self-select into the export market.

Keywords: Manufacturing exports, learning-by-exporting, self-selection, total factor efficiency, scale efficiency, technical efficiency, Chile

JEL-classification: D24, F14, L60, O12

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1 Introduction

The neoclassical relationship between exports and economic growth and the differences between export promotion and import-substitution have been a subject of much interest in the development literature. Since the 1970's import-substitution policy has come under challenge by an emerging consensus in favour of export promotion in developing countries. Although some studies, for example Rodrik (1997), have questioned their effectiveness, export promotion and export-led growth have become still the strategies favoured by mainstream practitioners of economic theory and policy.

Most empirical research looking for evidence of export-led growth analyses the relation between output growth and export growth using cross-country data or times-series data for individual countries.[20] Almost all of these studies regress the growth rate of GNP on the growth rate of exports. Although the results from these studies have varied in some respects, the results generally provide support for the export-led growth hypothesis. There is, however, a need for caution in interpreting the results from both cross-country and times-series studies.[21] One reason is the difficulty to isolating the effect of trade policy from the effect of the macro-stabilisation programmes typically accompanying trade liberalisation. Higher growth rate in productivity is not necessarily determined by trade, but rather by different processes which are independent of exports and trade policy. Another weakness with many studies testing the effects of export-promotion on economic growth is that the direction of causality from exports to growth is taken for granted.[22]

Since the explanation of the link between export activities and productivity emphasises improved firm performance, there is a need for micro studies based on firm- or plant-level data. This study uses a census-based plant-level dataset for the Chilean manufacturing sector covering the period 1989-1991 to analyse the link between efficiency and exports. A method to calculate deviations from potential productivity,

[20] See Giles and Williams (2000a) for a comprehensive survey of applied research on export-led growth.
[21] Critical assessments of the empirical literature on export-led growth and the link between openness and growth can be found in Rodriguez and Rodrik (1999) and Giles and Williams (2000b).
[22] E.g. Krueger (1978) and Ram (1987).

referred to as total factor efficiency, using a translog production function is proposed. To be able to separate the effect of exports on technological capabilities from effects on economies of scale, total factor efficiency is decomposed into the two components, technical efficiency and scale efficiency.

In line with several earlier studies, we found in this paper that technical efficiency is higher for exporting plants than for their domestically oriented counterparts. Our results suggest however that the main explanation for higher total factor efficiency among exporters in Chilean manufacturing is due not to higher technical efficiency but to higher scale efficiency. With learning effects from exporting, we would expect plants with a long export history to be technically more efficient than plants that recently entered the export market. We found no significant differences in either technical efficiency or scale efficiency between plants with export history and those with short. Plants just prior to the start of exporting are significantly more productive than plants that remain out of the export market. This suggests that relatively efficient firms self-select into the export market.

The next section briefly covers the arguments for export-led growth as well as the alternative hypothesis claiming that productivity growth precedes export growth. Section 3 discusses the data and provides an overview of export activities in the manufacturing sector. Section 4 derives the measures of productive efficiency and formulates the model for estimation of the frontier production function. Empirical results are given in Section 5. The final section summarises major results and derives conclusions.

2 Exports, Productive Efficiency and Causality

Several explanations for a link between exports and productive efficiency at the firm level have been put forward. They are that: First, a higher level of export allows the firm to gain from economies of scale because, quite simply, the inclusion of the international market permits larger scale operations than domestic alone; Second, stronger exposure to international competition by higher exports increases pressure on the export firms to keep costs low and provides incentives to reduce productive inefficiency; Third, the process of exporting reduces technical inefficiency via acquisition of new knowledge and technical diffusion gained from their international buyers, i.e. learning-by-exporting. Finally, exporters generate benefit for other firms, either by acting as conduits of the knowledge they acquire through wider trade, or by spurring general improvements in international transport and export support services.

The mechanisms discussed above, through which export promotion contributes to productivity, share a common feature. They all argue that export growth precedes productivity growth. Thus the hypothesis of export promotion should be taken to be not only an assertion of correlation, but also an assertion of causation. An alternative hypothesis is that productivity growth causes export growth. Roberts and Tybout (1997) develop a model of exporting in which the sunk cost of entry is deemed to imply that only relatively productive firms will pay the costs to enter the export market. The additional sunk cost associated with selling goods in foreign markets might include transport costs, expenses related to establishing a distribution channel, or production costs to modify domestic models to foreign tastes. These extra costs constitute an entry barrier that less successful firms cannot overcome. Relatively more efficient plants self-select into export markets because the returns on doing so are relatively high for them. The end result is that, in a sample of non-exporting firms within the same industry, the more efficient firms should be more likely to become exporters.

The causal link between exports and productivity or output growth has been examined extensively at the macro level. Using Granger causality tests, Jung and Marshall (1985) found statistical evidence for the export-led growth hypothesis for only five of the 37 countries included in the study, while the results supported growth-led export for eleven countries (including Chile). The Jung and Marshall study has been followed by numerous other studies which look at the causal relationship between exports and GDP growth. Dodaro (1993), for instance, found evidence for export-led growth in eight of 87 countries and evidence for growth-led export in fourteen countries (including Chile). Both studies cited above lacked evidence for causality in any direction for the majority of the investigated countries.

At the micro level, empirical studies often find that exporting plants in developing countries are more efficient than their domestically oriented counterparts (Chen and Tang, 1987; Haddad, 1993; Aw and Hwang, 1995; Handoussa, Nishimizu and Page, 1986; Tybout and Westbrook, 1995; Aw, Chung and Roberts (1998); Clerides, Lach and

Tybout, 1998; Bigsten *et al* (2000); Granér and Isaksson, 2001). This result has been interpreted as giving support to the export-promotion hypothesis. But, only a few micro studies have empirically investigated whether exporting *causes* efficiency gains at the micro-level. Clerides, Lach and Tybout (1998) tested causality from exports to efficiency on plant-level data from Colombian, Mexican, and Moroccan manufacturing. They found that "exporting history did not significantly shift the cost function, and to the extent that it did, the shift was in the wrong direction". Bernard and Jensen (1999) analysed the causal relationship between firm performance and exports in US manufacturing. They found no evidence that exporting increased productivity growth. However, they did found evidence for reversed causality - productivity increased the probability that a firm will export. Aw, Chung and Roberts (1998), however, find that both self-selection and learning explain the higher productivity among exporting plants in Taiwanese manufacturing, while none of the hypotheses explain the disparity in productivity between exporter and non-exporters in the South Korean manufacturing sector. Bigsten *et al* (2000) acquire similar support for both hypotheses for four SSA countries.

3 Data

The empirical analysis is based on plant-level survey data collected by Statistics Chile. The sample includes all plants in the manufacturing sector with more than ten employees, and covers the period 1989 to 1991. After removing industries with less than 20 plants the sample consists of 17 industries at the three-digit level of the International Standard Industrial Classification (ISIC, rev. 2). These industries covered 3989 plants and had 10174 observations altogether. Due to missing values, however, the sample was reduced to 3604 observations of 1368 plants. Most of the observations excluded are due to missing-capital stock data. Unfortunately, capital stock was reported only in 1980 and 1981. Therefore, capital-stock variables, derived from the perpetual inventory method, could not be constructed for entrants after 1981.[23] In addition, several plants in 1980 and 1981 did not report capital stock.[24]

[23] If all plants entered the panel was new establishments, investment data could be used to calculate the capital-stock. However, since our data only cover plants with 10 or more workers, entry may also reflect an

To estimate productivity, data on output and inputs is used. Output is measured by value added, defined as sales adjusted for changes in inventories minus the cost of raw materials, energy inputs, goods purchased for resale, and contract work. The inputs are capital and labour. Capital is defined as the book value of machines and equipment, corrected for the number of operating days. Data on investments and book value depreciations for the years after 1981 were used to construct the capital-stock variable. Labour is divided into blue-collar and white-collar. For both types of labour, the average numbers of employees are used as input measure.

All variables are deflated to 1990 prices using sector-specific price indices. Output price-deflators were constructed directly from average-price indices obtained from Statistics Chile. Deflators for capital and raw materials were constructed from sectoral output prices using the 1986 Chilean input-output table. Summary statistics of output and inputs for each industry are presented in Table 1.

Table 1. Means of value added, capital, blue-collar labour, and white-collar labour 1989-1991 per industry.

ISIC number	Industry	Obs.	Value added	Capital	Blue-collar labour	White-collar labour
311-12	Food products, except Bakeries	586	1061	814	102	42
313	Beverages	135	1559	516	82	53
321	Textiles	459	456	241	85	28
322	Wearing apparel	323	323	81	74	23
324	Footwear	149	504	143	107	19
331	Wood products	294	403	252	76	13
341	Paper	76	4678	5958	120	71
342	Printing and publishing	208	847	505	58	48
352	Non-industrial Chemicals	253	1832	369	78	64
355	Rubber products	66	911	547	63	27
356	Plastic products	194	486	198	66	23
361-62	Ceramics and glass	54	1008	766	97	36
369	Non-metallic minerals	149	1114	1077	59	27
381	Fabricated metal products	392	569	235	70	27
382	Non-electric machinery	132	665	295	81	46
384	Transport equipment	88	710	349	101	30
390	Other manufactured products	46	209	485	42	19

Note: Numbers in parentheses are standard errors. Value added and capital is measured in million Chilean pesos in 1990 prices.

increase in labour over the cut-off point. Since we can't identify the reason for entering the panel, all entering plants are excluded.

[24] All plants that reported zero value of machines and equipment are considered as non-responders.

Table 2 shows the proportion of plants that sell in the export market for the sample used for estimation of technical efficiency, as well as within the total population. The industries with the highest proportions of exporting plants in the total population are non-industrial chemicals with 51 percent exporters, and food with 44 percent exporters. Printing has the lowest proportion of exporters with only 9 percent of the plants that sell in export market. Table 1 also shows the export share for each industry in the sample and in the population calculated as an average for the three years. In the total population, the industry of wood products has the highest proportion of export with 35 percent of total sales oriented to foreign markets. Ceramics and glass together with non-electric machinery are the most inward-oriented sectors with only one percent of total sales exported. Differences between the population and the sample with respect to the proportion of exporters export shares reveal that the sample does not provide a perfect representation of the population. However, the differences are, with some expectations, rather small suggesting that sample selection bias is not too severe.

Table 2. Number of plants, proportion exporters, and export shares 1989-1991 per industry.

ISIC number	Industry	Number of Plants		Proportion in export market		Export share	
		Sample	Total	Sample	Total	Sample	Total
311-12	Food products, except bakeries	221	698	0.37	0.44	0.17	0.24
313	Beverages	51	106	0.35	0.33	0.05	0.11
321	Textiles	171	412	0.28	0.20	0.05	0.05
322	Wearing apparel	130	407	0.14	0.13	0.04	0.08
324	Footwear	55	171	0.33	0.30	0.10	0.11
331	Wood products	115	378	0.22	0.25	0.28	0.35
341	Paper	28	77	0.46	0.41	0.33	0.31
342	Printing and publishing	83	223	0.13	0.09	0.05	0.03
352	Non-industrial chemicals	90	195	0.61	0.51	0.07	0.05
355	Rubber products	27	67	0.22	0.21	0.19	0.15
356	Plastic products	71	236	0.27	0.22	0.01	0.02
361-62	Ceramics and glass	20	42	0.40	0.43	0.01	0.01
369	Non-metallic minerals	57	145	0.19	0.16	0.01	0.02
381	Fabricated metal products	146	424	0.25	0.15	0.04	0.03
382	Non-electric machinery	51	221	0.18	0.16	0.01	0.01
384	Transport equipment	32	122	0.25	0.14	0.13	0.08
390	Other manufactured products	20	65	0.17	0.20	0.01	0.02

Note: A plant was considered as an exporter if the plant exported at least one year during the sample period. Export shares were calculated as the sum of the value of export sales between 1989-1991 divided by the sum of the value of total sales. Both export sales and total sales were deflated to 1990 prices.

4 Methodology

This section includes the measures of productive efficiency and the models for estimation of the frontier production function.

4.1 Measuring Productive Efficiency

In order to test the effect of export orientation we first need to arrive at reliable measures of productive efficiency. Most efficiency studies using an econometric approach estimate technical inefficiency, while inefficiency due to operations at sub-optimal scale is neglected. Here is a method to calculate deviations from maximal productivity for a technology approximated with a translog production function proposed. This efficiency measure, which is decomposed into a technical efficiency component and a scale efficiency component, is named *total factor efficiency*.[25] After presenting the definitions of the efficiency components, we conclude this section with a description of the empirical model that underlies the estimation of efficiency.

4.1.1 Technical Efficiency

A production frontier specifies maximum outputs for given sets of inputs and existing production technologies. Failure to attain the frontier is due to technical inefficiency. The output-based version of the Farell (1957) technical efficiency measure is defined as that ratio between observed output and potential output at a given level of input. This measure necessarily has values between zero and one. If a firm's technical efficiency is 0.85, then it implies that the firm realizes, on average, 85 percent of the production possible for a fully efficient firm having comparable input values. The technical efficiency measure is illustrated in Figure 1, where $F_i(X)$ is the production function for the observed unit *i*, while $F'(X)$ is the frontier production function. The production unit produces $F_i(X_i)$ with the input level X_i, while the potential production with this input level is $F'(X_i)$. Technical efficiency (TE) is then

[25] Total factor efficiency is analogous to a measure named gross scale efficiency in Førsund and Hjalmarsson (1979).

$$TE_i = \frac{F_i(X_i)}{F'(X_i)}. \tag{1}$$

4.1.2 Scale Efficiency

Scale efficiency measures productivity losses associated with operation that deviate from the optimal scale that minimizes costs. With a non-homothetic production function, there is an infinite number of output and input combinations consistent with optimal scale. One way to approach optimal scale is to multiply the inputs with a proportionality factor, λ, such that

$$\frac{\partial F(\lambda_i X_i)}{\partial \lambda_i} \frac{\lambda_i}{F(\lambda_i X_i)} = \frac{\partial \ln F(\lambda_i X_i)}{\partial \ln_i \lambda_i} = 1. \tag{2}$$

Scale efficiency (SE) may then be defined as

$$SE_i = \frac{F_i(X_i)/G(X_i)}{F_i(\lambda_i X_i)/G(\lambda_i X_i)}, \tag{3a}$$

where $G(X)$ is the unknown input aggregation function (see Figure 1). The numerator in (3a) is observed productivity and the denominator is productivity at optimal scale. One desirable property of an input aggregation function is homogeneity of degree one.[26] With this property fulfilled, (3a) can be rewritten as

$$SE_i = \lambda_i \frac{F_i(X_i)}{F_i(\lambda_i X_i)}. \tag{3b}$$

4.1.3 Total Factor Efficiency

Technical efficiency may be defined as the ratio of observed productivity to frontier productivity given constant input level, while scale efficiency is defined as the ratio of observed productivity to productivity at optimal scale given observed input ratios and technical efficiency. Total factor efficiency (TFE) is here defined as the ratio of observed

[26] See Diewert (1976) for a discussion on the properties of an input aggregation function.

productivity to the frontier productivity at optimal scale. In other words, total factor efficiency is the relative deviation from maximal productivity, given observed factor proportions. Algebraically this may be expressed as:

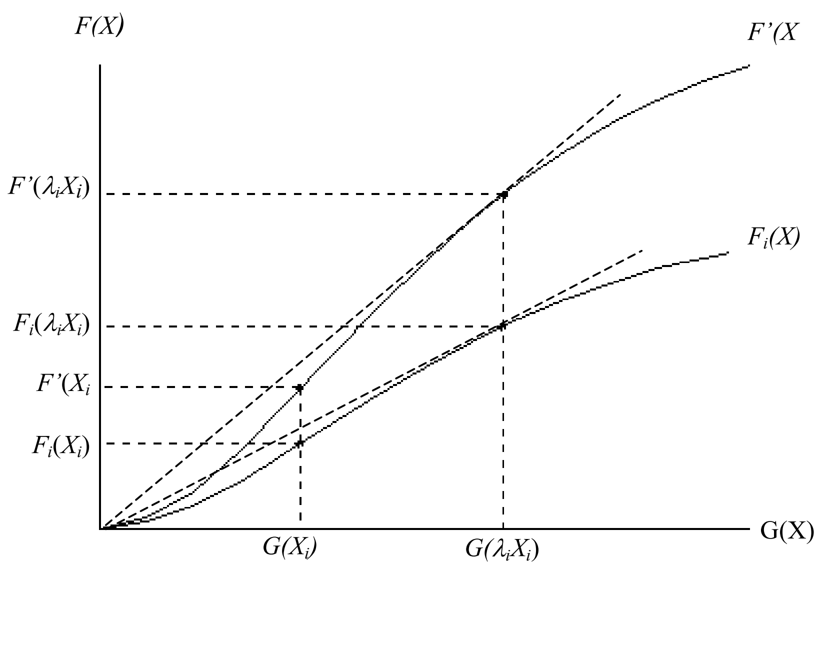
$$TFE_i = \frac{F_i(X_i)/G(X_i)}{F'(\lambda_i X_i)/G(\lambda_i X_i)}. \tag{4a}$$

Given a linearly homogenous input aggregation function, (3a) may be rewritten as:

$$TFE_i = \lambda_i \frac{F_i(X_i)}{F'(\lambda_i X_i)}. \tag{4b}$$

Given neutrality between the production function for the observed unit and the frontier production function (i.e., technical efficiency is constant along the production function), it may easily be shown that the product of technical efficiency and scale efficiency equals total factor efficiency.

Figure 1. Illustration of Technical Efficiency, Scale Efficiency, and Total Factor Efficiency



4.2 Empirical Model

Aigner, Lovell and Schmidt (1977), Battese and Corra (1977), and Meeusen and van den Broeck (1977) independently proposed the stochastic composed-error frontier production function, in which random errors are incorporated into the model to account for the effects of factors outside the controls of the firms. The stochastic frontier production may be formulated as

$$Y_{it} = F(X_{it};\beta)\exp\{v_{it} - u_{it}\} \tag{5}$$

where Y_{it} denotes the production of plant i at time t, X_{it} is a vector of inputs and other explanatory variables, and β is a vector of technology parameters to be estimated. The random disturbance term v_{it} captures deviations from the frontier outside the control of the firm, and is assumed to be independently and identically distributed as $N(0,\sigma_v^2)$. The second disturbance term, $u_{it,}$ is associated with technical inefficiency and assumed to be an independent and identically distributed non-negative variable.

The production function in (1) can be written in translog form as

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{3}\beta_j \ln X_{jit} + \frac{1}{2}\sum_{j=1}^{3}\sum_{k=1}^{3}\beta_{jk}\ln X_{jit}\ln X_{kit} + (v_{it} - u_{it}) \tag{6}$$

where Y represents value added, X_1 represents capital, X_2 represents blue-collar labour, and X_3 represents white-collar labour.

As shown in the Appendix, the scale efficiency measure given in equation 3 may be calculated from a translog production function as

$$SE_{it} = \exp\left[\frac{\frac{1}{2}[1 - E_{it}]^2}{\partial E_{it} / \partial \ln \lambda_{it}}\right], \tag{7}$$

where E is returns to scale. From the production function specified in equation (6), returns to scale can be calculated from the sum of the marginal elasticities of output with regard to each input as

$$E_{it} = \sum_{j=1}^{3} \frac{\partial \ln Y_{it}}{\partial \ln X_{jit}} = \sum_{j=1}^{3} \beta_j + \sum_{j=1}^{3} \sum_{k=1}^{3} \beta_{jk} \ln X_{kit} \,. \tag{8}$$

The derivative of returns to scale with respect to the natural logarithm of the proportionality factor can be calculated as

$$\frac{\partial E_{it}}{\partial \ln \lambda_{it}} = \sum_{j=1}^{3} \frac{\partial E_{it}}{\partial \ln X_{jit}} = \sum_{j=1}^{3} \sum_{k=1}^{3} \beta_{jk} \,. \tag{9}$$

5 Results

The translog frontier production function has been estimated for each of the 17 industries under the alternative assumptions of half-normal and exponential distribution of the inefficiency component.[27] Table 3 shows estimated mean returns to scale for exporters, non-exporters and for the total sample.[28] The results indicate that for most industries, both export-oriented and domestically oriented plants on average exhibit increasing returns to scale. Comparisons of the means of returns to scale between exporting and non-exporting plants reveal that exporting plants generally are closer to optimal scale. On average, only in four industries do non-exporting plants operate closer to optimal scale (measured as absolute deviation from optimal scale).

[27] Frontier production functions were also estimated with a truncated normal distribution. The truncated normal distribution was, however, rejected in favor of half-normal distribution for all industries.

[28] Returns to scale presented in Table 3 were estimated under the assumption of a half-normal distributed inefficiency component. The model with exponential distributed inefficiency component provides similar estimates of returns to scale.

Table 3. Mean returns to scale by orientation and industry.

ISIC number	Industry	Exporters	Non-exporters	All	Exporters / Non-Exporters
311	Food products, except bakeries	1.10	1.28	1.22	0.86***
313	Beverages	1.31	1.58	1.49	0.83**
321	Textiles	1.04	1.22	1.19	0.85***
322	Wearing apparel	1.06	1.16	1.15	0.92***
324	Footwear	1.09	1.16	1.14	0.94**
331	Wood products	1.18	1.35	1.32	0.87***
341	Paper	0.71	0.75	0.73	0.95
342	Printing and publishing	1.08	1.19	1.18	0.91***
352	Non-industrial Chemicals	0.91	1.00	0.96	0.91***
355	Rubber products	1.12	1.25	1.22	0.90***
356	Plastic products	1.07	1.26	1.23	0.85***
361-2	Ceramics and glass	1.28	1.34	1.32	0.96
369	Non-metallic minerals	1.33	1.19	1.21	1.12
381	Fabricated metal products	1.18	1.16	1.17	1.02
382	Non-electric machinery	1.04	1.41	1.37	0.74***
384	Transport equipment	0.91	1.32	1.25	0.69***
390	Other manufactured products	0.61	1.23	1.13	0.50***

Note: * Indicates that the difference in means is statistically significant at the ten percent level, ** at the five percent level, *** at the one percent level .

Table 4 shows the efficiency measures using the ratio of exporting plants efficiency to domestic-oriented plants efficiency for 1991. If the value is greater than one, exporting plants are more efficient than non-exporting. The first column shows the ratio for technical efficiency predicted under the assumption of a half-normal distribution for technical efficiency.[29] The second column shows the same ratio under the assumption of exponential distributed technical efficiency.[30] The third column shows the ratio of scale efficiency as defined in equation 3 calculated using the formula in equation 7. Finally, the fourth column shows total factor efficiency as defined in equation 4 calculated as the product of technical efficiency with half-normal distribution and scale efficiency. The mean ratios generally suggest that exporting firms are more efficient, both in the technical efficiency component and in the scale efficiency component. The differences in mean technical efficiency are significant at the five percent level in eight of the 16 industries for which technical efficiency could be estimated, all with a higher mean for

[29] The point estimates of technical inefficiency under the assumption of half-normal distribution were calculated from the mean of the distribution using the formula proposed by Jondrow et al (1982).

exporting plants.[31] The difference in means for scale efficiency was significantly (at the five percent level) higher for exporting plants in 10 of 14 industries.[32] Finally, exporting plants have, on average, significantly (at the five percent level) higher total factor efficiency in 11 of the 13 the industries where estimates for both technical and scale efficiency are available.

Table 4. Comparison of productive efficiency: The ratio between the mean for exporting plants and non-exporting plants, by sector, 1991.

ISIC number	Industry	Technical efficiency ratio Half-normal	Technical efficiency ratio Exponential	Scale efficiency ratio	Total factor efficiency ratio
311	Food products, except bakeries	1.03	1.02	1.24***	1.27***
313	Beverages	1.07	1.04	1.25***	1.31***
321	Textiles	1.12***	1.10***	1.16***	1.27***
322	Wearing apparel	1.11**	1.08**	1.17***	1.25***
324	Footwear	1.14***	1.10***	1.04	1.12**
331	Wood products	0.98	1.00	1.28***	1.26***
341	Paper	--	--	0.99	--
342	Printing and publishing	1.13**	1.11**	1.39***	1.53***
352	Non-industrial Chemicals	1.16***	1.10***	1.01	1.10***
355	Rubber products	1.16	1.14	1.71***	2.02***
356	Plastic products	1.04**	1.01**	1.15***	1.16***
361-2	Ceramics and glass	1.02	1.00	--	--
369	Non-metallic minerals	1.03*	1.03	--	--
381	Fabricated metal products	1.05***	1.03***	--	--
382	Non-electric machinery	1.20***	1.12***	1.20***	1.35***
384	Transport equipment	0.90	0.94	1.22***	1.15*
390	Other manufactured products	1.05	1.04	0.93	0.97

Note: * Indicates that the difference in means is statistically significant at the ten percent level, ** at the five percent level, *** at the one percent level. Absolute values of t-ratios are reported in parenthesis.

We next ask if the productivity differential between exporters and non-exporters is a function of the degree of export intensity. Table 5 reports regressions of plant technical efficiency with assumptions of half-normal respective exponential distribution, scale efficiency and total factor efficiency on export intensity dummies. The intercept measures average efficiency for plants that do not export and the remaining parameters measure the

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[30] The point estimates of technical efficiency under the assumption of exponential distribution were calculated using the formula presented in Greene (1993).

[31] Technical efficiency could not be estimated for the paper industry since the estimated variance component was negative.

difference in efficiency between non-exporters and plants with different export intensity. Starting with technical efficiency, the results surprisingly indicate that technical efficiency falls with export intensity. While plants with low export intensity (<10 percent of production exported) and with medium intensity (10 to 50 percent) are significantly more technically efficient than non-exporters, there is no significant difference in average technical efficiency between plants with high export intensity (>50 percent) and non-exporters.

Table 5. Average productivity differences across plants based on export intensity.

Categories	Technical Efficiency (half-normal)	Technical Efficiency (exponential)	Scale Efficiency	Total Factor Efficiency
Intercept	0.567^{***}	0.692^{***}	0.727^{***}	0.502^{***}
	(78.27)	(110.89)	(83.01)	(60.61)
Low	0.056^{***}	0.046^{***}	0.116^{***}	0.130^{***}
	(7.54)	(7.29)	(12.10)	(14.20)
Medium	0.034^{***}	0.030^{***}	0.151^{***}	0.134^{***}
	(2.92)	(3.01)	(10.25)	(9.57)
High	-0.004	-0.005	0.136^{***}	0.092^{***}
	(0.28)	(0.54)	(7.92)	(5.50)
N	3506	3499	2973	2899
R^2	0.21	0.21	0.23	0.24
Hypothesis tests:				
Low = Medium	$F_{1,3485}=2.81^{*}$	--	$F_{1,2954}= 4.36^{**}$	--
Low = High	$F_{1,3485}=13.99^{***}$	$F_{1,3478}=14.04^{***}$	--	$F_{1,2881}=4.33^{**}$
Medium = High	$F_{1,3485}=4.35^{**}$	$F_{1,3478}=5.04^{**}$	--	$F_{1,2881}=3.93^{**}$

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent respectively. Absolute values of t-ratios in parenthesis. All regressions contain industry and year dummies. Test statistics significant at least at the 10 percent level are reported only.

Turning to differences in scale efficiency between non-exporters and plants with different export intensity, the average scale efficiency is significantly higher compared with non-exporters for all export intensity categories. Scale efficiency is significantly higher for plants with medium export intensity relative to plants with low export intensity. Scale efficiency for plants with high export intensity, however, is not significantly different

[32] Scale efficiency and total factor efficiency could not be calculated for three industries since the

from plants with lower export intensity. The results weakly suggest that scale efficiency is positively related to export intensity. Outward orientation provides opportunities to increase production, and, if the plant operates at increasing returns, to enjoy productivity gains due to economies of scale.

The difference in total factor efficiency between plants with low export intensity and plants with medium intensity is low and insignificant, while total factor efficiency is significantly lower for plants with high export intensity than it is for plants with low and medium export intensity.

In Table 6 we look at differences in efficiency between plant categories based on their export history. If a plant that exporting 1991 also exported in the two preceding years, the plant is categorised as a continuous exporter. If an exporter observed in 1991 started to export in 1989 or 1990, the plant is categorised as an entrant into the export market. And, finally, if a plant that in 1991 was a non-exporter exited the export market in 1989 or 1990, the plant is categorised as a quitter from the export market.
With learning effects from exporting, we would expect firms with a long export history to be technically more efficient than plants that recently entered the export market. If, on the other hand, self-selection explains the higher productivity among exporters, we would expect no differences in total factor efficiency between entering plants and plants with a longer export history. The results presented in Table 6 show that technical efficiency, scale efficiency and total factor efficiency are significantly higher for continuous exporters and entrants than for plants that stayed out of the export market.[33] Scale efficiency and total factor efficiency are significantly higher also for quitters compared to plants with no export activities during the three-year period. Average total factor efficiency is significantly higher for continuous exporters compared to quitters. This suggests that less productive plants are forced to leave the export market due to weak competitiveness.

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estimated production function did not fulfill the regular ultra passum law (see Appendix).

[33] With the exponential distribution the difference in technical efficiency between entrants and non-exporters is significant at the 10 percent level only.

The results presented in Table 6 do not provide support for learning effects. Even though average technical efficiency for continuous exporters is higher than for plants that recently entered the export market, the differences are not statistically significant.

Table 6. Average productivity differences based on past transition in or out of the export market, 1991.

	Technical Efficiency half-normal	Technical Efficiency Exponential	Scale efficiency	Total Factor Efficiency
Intercept	0.557***	0.685***	0.714***	0.486***
	(47.50)	(69.63)	(50.68)	(36.52)
Continuous	0.034***	0.031***	0.147***	0.136***
	(2.65)	(2.89)	(8.94)	(8.68)
Entrant	0.033**	0.025*	0.120***	0.117***
	(2.04)	(1.85)	(5.77)	(5.82)
Quitter	-0.007	-0.015	0.091***	0.067**
	(0.29)	(0.68)	(3.01)	(2.32)
N	998	995	840	817
R2	0.24	0.25	0.23	0.24
Hypothesis tests:				
Continuous=Quitter	--	$F(1, 976)=3.96^{**}$	$F(1,823)=2.86^{*}$	$F(1,801)=4.91^{**}$

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent respectively. Absolute values of t-ratios in parenthesis. All regressions contain industry and year dummies. Test statistics significant at least at the 10 percent level are reported only.

If self-selection explains the higher productivity among exporters, plants that in the future will enter the export market should be more productive than plants that remain out of the export market. In Table 7 we examine average efficiency differences based on future transition in or out of the export market. That is, 1989 average efficiency is compared among the groups described above.

The results suggest that future entrants are more efficient than non-exporters, independently of efficiency measure. Moreover, technical efficiency and total factor efficiency is higher for future entrants than for exporting plants that will exit the export market.[34] Thus, the results support the hypothesis that relatively efficient plants self-select into the export market. The results also suggest that plants that will exit the export market in 1990 or 1991 are on average less efficient in 1989 than plants that exported the

[34] The difference is significant at the 10 percent level only for technical efficiency estimated under the assumption of half-normal distribution.

whole period. This confirms the result from the analysis of past transition – inefficient exporters tend to exit the export market.

Table 7. Average productivity differences based on future transition in or out of the export market, 1989.

	Technical Efficiency half-normal	Technical Efficiency Exponential	Scale efficiency	Total Factor Efficiency
Intercept	0.563^{***}	0.693^{***}	0.722^{***}	0.486^{***}
	(49.29)	(75.54)	(53.97)	(36.52)
Continuous	0.060^{***}	0.048^{***}	0.142^{***}	0.136^{***}
	(4.86)	(4.65)	(9.11)	(8.68)
Entrant	0.040^{**}	0.032^{**}	0.114^{***}	0.117^{***}
	(2.52)	(2.44)	(5.73)	(5.82)
Quitter	-0.012	-0.021	0.083^{***}	0.067^{**}
	(0.47)	(1.00)	(2.23)	(2.32)
N	998	995	840	817
R2	0.24	0.26	0.26	0.24
Hypothesis tests:				
Continuous = Entrant	--	--	--	$F(1,801)=3.13^{*}$
Continuous = Quitter	$F(1,979)=7.34^{***}$	$F(1,976)=9.64^{***}$	$F(1.823)=3.62^{**}$	$F(1,801)=12.75^{***}$
Entrant = Quitter	$F(1,979)=3.24^{*}$	$F(1,976)=4.90^{**}$	--	$F(1,801)=4.29^{**}$

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent respectively. Absolute values of t-ratios in parenthesis. All regressions contain industry and year dummies. Test statistics significant at least at the 10 percent level are reported only.

6 Conclusions

Micro data in developing countries often show that exporting firms are more efficient than non-exporting firms. Comparisons of efficiency between exporting and inward-oriented plants in 17 industries in the Chilean manufacturing sector confirm that pattern, and add the findings that superior scale efficiency among exporters is more significant than the difference in technical efficiency. There is however no evidence for a positive relation between the level of exports and plant performance.

This study also addresses the question of causality between efficiency and exports. Our results give no support for the hypothesis that export activities precede efficiency change. Thus, we find no evidence for the notion that exporting plants increase productive efficiency through learning-by-exporting. Instead, the results propose that plants that will enter the export market in the future are significantly more productive than plants that remain out of the export market. This suggests that relatively efficient firms self-select into the export market.

These results are consistent with the theoretical model in Roberts and Tybout (1997). Sunk costs provide an entry barrier into the export market that inefficient firms cannot overcome. Thus, our results suggest that the efficiency gap between exporters and non-exporters in Chilean manufacturing is due to self-selection of relatively more efficient plants into the export market, rather than due to learning by exporting or decreased x-inefficiency following stronger exposure to international competition.

Appendix

Derivation of the scale efficiency measure

Frisch (1965) shows that under proportional variations in input the proportionality factor λ can be multiplicatively separated.[35] Given a translog production function, λ may be separated as

$$F(\lambda X) = \lambda^{\frac{1}{2}\left[E(\lambda X)+E(X)\right]}F(X) \qquad \text{(A1)}$$

where E(X) *and* E(λX) *are local returns to scale at* F(X) *and* F(λX) *respectively. Taking the natural logarithm of (A1) gives*

$$\ln F(\lambda X) = \tfrac{1}{2}\left[E(\lambda X)+E(X)\right]\ln\lambda + \ln F(X). \qquad \text{(A2)}$$

The derivative of (A2) with respect to lnλ is

$$\frac{\partial \ln F(\lambda X)}{\partial \ln\lambda} = E(\lambda X) = \tfrac{1}{2}\ln\lambda\frac{\partial E(\lambda X)}{\partial\lambda} + \tfrac{1}{2}\left[E(\lambda X)-E(X)\right]. \qquad \text{(A3)}$$

When *F(λX)* is output at optimal scale both *E(λX)* and the derivative of ln*F(λX)* with respect to lnλ are equal to one. Solving for λ gives

$$\lambda = \exp\left\{\frac{1-E(X)}{\partial E(X)/\partial\ln\lambda}\right\}. \qquad \text{(A4)}$$

To satisfy the *Regular Ultra Passum Law* (Frisch, 1965), returns to scale should decrease with a proportional increase in inputs.[36] Thus, lambda is greater than one (less than one) for a firm with IRS (DRS).

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[35] In Frisch (1965), there is an identity called the *second order form of beam variation equation* which shows that under proportional variation in inputs, the proportionality factor λ can be multiplicatively separated.

[36] A regular ultra-passum law is a production law which is such that if all factor quantities simultaneously increase, or more generally no factor quantity diminishes and at lest one rises, returns to scale ε will diminish steadily from values in excess of 1 to values less than 1.

Substituting (A1) and (A4) into equation (3b) in section 4.1.2, and after rearranging, we finally get a scale efficiency measure as

$$SE = \exp\left[\frac{\frac{1}{2}\left[1 - E(X)\right]^2}{\partial E(X) / \partial \ln \lambda}\right]. \tag{A5}$$

Given that the regular ultra passum law holds, i.e., that the denominator in (A5) is negative, scale efficiency is bounded between zero and one. Scale efficiency equals one at optimal scale and decreases with deviations from optimal scale.

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Firm Efficiency and the Direction of Exports: Evidence from Kenyan Plant-level Data

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Abstract: This paper investigates the link between efficiency and exports in Kenyan manufacturing. Like many similar studies we find that exporters are more efficient than non-exporters. The analysis supports that relatively efficient firms self-select into exports activities, but we also find some evidence in favour of learning from exports. Our results provide no evidence for the hypothesis that trade direction influences either the export effect on technical efficiency or the efficiency effect on exports. However, while the probability to export to other African countries increases with physical and human capital intensity, firm size appears more important for export activities outside Africa.

Keywords: Direction of Exports, Firm Efficiency, Learning-Effects, Self-Selection, Kenya, Manufacturing

JEL Classification: C35; D24 ; F14; L60; O12

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1 Introduction

By now there seems to have emerged a consensus understanding of the often-observed statistical correlation between a firm's export activities and its technical efficiency.[37] Earlier work tends to emphasise the conclusion that export participation leads to increased efficiency through so-called learning effects.[38] However, recent studies focus on an alternative explanation, the notion that relatively efficient firms self-select into export activities because the returns on doing so are relatively high for them (Roberts and Tybout, 1997). If this is true, it is not export-participation per se that makes a firm more efficient, but rather efficiency that causes export-participation. This could call for policies different than if the learning-effects hypothesis holds.

In the past 15 years or so, the issue of direction of exports appears to have been dormant.[39] This neglect is unfortunate and we make an attempt here at showing that taking into account a firm's direction of exports is of significant value for better understanding the relation between firm efficiency and export-decision. For instance, it is possible those exports directed to industrialised countries might contain more learning effects than that directed to other developing countries.[40] Furthermore, while one might accept that firm efficiency is a requirement for entering industrialised countries' markets, it may be expected that penetration of other developing countries' markets is less demanding. It is even possible that policy conclusions drawn from a 'traditional' analysis of the exports-efficiency relation might turn out more accurate, or at least subject to alteration.

Learning effects from exporting hinges primarily on the notion that the export recipient is relatively more technologically advanced than the exporter, i.e., the main focus is on South-North trade. But what if a country directs its exports to a country at a

[37] Or productivity, but from hereon we will use the term efficiency throughout the paper unless there are particularly strong reasons to maintain the term of productivity.

[38] The World Bank has repeatedly (e.g. World Bank, 1993) argued that the East-Asian Miracle to a large extent can be explained by learning effects with consequent improvements in Total Factor Productivity (TFP). Aggregate growth led by improvements in TFP finds strong support in, for instance, Forstner and Isaksson (2002). A contrasting view is maintained by, for instance, Young (1995) who found that these countries had grown the "old-fashioned" way, that is, through accumulation of the labour force and capital.

[39] The last time the issue was at serious discussion seems to have been at a World Bank conference in 1987.

similar or lower level of technological development? Would there still be productivity gains to be made? An equally relevant question is whether the determinants of exports to North and South are the same. Previous literature seems to suggest that South-South exporting is more intense in its use of human and physical capital, while South-North exporting is relatively labour-intensive (seen from the perspective of the developing country).[41]

The relation between exports and efficiency in developing countries has been investigated several times before, however, mainly on Latin American and Asian countries. Moreover, compared with the great volume of empirical studies based on macro-data, there are relatively few studies using micro-data. To our knowledge, there are only four previous studies linking efficiency and exports that use micro-data from Sub-Saharan African (SSA) countries (Biggs, 1995; Bigsten *et al.*, 2000; Granér and Isaksson, 2001; and Rankin, 2001). The reason why there are so few studies on SSA is mainly due to the scarcity of plant-level data from this region. This study uses detailed data on Kenyan manufacturing firms for the period 1992-94.

We start by empirically investigating the link between technical efficiency and exports in the 'standard' way, i.e. without taking export direction into account. As in many similar studies, we find that technical efficiency, on average, is higher among exporters than among non-exporters. Exporters are also larger and more relatively intense in their use of physical and human capital than non-exporters. The regression analysis supports that relatively efficient firms self-select into exports activities, but we also find evidence in favour of learning from exports.

Thereafter, we show that firms that export within Africa are smaller, but more capital- and skill-intensive than firms that export outside Africa. The econometric results provide some evidence for interdependence between export activities and technical efficiency. Our results provide no evidence for the notion that trade direction influences the export effect on technical efficiency or the efficiency effect on exports. However, direction of exports matters for the effect from other determinants on the export decision. Firm size has a positive effect on the decision to export outside Africa, while we find no

[40] This very issue has been debated and we return to that discussion later in the paper.
[41] We will use the terms skill and human capital interchangeably throughout the paper.

evidence for that firm size influences the decision to export within Africa. Another interesting result is that high capital intensity increases the probability to export within Africa while factor proportions have no explanatory power on export activities outside Africa.

The paper proceeds as follows: In Section two we explore the link between technical efficiency and exports as well as the role of other explanatory variables. Special focus is laid upon the direction of exports. In the third Section, we present the data and discuss what we can infer from descriptive analysis. The estimation results are presented in Section four, while Section five concludes the paper.

2 Firm efficiency and the direction of exports

In this Section, we first discuss the relation between efficiency and exports. Thereafter, we consider the role of other determinants of efficiency and of the decision to become an exporter. Finally, we dwell on how the issue of direction of trade enriches an analysis of exports and efficiency.

2.1 The relation between efficiency and export-participation

There is widespread empirical evidence that exporting plants in developing countries are more efficient than their domestically-oriented counterparts (e.g. Chen and Tang, 1987; Haddad, 1993; Aw and Hwang, 1995; Handoussa, Nishimizu and Page, 1986; Tybout and Westbrook, 1995; Clerides, Lach and Tybout, 1998; Granér, 2002). Until recently, this evidence has often been interpreted as giving support to the theory that learning effects are gained from export activities.

One argument for a causal link from exports to technical efficiency at the firm level is that export participation produces learning effects. For instance, foreign customers may offer exporters technical assistance, market information or guidance in quality control. Learning could also be acquired more indirectly nature however, by, for instance, a firm's monitoring feedback from its own activities, or through informal discussions with foreign contacts (Webb and Fackler, 1993). The existence of arduous international competition can also serve as an argument for the notion that productive efficiency is driven by export. Strong exposure to international competition is seen as increasing the pressure on exporting firms to keep costs low. To keep track of the international frontier, firms are forced to adjust in two ways: to exploit economies of scale and reduce technical inefficiencies.

An alternative explanation developed in later years for the superior performance among exporters is that it reflects the self-selection of more efficient producers into a highly competitive market. The decision to become an exporter has theoretically and empirically been shown to depend to a large extent upon additional sunk costs of selling goods in the foreign market (Roberts and Tybout, 1997). The presence of sunk costs provides an entry barrier into the export market. These costs might include expenses related to establishing a distribution channel, or production costs to modify domestic products to foreign tastes.

To compete with international producers, domestic firms must have access to new and efficient technology, or use the same technology with low x-inefficiency. The investment required to enter the export market is lower for firms with a high level of productive efficiency. Thus, in the case of self-selection, causality runs from productivity to exports.

Recent empirical literature tends to support the second interpretation of the correlation between exports and efficiency. For instance, Clerides, Lach and Tybout (1998) examine the issue of causality using plant-level data for Colombia, Mexico and Morocco. They find no evidence for efficiency gains from learning and conclude that the self-selection of more efficient producers is the main reason for the productivity differentials between non-exporters and exporters. In a study of the Chilean manufacturing sector, Granér (2002) obtains no significant differences either in technical efficiency or in scale efficiency between plants with respect to export history. However, non-exporting firms that are relatively efficient are more likely than inefficient firms to enter the export market, i.e. exporting firms are already relatively efficient before they become exporters. Bernard and Jensen (1999) reach similar results for U.S. manufacturing.

Aw, Chung and Roberts (1998), however, find that both self-selection and learning explain the higher productivity among exporting plants in Taiwanese manufacturing, while none of the hypotheses explain the disparity in productivity between exporter and non-exporters in the South Korean manufacturing sector. Bigsten *et al.* (2000) acquire similar support for both hypotheses for four SSA countries, including Kenya.

2.2 Other determinants of firm efficiency and export-participation

The correlation between productivity and exports may also be due to other factors correlated with both technical efficiency and exports. Export-participation and technical efficiency signal more than that a firm is an exporter and that the firm has attained a certain efficiency level. For instance, several empirical studies show that relatively efficient firms in developing countries tend to be large. There is also evidence that manufactured exports source mainly from relatively large firms. Several other firm characteristics, such as capital-intensity and the skills of the employees, may influence both the decision to export and technical efficiency. It is to such characteristics we now turn attention.

2.2.1 Sources of technical efficiency

Besides export activities, several other firm-specific variables may explain intra-industry variations in technical efficiency. One potential determinant is the size of the firm. Several empirical studies show that relatively efficient firms in developing countries tend to be large (e.g. Pitt and Lee, 1981; Haddad and Harrison, 1993; Mengistae, 1995; Brada, King, and Ma, 1997; Lundvall and Battese, 1998).

Arguably, the most influential theory linking firm size and technical efficiency is Jovanovic's (1982) version of the passive learning model of firm dynamics. Jovanovic's model predicts that larger firms are more efficient than smaller ones. A selection process leads to an outcome in which efficient firms grow and survive, while inefficient firms stagnate or exit the industry.

The potential effect of firm size can be addressed in other ways as well. If the characteristics of measured inputs differ across size classes of firms, firm size may serve as an instrument for omitted or poorly measured factors of production. For instance, Mengistae (1995) found that firm size (and firm age) "mainly proxy for the influence of owner human capital" in Ethiopian manufacturing. Hence, if managers of large firms are more competent, and if this factor is omitted in the estimation of efficiency, firm size may appear to be positively related to the estimates of technical efficiency.

It can also be argued that the characteristics of measured physical capital and labour differ across size classes. For instance, smaller scale enterprises may employ capital equipment that is older than that of larger firms. If measured capital fails to reflect productivity differentials due to different vintages of capital, smaller firms may appear to be relatively inefficient. Hours worked by the labour force may also differ between small and large firms. It may be the case that family labour, which is applied with greater intensity in small firms, works longer and with greater intensity than hired labour. If this is the case, a best-practice frontier, based on labour force data that fail to reflect hours worked or intensity of effort, may falsely indicate that relatively small firms are closer to the frontier.

We now turn to factor proportions as a determinant of firm differences in technical efficiency. A common argument in favour of the adoption of capital-intensive technologies in developing countries is that such technologies generally are the latest and most efficient (White, 1978). On the other hand, with a putty-clay production structure that gives rise to different vintages of capital, technical efficiency may be negatively correlated with capital intensity (Hjalmarsson, 1973).

The skill level of employees differs between firms. We assume that the average wage cost per employee adequately reflects employees' skills. Another reason to proxy human capital by wage costs as a variable explaining technical efficiency is that, in the estimation of it, labour input is measured as the average number of employees during the year. This measure, however, does not take into account the heterogeneity in the labour force or hours worked.

Firm age may capture the extent of a firm's learning experience. Older firms are usually considered to be more efficient than younger ones, because owners, managers and employees have gained experience from past operations, and their survival per se may reflect their superior efficiency. On the other hand, young firms may be more likely to use modern capital equipment in the production process. This may dampen the positive effect from learning, or even result in a negative effect from firm age on technical efficiency.

One of the arguments for trade liberalisation in developing countries is that a more rational market structure will attract foreign investors and thus promote the adoption of new and superior technologies. Foreign multinational corporations operating in developing countries are assumed to be more efficient than domestic firms because of greater experience in management and superior organisational structure.

2.2.2 Determinants of the export decision

Firm size may also influence managers' decision to export. Berry (1992) has surveyed the literature linking firm performance and trade policies in developing countries. He finds that, in a typical developing country, there is evidence that manufactured exports source mainly from relatively large firms. This is the case also in the Kenyan manufacturing sector, as will be shown in Section 3.2. The reason for this may either be that export-participation has a positive impact on firm size, or that large firms self-select into the export market. The latter can be explained by the idea that large firms have the necessary resources to incur the extra costs of diversifying into foreign markets. For instance, exporting may give the firm higher marketing costs than domestic sales, but the larger the firm the lower the average cost of exporting (Bigsten *et al.*, 1999). Firm size may also serve as a proxy for a firm's resources, such as, for example, its access to new technologies, know-how, and credit. These are important considerations for a decision to enter international markets.

Sunk costs associated with entry into the export market may vary with, besides the already discussed firm size and technical efficiency, the firm ownership structure. The structure of ownership may be important for the cost to access foreign markets. The importance of foreign ownership in the manufactured exports in many developing countries reflects the advantage of proprietary information, as well as special access to marketing networks abroad (Berry, 1992). We thus expect a positive effect from foreign ownership on export decision.

The relation between factor proportions and export activities rests on the mapping from factor endowments to trade patterns predicted by the Heckscher-Ohlin-model of comparative advantage. If this model is valid at firm-level, manufacturing exports should be concentrated in firms that use the relative abundant factor intensively. Thus, if a country is labour-abundant, the theory predicts that capital intensity will be negatively related to export activities.

The skill intensity of operations may capture the potential for technological activities, such as R&D. Furthermore, a high educational level within a firm facilitates international contacts. Firm age may capture the extent of a firm's learning experience. All these factors may positively influence the international competitiveness of the firm, and, hence, the firm's decision to export.

2.3 The importance of trade direction

The literature on learning effects, as well as on the decision to export from developing countries, to some degree hinges on whether the exports are directed to more developed countries. Exports to other developing countries may be expected to generate fewer direct learning effects from exports, but its mere incidence can be rationalised on the grounds of, for instance, geographical proximity and similar consumption patterns. Furthermore, South markets should be easier to penetrate than North markets. Therefore, it is of interest to examine whether the determinants of Kenyan exports within Africa differ from those of Kenyan exports outside Africa. In addition, we would like to know the extent to which learning effects from exports and self-selection behaviour are sensitive to export direction.

It has been recognised that South-South exports are more intensive in physical and human capital than are exports from South to North (Amsden, 1980; Havrylyshyn and Wolf, 1987). In theory, this may be explained within the framework of an extended Heckscher-Ohlin model, such as the one presented by Havrylyshyn and Wolf (1987) . Amsden (1986) argues that the scope for learning-by-doing is greatest in industries which are both relatively skill- and capital intensive. Since greater South-South trade increases the skill and capital content of production, Amsden argues that South-South exports embody high learning effects while learning effects from labour-intensive South-North exports are more or less absent. Lall (1987) offers support for the view that South-South trade has larger gains from dynamic comparative advantage compared with South-North trade. But, like Amsden, Lall discusses learning-by-doing and not learning effects from exporting *per se*.

Havrylyshyn and Wolf (1987) admit that, in theory, South-North exports may have a greater potential for learning, but argue that the relatively poor export and growth performance of most countries strongly biased towards trade to other developing countries does not suggest that learning is all that strong in practice. One reason may be that learning potential arising from knowledge and technology transfer from the export recipient is higher for South-North exports.

Are the determinants of South-South exports different from the determinants of South-North exports? Since there is no obvious technology gap between the exporting and the recipient country in South-South trade, one may expect that firm efficiency is less important as an explanatory factor for export-participation compared with South-North exports. The cost of servicing customers abroad is probably lower for neighbouring countries with similar structure, since there usually exist lower cultural and language barriers. If this is true the argument that firm size is an important determinant of the decision to export should be weaker in the case of South-South trade. A lower significance of the sunk cost argument in South-South exports leaves a larger space for the traditional Hecksher-Ohlin explanation. Thus, we may expect that factor proportions are more important in explaining South-South trade than in explaining South-North trade. In particular, we expect capital and skill intensities to have a positive impact on the decision of Kenyan firms to export to other African countries only.

3 Data and descriptive analysis

In this Section, we first briefly discuss the data. Thereafter, we provide some descriptive analysis of the key variables.

3.1 Data description

The data used in this paper is based on a comprehensive panel data set on a sample of firms within the Kenyan manufacturing sector for 1992-94, collected over the period 1993 to 1995. The collection of the data gathered over three annual surveys, was organised by the World Bank in a research project called Regional Program on Enterprise Development.

The original dataset consists of more than 200 firms from four different sub-sectors: Food, Wood, Textile, and Metal. These sectors were selected because they were perceived to have the greatest likelihood of exporting. The firms are located in four different cities, Nairobi, Mombasa, Nakuru, and Eldoret. In terms of size, they range from micro-firms to multinationals with several thousands of employees. The dataset contains both formal and informal firms.[42]

Not all the firms in the original survey are included here. We excluded Bakeries, on the grounds they mainly produce goods that do not fare well for exports. Firms with less than six employees were also excluded, because of unreliable data.[43] The dataset thus consists of 339 observations of 161 firms. However, in the subsequent regression analysis a further number of observations were excluded due to missing data. It should be noted that for most firms, data are observed less than three years.

3.2 Comparative behaviour of exporting and non-exporting firms

The proportion of exporting firms by sector and firm size is shown in Table 1. Firm size is defined by the value of output.[44] Exporting firms are defined as those that direct some fraction of sales towards foreign markets.

In the total sample, 38 per cent of the firms export. The proportion of firms that export are highest in the Metal sector and lowest in the Wood sector. The propensity to export increases dramatically with firm size; only 13 per cent of the small firms are exporters, while as many as 67 per cent of the large firms direct some portion of their sales to foreign markets. The positive relation between export propensity and firm size is common for all sectors.

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[42] All detail about the data collection, sampling procedure and the distribution of firms across sectors, location and various firm characteristics can be found in Aguilar and Bigsten (2001).

[43] Liedholm and Mead (1987) argue that measurement errors in survey data are more pronounced and frequent for small firms.

[44] All variables are in constant 1992 prices.

Table 1. Proportion of firms exporting, by sector and firm size, average of 1992-94.

Sector	*Proportion of exporting firms*			
	Small	Medium	Large	ALL
Food	0.21	0.47	0.74	0.47
Textile	0.05	0.22	0.64	0.30
Wood	0.04	0.14	0.46	0.21
Metal	0.24	0.64	0.88	0.58
ALL	**0.13**	**0.36**	**0.67**	**0.38**

Note: The size categories were obtained by dividing the firms into three equal-sized groups based on output of the firms in each sector. Small corresponds to the lowest third, medium to the middle third, and large to the highest third.

The relation between technical efficiency and firm size is shown in Table 2, where the means and the medians of technical efficiency are presented for three different size categories. Technical efficiency estimates are obtained from Data Envelopment Analysis, (DEA).[45] The Table confirms the findings of many previous studies that large firms are more efficient in production. The mean technical efficiencies for large firms are higher than for small firms in all sectors. However, in Food and Textile the mean technical efficiencies are higher among small firms than for medium-sized firms. Median technical efficiency (in parenthesis) always increases with firm size.

Table 2. Mean (Median) technical efficiency, by sector and firm size, average of 1992-94.

Sector	*Mean (Median) technical efficiency*			
	Small	Medium	Large	ALL
Food	0.57 (0.42)	0.47 (0.45)	0.71 (0.67)	0.58 (0.49)
Textile	0.65 (0.53)	0.64 (0.59)	0.79 (0.84)	0.70 (0.66)
Wood	0.37 (0.29)	0.38 (0.31)	0.51 (0.48)	0.42 (0.35)
Metal	0.31 (0.15)	0.48 (0.38)	0.76 (0.74)	0.51 (0.46)
ALL	**0.46 (0.37)**	**0.49 (0.43)**	**0.68 (0.66)**	**0.55 (0.49)**

Note: Technical efficiency is an index ranging from 0 to 1, where 1 indicates full efficiency. The size categories were obtained by dividing the firms into three equal-sized groups based on output of the firms in each sector. Small corresponds to the lowest third, medium to the middle third, and large to the highest third.

[45] The Linear Programming algorithm to obtain technical efficiency based on DEA is presented in Appendix 1.

In Table 3, the following six relative characteristics of exporting and domestically oriented firms are compared: technical efficiency, firm size, capital-labour ratio, human capital, firm age and the proportion of foreign ownership between the two groups. Technical efficiency and firm size are defined as above. Capital-labour ratio is the ratio of the replacement cost of machines and equipment in million Kenyan shilling (Ksh) and the average number of employees. Human capital is computed as the total remuneration to workers in thousand Ksh divided by the number of employees.

The comparison of firm characteristics between exporting firms relative to those producing solely for the domestic market confirms what earlier empirical work has documented. Exporters are more efficient, larger and more intensive in physical as well as human capital. Technical efficiency is higher for exporters in all sectors, ranging from eight per cent higher in mean efficiency for Textile to 28 per cent higher in Wood. The pattern is similar when medians are compared.

The difference in mean firm size between exporters and non-exporters is striking. Sector-wise comparisons reveal that exporting firms are between approximately twice as large (Food) and seven times (Textile) larger than non-exporters. This result confirms the general observation for developing countries that exports tend to originate from relatively large establishments.

The mean capital-labour ratio among exporters is 67 per cent larger than for their domestically oriented counterparts in the total sample. In the Food sector, however, exporters, on average, are less capital-intensive than non-exporters. This is also the sector with the smallest mean difference in size between exporters and non-exporters.

It is usually assumed that developing countries like Kenya are labour-abundant compared to their relatively developed trade partners and, therefore, it is expected to export relatively labour-abundant commodities. The contradicting result in Table 3 (except in the Food-sector) may be explained by the observed positive relation between exports and firm size together with the observation that large firms tend to be more capital-intensive than smaller ones (see Table 4). This issue will be further investigated in Section 4.

Exporting firms seem to possess a higher level of human capital. No clear pattern emerges from comparisons of firm age between the groups. Exporting firms tend to be older in the Food sector and younger in the Textile sector. Finally, Table 3 shows that the proportion of foreign ownership is more than three times as high among exporters.

Table 3. Comparison of firm characteristics: the ratio between the mean (median) for exporting firms and non-exporting firms, by sector, average 1992-94.

	Food	Wood	Textile	Metal	All
Technical Efficiency (VRS)	1.43 ***	1.56 ***	1.10	1.67 ***	**1.41** ***
	(1.33)	(1.80)	(1.00)	(2.28)	**(1.60)**
Firm Size	2.10 ***	6.67 ***	7.33 ***	4.07 ***	**4.39** ***
	(11.42)	(5.96)	(6.42)	(6.00)	**(7.63)**
Capital-Labour Ratio	0.73	1.22	2.91 ***	1.32 ***	**1.67** ***
	(1.14)	(1.23)	(4.10)	(1.29)	**(2.18)**
Human Capital	1.67 **	1.25 **	1.12	1.47 ***	**1.51** ***
	(1.11)	(1.53)	(0.99)	(1.30)	**(1.33)**
Firm Age	1.44 ***	1.16 *	0.53 ***	1.07	**0.98**
	(1.93)	(0.94)	(0.67)	(1.00)	**(1.03)**
Foreign Ownership [a]	4.72 ***	1.97 ***	4.29 **	4.15 ***	**3.52** ***

Note: Figures greater than one indicate a higher mean for exporting firms. ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively. [a] The ratio between the proportion of foreign ownership for exporting firms and non-exporting firms.

Table 4 reveals that it is not only firm size that is positively correlated with technical efficiency, but also human capital. All variables thought to influence technical efficiency and the export decision are significantly positively correlated with each other. For instance, large firms are more intense in physical and human capital, have a higher degree of foreign ownership and are older compared to smaller firms.

Table 4. Pearson correlation coefficient between technical efficiency, firm size, capital-labour ratio, human capital, and firm age, average 1992-94.

	Technical Efficiency	Firm Size	Capital-Labour Ratio	Human Capital	Firm Age	Foreign Ownership
Technical Efficiency	1.000	0.233***	0.072	0.236***	0.073	0.021
Firm Size	0.233***	1.000	0.334***	0.324***	0.201***	0.241***
Capital-Labour Ratio	0.072	0.334***	1.000	0.361***	0.099*	0.182***
Human Capital	0.236***	0.324***	0.361***	1.000	0.150***	0.320***
Firm Age	0.073	0.201***	0.099*	0.150***	1.000	0.116**
Foreign Ownership	0.021	0.241***	0.182***	0.320***	0.116**	1.000

Note: ***, ** and * indicate statistical significance at 1%, 5% and 10%, respectively

Table 5. Comparison of firm characteristics: the ratio between the mean for firms exporting to Africa solely and non-exporting firms, firms exporting to Africa and elsewhere ("Outside") and non-exporting firms, and firms exporting to Africa solely and firms exporting to Africa and elsewhere.

	Africa vs no exports	Outside vs no exports	Africa vs Outside
Technical Efficiency (VRS)	1.20 **	1.41 ***	0.85
Firm Size	3.36 ***	4.95 ***	0.65 ***
Capital-Labour Ratio	2.63 ***	1.51	1.43 ***
Human Capital	2.12 ***	1.46 **	1.31 **
Firm Age	1.16 *	1.19	0.97
Foreign Ownership [a]	4.64 ***	3.29 ***	1.11

Note: ***, **, and * indicate statistical significance at 1%, 5 %, and 10 %, respectively. Figures greater than one indicate a higher mean for exporting firms in the first two cases and higher firms specialising on exporting to Africa in the third case. Significance levels in the first two cases were obtained by regressing the dependent variable on a constant and a dummy variable indicating direction of exports. In the third case, significance levels were obtained from a regression of the dependent variable on dummy variables indicating exports to 'Africa solely' and 'Outside Africa', respectively. Thereafter, the hypothesis $\beta_{AFRICA} = \beta_{OUTSIDE}$ was tested. Note that 'Outside Africa' is composed of firms that direct some of their exports outside Africa.

In Table 5, we focus on how the characteristics of firms that export to other African countries solely relate to firms that direct some or all of their export outside Africa.[46] Columns one and two compare export destination with the alternative of not exporting at all. We largely confirm previous results that exporting firms are more efficient, larger and more intensely use physical and human capital as well as tend to have some foreign ownership.

But there are important differences to report depending upon where exports are directed. Firms exporting within African solely tend to be smaller, but relatively abundant in both physical and human capital. This is in line with Lall's (1987) observations on India and with a view that Kenyan manufacturing firms have a comparative advantage in these two types of capital when compared with firms in other SSA countries, especially its main trading partners, the neighbours Tanzania and Uganda. To the extent the theory of comparative advantage is applicable here, it also dictates trade with countries outside Africa because relatively low-skilled and labour-intensive products dominate that kind of export.

Even though the descriptive analysis shows that technical efficiency is higher among exporters, we cannot at this stage tell whether this is due to that export activities spur technical efficiency, due to that efficient firms start exporting, or due to other characteristics that influence both technical efficiency and the probability to be an exporter. The results in Table 4 show that both firm size and human capital are correlated with export participation and technical efficiency. Both these variables are, however, correlated with other firm characteristics that may influence export participation and technical efficiency. With a multivariate analysis we will be able to better isolate the effect from firm characteristics on the exporting decision and on technical efficiency.

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[46] Approximately 23 per cent of the firms export. Of these, almost half of them direct their exports to other African countries (mainly Tanzania), the rest direct their exports to both within and outside Africa, or exclusively outside Africa.

4 Regression analysis

Having provided a descriptive analysis with special emphasis on exports we now discuss in this section a few modelling concerns. Thereafter, we analyse the results obtained from regression analysis.

4.1 Modelling issues

We have two objectives. The first is to understand what drives firm efficiency and export-participation, respectively. To this end, we estimate two standard models, the first of which explains technical efficiency and has, among the explanatory variables, a dummy variable indicating whether a firm exports or not. The second model has the export dummy variable as the dependent variable and efficiency as one of its arguments.

The second objective is to investigate the effects of taking into account the direction of exports and we estimate similar models as for the first objective. The difference is that, in the efficiency regression, the export dummy variable is replaced by two direction-of-exports dummy variables, while in the export decision regression, the dependent variable is now a trichotomous one: firms that do not export at all; those that export to other African countries solely; and those that direct at least some of their export outside of Africa. These decisions are estimated simultaneously in a multinomial logit.

In all models mentioned above, the explanatory variables, besides exports and efficiency, are firm size, capital-labour ratio, firm age, human capital, and foreign ownership. For all models, using the first lag of these variables hopefully helps to rectify the suspected simultaneity bias caused by potentially endogenous explanatory variables. All continuous variables are in logs.

With the exception of firm size, the variables discussed in the descriptive analysis are defined here as before. However, for the regression analysis we have chosen what we think is a more appropriate measure of firm size. An ideal measure of firm size would take into account the level of all production factors. In the literature, a common measure of firm size is the number of employees, which is a partial measure only.[47] Since there are

[47] Obviously, the mirror image of this 'problem' arises if the capital stock is used as a proxy for firm size. If exporters produce with a more capital-intensive technology than do non-exporters, we will overestimate the size difference between firms.

systematic differences in capital-labour ratios between exporters and non-exporters on one hand, and firms with different output levels on the other, we will underestimate the size difference between firms, and particularly between exporters and non-exporters (e.g. see Table 4). We therefore use firms' potential output as a measure of size, defined as observed output divided by technical efficiency. Potential output is a weighted sum of capital and labour. Apart from reducing the above-mentioned flaw, it is important to note that our definition is also independent of variations in technical efficiency.[48]

Finally, for both the technical efficiency and the export decision regressions, we have included a number of control variables. These are: industry dummy variables to capture unobserved industry-specific variables such as product characteristics or the extent of domestic and foreign competition, and time dummy variables to capture the influence of time-varying macro-variables such as credit-market conditions, exchange rates, and trade policy.

4.2 Estimation results

Table 6 presents the results for the efficiency equations as well as for the export decision equations. The first and second columns show the parameters for two different specifications of the technical efficiency equation, both of which are estimated by OLS with the assumption of Variable Returns to Scale (VRS) technology. The first specification contains a dummy variable for exports activities, taking the value of one if the firm exports and zero otherwise. In the second specification, the export dummy variable for export is replaced by two dummy variables, indicating whether firms export to Africa solely or whether they direct some or all of their exports to countries outside Africa.

Column three presents the marginal effects (evaluated at means) for the export-decision equations with the choices export or no export. A positive marginal effect indicates a positive impact on the probability that a firm is an exporter. Columns four and five present the marginal effects (evaluated at means) for the export-decision equations

[48] This is because technical efficiency is measured in the output-direction. We also used observed output as a proxy for firm size to check that the results were not driven by our size measure. The results were similar and did not alter any of the conclusions.

obtained from a multinominal logit with the choices exports to Africa solely and exports outside Africa respectively. An exporter belongs to the latter category if some fraction of exports is directed outside Africa. It should be noted that, while the binary logit is corrected for heteroscedasticity caused by firm size, the multinomial logit could not be adjusted for heteroscedasticity. In addition, in the binary logit we could also include sector dummy variables, which we could not do in the multinomial logit because one of the exports choices had no variation in one of the sectors.[49] The inclusion of sectors does not qualitatively alter the estimation results obtained in the binary logit model. However, for technical efficiency and firm size, a huge difference with respect to their respective marginal effects is caused by a correction for heteroscedasticity (the other marginal effects are practically unchanged by this correction). Hence, the results for the multinomial logit have to be interpreted with some caution.

Starting with the results for technical efficiency, we find some support for the existence of learning effects (at the 10 per cent level of statistical significance). The point estimate of the export parameter suggests that export activities, on average, increase efficiency by 20 per cent. The effect is large and seems to emanate from exports to Africa only, which, if true, would lend some support to the hypotheses of Amsden (1980; 1986) and Lall (1987) about the benefits of South-South trade. However, a test of the null that direction of exports matter (i.e. $\beta_{AFRICA} = \beta_{OUTSIDE\ AFRICA}$) reveals that no such conclusion can be drawn. We thus conclude that Kenyan firms appear to learn from exporting, and that these effects cannot be said to differ with respect to destination. The other parameters in the two specifications are very similar and from here on we, therefore, do not distinguish between the two specifications.

The marginal effect on technical efficiency with respect to firm size is positive and statistically significant. Since the results suggest a causal link from firm size to technical efficiency, the result cannot be explained by the selection process proposed by Jovanovic (1982). As discussed in section 2.2.2, a plausible explanation for this result is that firm size serves as an instrument for omitted or poorly measured factors of production.

The parameter of the capital-labour ratio is statistically significant at the ten per cent level and carries a negative sign. The negative effect from capital-intensity on

[49] None of the firms in the metal sector exports outside Africa.

technical efficiency may be due to different vintages of capital that give rise to deviations from the production frontier, but that are nevertheless optimal from an economic point of view. The relative fixity of capital compared with, for instance, labour, creates problems for a capital-intensive firm in adjusting to changes in demand. Such firms often operate below full capacity utilisation. Another plausible explanation for the negative parameter is that when new investments in capital are undertaken there is an adjustment period. This adjustment often involves a slump in performance because the labour force needs to be trained on the new equipment (Huggett and Ospina, 2001).

Human capital enters with an expected positive sign and indicates that firms with a greater amount of human capital are more efficient. On the other hand, if variations in average wage (our proxy for human capital) represent variations in average hours worked, the positive parameter might only reflect our failure to properly measure labour input in the DEA estimations. Neither firm age nor foreign ownership are significant in any of the specifications. Hence, the common presupposition that firms with some foreign ownership are more efficient than domestic ones finds no support in our regressions.

Next, we turn to the results for the export-decision regressions. We start with a discussion of the results from the standard logit model. With this specification, the marginal effect of technical efficiency on the decision to export is positive and statistically significant. This result strongly underscores that the cost of entering the export market is lower for relatively efficient firms and provides support for the self-selection hypothesis. Hence, our results confirm what today seems to be the standard result in these types of regressions, i.e. relatively efficient firms self-select themselves into the export market.

Before turning to the direction of exports regressions, we will have a look at the other explanatory variables as well. Also related to the costs of exporting is firm size. The variable enters the specification with a marginal effect that is positive as well as economically and statistically significant. The significance of the parameter of firm size can be interpreted as suggesting that larger firms can bear the costs associated with starting and maintaining export operations.

The marginal effect for firm age is statistically significant at the ten per cent level with a negative sign. The unexpected negative effect of firm age may be explained by the possibility that relatively young firms utilise more recent technology, while older firms are stuck with relatively obsolete physical capital. Thus, in contrast to our expectations, controlling for firm size and efficiency, older firms may be less competitive in the international market. Another explanation, related to the aforementioned one, is that old firms may yet have to adjust from the x-inefficiency caused by protection during the import-substitution policy period.

Table 6. Technical efficiency, export-participation and direction of exports.

	Technical Efficiency		Export Participation		
	Single export dummy	Exp. direction dummies	Anywhere (binary logit)	Africa Only (multinomial logit)	Outside Africa (multinomial logit)
Constant	-1.372*** (5.669)	-1.404*** (5.629)	0.097 (0.431)	0.115 (0.757)	-0.035 (0.297)
Technical efficiency$_{t-1}$			0.377*** (4.976)	0.077* (1.692)	0.070* (1.705)
Exports$_{t-1}$ (Anywhere)	0.213* (1.841)				
Exports$_{t-1}$ (Africa only)		0.256* (1.768)			
Exports$_{t-1}$ (Outside Africa)		0.190 (1.382)			
Firm size$_{t-1}$	0.065*** (3.804)	0.065*** (3.902)	0.283*** (6.952)	-0.002 (0.105)	0.033** (2.542)
Capital-labour ratio$_{t-1}$	-0.077* (1.842)	-0.081* (1.910)	0.028 (0.732)	0.103*** (3.645)	-0.007 (0.312)
Human capital $_{t-1}$	0.118*** (3.013)	0.117*** (2.973)	0.045 (1.040)	0.066* (1.825)	0.006 (0.255)
Firm age $_{t-1}$	-0.028 (0.367)	-0.026 (0.349)	-0.110* (1.853)	-0.037 (0.774)	-0.067* (1.861)
Foreign ownership	0.056 (0.479)	0.045 (0.380)	0.315*** (3.001)	0.237*** (3.356)	0.162*** (2.878)
Food	0.225 (1.554)	0.253* (1.673)	-0.029 (0.252)		
Textile	0.609*** (4.619)	0.628*** (4.487)	-0.104 (0.959)		
Wood	0.072 (0.588)	0.096 (0.738)	-0.184* (1.889)		
Year 2	0.003 (0.037)	0.003 (0.036)	0.008 (0.104)	-0.035 (0.607)	0.031 (0.643)
N/Firms	191/127	191/127	191/127	191/127	191/127
R^{2} [a]	0.22	0.22	0.60	--------	--------
Log-Likelihood	--------	--------	-71.86	-121.14	-121.14
Hypothesis tests:					
Joint β=0[b, c]	5.07 [10,179]***	4.54 [11,178]***	103.8[10]***	92.65[14]***	92.65[14]***
Mlogit vs logit[d]				14.37[8]**	14.37[8]**
$\beta_{Exp(Afr)} = \beta_{Exp(Out)}$[e]		0.12[1]			
$\beta_{AFR\text{-}eff.} = \beta_{OUT\text{-}eff}$[f]				0.18[1]	
$\beta_{AFR\text{-}size} = \beta_{OUT\text{-}size}$[f]				7.60[1]***	
$\beta_{AFR\text{-}caplab} = \beta_{OUT\text{-}caplab}$[f]				5.49[1]**	
$\beta_{AFR\text{-}human} = \beta_{OUT\text{-}human}$[f]				1.37[1]	
$\beta_{AFR\text{-}age} = \beta_{OUT\text{-}age}$[f]				0.84[1]	
$\beta_{AFR\text{-}foreign} = \beta_{OUT\text{-}foreign}$[f]				0.05[1]	
Heteroscedasticity [g, h]	17.11[10]***	16.49[11]***	24.73[1]***	--------	--------

Note: ***, **, and * indicate statistical significance at 1%, 5 %, and 10 %, respectively. T and z-values for marginal effects are in parenthesis. All continuous variables are in logs.

[a] For Logit: Pseudo R^2 (Zavoina and McElvey, 1975).

[b] For OLS: F-test of slope parameters jointly = 0, F[k, N-k-2].
[c] For Logit and Mlogit: H_0: Wald tests of slope parameters jointly = 0, χ^2[df].
[d] Wald test of mlogit(Africa only) slope parameters jointly = mlogit (Outside Africa) slope parameters, χ^2[df].
[e] Wald test of parameters Exports(Africa only) = Exports(Outside Africa), χ^2[df].
[f] Wald test of β_i(Africa only) = β_i(Outside Africa), χ^2[df].
[g] For OLS: Breusch-Pagan test of H_0: homoscedasticity, χ^2[df].
[h] For Logit : Likelihood ratio test of H_0: homoscedasticity, χ^2[df].

Introducing some foreign ownership increases firms' probability of participation in exports by 0.30. Foreign ownership must, therefore, be considered to be an important determinant of exporting. For the overall decision of whether to export or not, capital-intensity and human capital appear to be of little consequence.

Finally, we analyse the results obtained by multinomial logit for direction of exports. The model provides some interesting results, but before going ahead, two things warrant attention. First, as was previously indicated, the size of the marginal effects has to be interpreted with great caution with respect to technical efficiency and firm size, since no correction for heteroscedasticity was made in the multinomial logit. This is also to some extent true for capital-labour ratio and human capital.[50] And second, a Wald-test to determine whether the analysis of direction of exports, compared with the analysis of a standard binary logit model, is statistically meaningful, reveals that this, indeed, is the case.[51]

The effect of technical efficiency on the export decision is similar for firms that direct their exports to Africa solely and for ones that direct some of their exports outside Africa. That is, for both markets it is needed that firms be efficient prior to their entrance. This result stands in contrast to the results of, for instance, Rankin (2001) for South Africa. In that study it was found that firms exporting outside the South African Development Community (SADC) area were more efficient than firms trading within it.

Firm size has a positive and statistically significant effect on the decision to export outside Africa, while the marginal effect of firm size on decision to export within Africa only is statistically insignificant. This differing effect is statistically significant at the one per cent level. Thus, the positive size effect found in the binary logit model seems to be due to the effect of exports directed outside Africa. The reason for this may be that the

[50] To give a hint at the possible bias of the marginal effects, the marginal effects of exports to Africa only and exports outside Africa should add up to the marginal effects for exports anywhere.

cost to enter the export market is lower in the African market then it is to the market outside Africa.

Another interesting result is that high physical capital-intensity as well as human capital increases the probability to export within Africa, while factor proportions have no explanatory power on export activities outside Africa. This means that Kenyan firms might have a comparative advantage in physical and human capital within Africa. However, we should note that the difference between the effects on export within Africa and outside Africa is statistically significant for the capital-labour ratio only (at the five per cent level).

There is no statistically significant difference arising from foreign ownership on the probability to export between the two export directions. Thus, influence from foreign ownership seems to be important for any venture into exports. A plausible explanation for that foreign ownership significantly increases the probability to export within Africa is that firms from developed countries tend to enter the perhaps relatively unknown African market by forming joint ventures with Kenyan firms.

While we were already concerned about the negative marginal effect for firm age (in the binary logit model), it is statistically significant here only in the case of exports outside Africa. It is possible, again, that relatively young firms are better equipped with newer technology for penetrating the more demanding markets outside Africa. Furthermore, it could also be that young firms start with the goal of exporting outside Africa and, therefore, from the start-up stages make the necessary adjustments to be able to do so (see e.g. Fafchamps, El Hamine and Zeufack, 2001).

5 Conclusions

The general finding that efficiency and export activities in developing countries are positively correlated has often been interpreted as support for the existence of learning effects. However, a competing strand of literature maintains that relatively efficient firms self-select into export activities. The implied causalities of these theories thus run in opposite directions. This study's first conclusion is that support can be found for both

[51] The χ^2 value is 14.37 and significant at five per cent.

hypotheses, i.e. there are both learning effects and self-selection behaviour among Kenyan manufacturing firms. In that, we thus agree with, for instance, Bigsten *et al.* (2000).

Such findings have important implications, such as supporting export promotion policies for the sake of increasing efficiency. However, stopping at such conclusions runs the risk of concealing more than it reveals. This study also looks into the relation between efficiency and the direction of exports – an important topic because there is presumably more scope for learning from relatively developed countries, although researchers like Alice Amsden have suggested differently. However, we could not find support the notion that exports to North carries more learning effects than exports to South. In other words, any export direction appears conducive to improvements in efficiency. Our study also addresses the question whether requirements for entering a South market are the same as those for entering a North market. We find that efficiency is important for entry into both markets.

But there are also important differences with respect to the inference of exports within Africa respective outside Africa to report. First, the importance of firm size pertains to exports outside Africa only. This result may be explained by higher costs of penetrating North markets than South markets. For that reason, firms have to be relatively large to bear the cost associated with starting and maintaining export operations outside Africa. We think the different costs of penetrating different markets are another important consideration not brought about in traditional analysis of exports and efficiency.

Second, we observe that firms exporting to other African countries more intensively use physical and human capital and, controlling for other factors, that the probability for a firm to export within Africa increases with the firms' physical and human capital intensity. These findings might lead one to speculate that Kenyan firms have a comparative advantage in production intensive in its use of those factors of production for exports destined to other African countries.

The main contribution of the paper is to highlight differences like those discussed above. Although our study does not permit any far-reaching policy conclusions, we emphasise here that such differences are well hidden in an analysis not taking into account direction of exports.

Finally, let us point to two caveats of the study. The first one is that our distinction between exports directions is not as clean as one would wish. We are only able to distinguish between firms that export to Africa solely and those that *mix* direction of exports. The explanation for our choice to cluster the specialist exporters with the mix exporters is simply that there are very few firms specialised in exports to North. This could be the reason why we do not observe differing effects from exports on efficiency or, vice versa, from efficiency on exports.

The second caveat is that we have access to data from one African country only. Thus our conclusions can hardly be regarded to be general for the African context, although a priori this possibility cannot be dismissed. We think that learning effects from export is an area for further research and hopefully future work will also take into greater account the direction of exports.

Appendix

The Model of Efficiency Measurement

We analyse technical efficiency based on deterministic nonparametric frontiers or data envelopment analysis (DEA). The approach is based on Farrell (1957) and extensions of his work by Charnes *et al*. (1978), and related work by Färe *et al*. (1983, 1985) and Banker *et al*. (1984). In this approach efficiency of a production unit is measured relative to the efficiency of all the other production units, subject to the restriction that all units are on or below the best practice frontier.

Let the technology for each manufacturing sub-sector be represented by a technology set, S, defined as:

$$S = \{(x, y) : y \text{ can be produced by } x\} \qquad \text{(A1.1)}$$

where y is a vector of outputs and x a vector of inputs. We assume that S is closed and convex, it has free disposability of outputs and inputs and variable returns to scale is allowed. Since the sub-sectors are heterogeneous, each sector has its own specific technology and we define the technology as a common technology over time. Thus, for each sub-sector, efficiency is measured relative the most productive units during the entire period. The Farrell output efficiency measure is the ratio of the observed output quantities and the output quantities produced at the frontier given the input and output mix, and for a feasible point (x, y) it is defined as:

$$E^o(y,x) = min_\delta \left\{ \delta : (x, \frac{y}{\delta}) \in S \right\}, \delta > 0. \qquad \text{(A1.2)}$$

Based on the non-parametric technology given the assumption of variable returns to scale the Farrell output efficiency measure equals the inverse of the optimum value of the linear programming problem (x.3) to (x.6), i.e. $E^o(y,x)=\mu^{-1}$

$$Min\ \mu = \sum v_i\, x_{i0} + v_0 \tag{A1.3}$$

$$\sum_{k=1}^{s} \mu_k\, y_{k0} = 1 \tag{A1.4}$$

$$-\sum_{k=1}^{s} \mu_k y_{kj} + \sum_{i=1}^{m} v_i\, x_{ij} + v_0 \geq 0 \quad j = 1, \ldots, N \tag{A1.5}$$

$$\mu_k,\ v_i \geq 0, \quad v_0 \text{ unrestricted} \tag{A1.6}$$

where μ_k and v_i are the weights of the Linear Programming problem, m is the number of inputs and s is the number of outputs. There is a single output and three inputs, where the latter are capital, labour and materials. N stands for the number of production units in the sub-sector times the number of years.

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Foreign Ownership, Factor Proportions and Technical Efficiency:
The Case of the Chilean Chemical Sector

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Abstract: This study investigates the technical efficiency of foreign- and domestic-owned plants in the chemical sector in Chile. The model combines a stochastic frontier production function in which technical inefficiency effects are modelled in terms of ownership and input level. The results indicate that the higher average inefficiency observed among domestic-owned plants stems partly from the inefficient use of capital. Increased use of labour inputs improves technical efficiency for domestic-owned plants, while increased uses of capital reduce efficiency. Thus, the shift towards more capital-intensive production techniques in Chile, following the trade liberalization, may have brought adjustment costs in the form of reduced technical efficiency.

Keywords: Technical efficiency, non-neutral stochastic frontier, foreign ownership, Chile, chemical industry.

JEL classification: C23, C24, D24, F23, L65

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1 Introduction

One of the arguments for trade liberalization in developing countries is that a more rational market structure will attract foreign investors and thus promote the adoption of new and superior technologies. Multinational corporations (MNCs) are assumed to be more efficient than domestic-owned firms because of greater experience in management and superior organisational structure. On the other hand, such foreign-owned firms may be inefficient when they operate in an unfamiliar environment. For instance it may be that, because of the low labour costs in developing countries, the cost-minimising foreign firms adopt a more labour-intensive technology than they use in home operations, and the unfamiliar labour-intensive technique may negatively affect technical efficiency.[52] For a developing country undergoing trade liberalization, there may be a similar explanation for inefficiency among domestic producers. Because of the typical fall in the price of capital relative to labour costs following a trade liberalization, firms may adopt an unfamiliar capital-intensive technology, with resulting inefficiency.

Even if MNCs operating in a developing country adopt a more labour-intensive technique than in home operations, they typically use a more capital-intensive technique than do local-owned firms.[53] This use may be explained by a higher marginal product of capital among MNCs, who are generally thought able to use capital more efficiently.[54] To minimise cost, however, foreign firms operating in developing countries with low labour costs may choose a capital-labour ratio below the one that would have been optimal from a technological point of view. This economically optimal deviation for the production frontier suggests a positive correlation between capital-intensity and technical efficiency among foreign firms. If domestic firms are less familiar with capital-intensive techniques, one would expect the correlation to be smaller than for foreign-owned firms, or even negative.

[52] See Morley and Smith (1977).

[53] For empirical evidence, see White (1978), Pitt and Lee (1981), and Haddad and Harrison (1993).

[54] Another possible explanation for the higher capital-intensity among foreign-owned firms in developing countries is that capital-intensive technologies are generally the latest and most efficient, and that MNCs are more likely to have adopted the latest technology (White, 1978).

Technical efficiency may also be related to firm size: large firms in developing countries are often thought to be more efficient than small firms. This higher efficiency has been attributed superior technical knowledge, as well as to the relatively higher growth rate of efficient firms. The manufacturing industry in Newly Industrialised Countries (NICs) like Chile usually has a dual structure. Most of the output is produced by a small number of large ”modern” firms using capital-intensive technology, while the rest is produced by a large number of small ”traditional” firms using much more labour-intensive technology. Since the ”traditional” part of the industry likely consists entirely of domestically-owned firms, while the ”modern” part may be heavily foreign-owned, a direct efficiency comparison between the average foreign firm and the average domestic one will be misleading. This is so because differences in both size and capital intensity need also to be considered (Blomström, 1989).

This paper examine the impact of foreign ownership, factor proportions, and firm size on technical efficiency in Chile's chemical industry during the period 1988 to 1991. One shortcoming of the conventional stochastic frontier model is that it assumes technical inefficiency to be independent of production factors. Huang and Liu (1994) proposed a model for a stochastic frontier in which technical inefficiency is allowed to be a function of the inputs and other explanatory variables. By including inputs as determinants of inefficiencies, the conventional assumption that technical efficiency is independent of the factors of production is dropped. The non-neutral shifts of the production function obtained from this specification make it possible to test the following two hypotheses: (i) increased labour-intensity reduces technical efficiency for foreign-owned firms; and (ii) increased capital-intensity reduces technical efficiency for domestic-owned firms.

In the econometric analysis, we found no support for the first hypothesis. Hence, the results provide no evidence for a significant impact of factor proportions on technical efficiency. However, the econometric analysis supports the second hypothesis. The results suggest that increased use of labour inputs improves technical efficiency for domestic-owned plants, while increased uses of capital reduce efficiency. Thus, the shift towards more capital-intensive production techniques in Chile, following the trade liberalization, may have brought adjustment costs in the form of reduced technical efficiency.

The model for the frontier production function and inefficiency effects is discussed in Section 2. Section 3 discusses the data, together with the empirical model and compares characteristics of foreign-owned plants with ones domestically-owned. Empirical results are given in Section 4. The final section summarises major results and derives conclusions.

2 The Non-Neutral Stochastic Frontier Model

A production frontier specifies maximum outputs for given sets of inputs and existing production technologies. Failure to attain the frontier is due to technical inefficiency. Aigner, Lovell and Schmidt (1977), Battese and Corra (1977) and Meeusen and van den Broeck (1977) proposed independently the stochastic, composed error, frontier production function in which random errors are incorporated into the model to account for the effects of factors outside a firm's control.[55] A stochastic frontier production function for panel data may be formulated as

$$y_{it} = f(x_{it};\beta)\exp\{v_{it} - u_{it}\} \tag{1}$$

where y_{it} denotes the production of firm i at time t; x_{it} is a vector of inputs and other explanatory variables; β is a vector of technology parameters to be estimated; v_{it} is a random disturbance term which captures effects outside the control of the firm, and is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$; u_{it}, is a non-negative random variable associated with technical inefficiency, and is assumed to be distributed independently of v_{it}. The Farrell (1957) output-oriented technical efficiency measure (TE) is written as

$$TE_{it} = \frac{y_{it}}{y_{it}^*} = \frac{f(x_{it};\beta)\exp\{v_{it} - u_{it}\}}{f(x_{it};\beta)\exp\{v_{it}\}} = \exp\{-u_{it}\} \tag{2}$$

[55] Hereafter referred to as the conventional error-component model.

where y_{it}^{*} denotes stochastic frontier output.

The conventional error-component model suffers from a serious drawback: It assumes that technical inefficiency occurs randomly across firms and, hence, is independent of the input level and of other firm-specific characteristics. A question of interest, however, is whether some firms have predictably higher levels of inefficiency than others. If the occurrence of inefficiency is not totally random, then it should be possible to identify factors that contribute to the existence of inefficiency.

The majority of empirical attempts to explain inefficiency adopt a two-step process: The first step is prediction of the technical efficiency and the second is a regression of the efficiency index on some explanatory variables.[56] However, this approach may lead to inconsistent estimates, since the assumption of randomly distributed efficiency is violated in the second step.[57] Kumbhakar, Ghosh, and McGuckin (1991) and Refschneider and Stevenson (1991) proposed models in which technology parameters, and the parameters of the firm-characteristic variables which are thought to influence inefficiency, are estimated simultaneously. However, these models did not include input levels as determinants of inefficiency.

Independence of efficiency from input levels, as assumed in the models mentioned above, implies that the marginal rate of technical substitution remains unchanged when there is variation in observed output, at constant input levels, thus shifting the efficiency index. Therefore, marginal products should decrease proportionally with the efficiency index, and a technically inefficient firm would be equally inefficient in all inputs. However, firms might be more efficient in their use of some inputs than with others, for instance, if they have acquired more information and experience with using one.

Huang and Liu (1994) proposed that inefficiency be made a function of both firms-specific variables and input levels. In this case, the marginal rate of technical substitution changes when shift in output, at constant input levels, cause the efficiency index to change. This is because the marginal products of the production factors do not change in proportion to changes in the efficiency index. The Huang and Liu specification makes is

[56] See e.g. Pitt and Lee (1981) and Kalirajan (1981).
[57] See Lovell (1993) for a discussion.

possible to estimate whether or not a production unit is equally efficient in all inputs, as is assumed in the conventional error-component model.

Huang and Liu specify the inefficiency error component, u_{it}, in the stochastic frontier production function (1) as

$$u_{it} = g(z_{it};\delta) + w_{it} \tag{3}$$

where z is a vector of explanatory variables associated with technical efficiency and δ is a vector of unknown coefficients. The z-variables may include input levels and sector- or firm-specific variables. The unexplained component of the inefficiency model, w_{it}, is defined as the truncation of a normal distribution with zero mean and variance σ_w^2, such that the point of truncation is $-z_{it}\delta$, i.e., $w_{it} \geq -z_{it}\delta$.

Using the Battese and Coelli (1988) formula firm-specific technical efficiency is calculated from the mode of the conditional expectations of u given (v-u) as

$$TE_{it} = E(e^{-u_{it}}) = \left\{\exp\left[-\mu_{*it} + \frac{1}{2}\sigma_*^2\right]\right\}\left\{\frac{\Phi\left((\mu_{*it}/\sigma_*) - \sigma_*\right)}{\Phi\left(\mu_{*it}/\sigma_*\right)}\right\} \tag{4}$$

where $\Phi(\cdot)$ represents the distribution function for the standard normal random variable,

$$\mu_{*it} = \frac{\sigma_v^2 g(z_{it};\delta) - \sigma_w^2\left(v_{it} - u_{it}\right)}{\sigma_v^2 + \sigma_w^2} \tag{5}$$

and

$$\sigma_*^2 = \frac{\sigma_w^2 \sigma_v^2}{\sigma_w^2 + \sigma_v^2}. \tag{6}$$

With inputs included in (3), output elasticity (E) with respect to a given input can be decomposed into two parts: Direct elasticity (ε), which is the change in output due to a movement along the production function, and indirect elasticity (λ), which is the change in output due to a shift in the production function because of a change in efficiency from a change in input. Output elasticity with respect to input j is the sum of the direct and indirect elasticities:

$$E_{jit} = \varepsilon_{jit} + \lambda_{jit} = \frac{\partial \ln y_{it}}{\partial \ln x_{jit}} + \frac{\partial \ln y_{it}}{\partial TE_{it}} \frac{\partial TE_{it}}{\partial \ln x_{jit}} \tag{7}$$

where $\partial \ln y_{it} / \partial TE_{it} = 1/TE_{it}$ and the derivative of technical efficiency with respect to the logarithm if input j is derived from (4) as

$$\frac{\partial TE_{it}}{\partial \ln x_{jit}} = \psi_{it} TE_{it} \left(\frac{\partial g}{\partial \ln x_{jit}} \right) \tag{8}$$

where

$$\psi_{it} = \frac{\sigma_*}{\sigma_w^2} \left(\frac{\phi\left(\mu_{*it} / \sigma_* - \sigma_*\right)}{\Phi\left(\mu_{*it} / \sigma_* - \sigma_*\right)} - \frac{\phi\left(\mu_{*it} / \sigma_*\right)}{\Phi\left(\mu_{*it} / \sigma_*\right)} - \sigma_* \right) \tag{9}$$

in which $\phi(\cdot)$ represents the density function for the standard normal random variable. Since ψ goes to zero when technical efficiency goes to one, λ equals zero at the frontier, and increases with inefficiency.

Returns to scale (RTS) can be calculated as

$$RTS_{it} = \sum_j \varepsilon_{jit} + \sum_j \lambda_{jit} \quad . \tag{10}$$

The first part on the right-hand side is returns to scale corresponding to the non-neutral specification of a production function, i.e., $\lambda_{jit} = 0$ for all j. The second part captures the effect on technical efficiency and, hence, output from proportional variations in inputs. This may be interpreted as the effect on technical efficiency from variations in size.

3 Data and Empirical Model

The chemical industry is chosen as a basis for the present analysis because it has the highest degree of foreign ownership in the Chilean manufacturing sector. The low degree of foreign participation in the rest of the manufacturing sector makes it difficult to produce significant results regarding differences in performance between foreign and domestic firms. In 1991, 20 percent of chemical firms with more than ten employees were partly or totally owned by foreigners, compared with 4.7 percent for the whole manufacturing sector, and their share of total sales in the sector was 47 percent. The sector is also highly exposed to foreign competition. More than 60 percent of domestic supply was imported in 1991, while about 10 percent of domestic production was exported.

The empirical analysis is based on plant-level survey data collected by Statistics Chile. The surveys include all enterprises in the manufacturing sector with more than ten employees, and covers the period 1979 to 1991. This study is limited to the years 1988 to 1991, however, since earlier surveys lack information on ownership. In our sample, there are ten four-digit subsectors.

The original sample covered 651 plants and had 2036 observations. Due to missing values, however, the sample has been reduced to 703 observations of 194 plants. Most of the observations excluded are due to missing-capital stock data. Unfortunately, capital stock was reported only in 1981. Therefore, capital-stock variables, derived from the perpetual inventory method, could not be constructed for entrants after 1981.[58] In addition, capital stock was not reported by several plants in 1981.[59]

The stochastic frontier production function in (1) can be written in translog form as

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[58] If all plants in the panel were new establishments, investment data could be used to calculate the capital-stock. However, since our data only cover plants with 10 or more workers, entry may also reflect an increase in labor over the cut-off point. Since we can't identify the reason for entering the panel, all entering plants are excluded.

$$\ln y_{it} = \alpha_0 + \sum_j \beta_j \ln x_{jit} + \beta_t t + \frac{1}{2}\{\sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + \beta_{tt} t^2\} + \sum_j \beta_{jt} x_{jit} t + \sum_l \alpha_l S_l + v_{it} - u_{it} \tag{13}$$

where y is output, x is input, t is time, and S is the dummy variable for the l^{th} nine ISIC four-digit subsectors (l=1,2,...,9). The composed-error terms v and u are as defined above.

Output is measured by value added, defined as sales adjusted for changes in inventories minus the cost of raw materials, energy inputs, goods purchased for resale, and contract work. The inputs are capital and labour. Capital is defined as the book value of machines and equipment, corrected for the number of operating days. Data on investments and book-value depreciations for the years after 1981 were used to construct the capital-stock variable.

Three different types of labour were reported in the surveys: blue-collar workers, white-collar workers, and home workers. For each type of labour, the average number of employees and wage costs are reported. Thus, physical labour and wage costs are two obvious candidates as measures of labour input. Since foreign firms pay higher wages on average, the choice might significantly influence our results. If foreign firms pay higher wages for equivalent units of labour, then a wage-bill variable will overestimate the labour input in foreign firms' production. On the other hand, if the higher wages in foreign firms reflect a more skilled labour-force, then a physical-labour variable will underestimate their labour input.

In this study, an intermediate measure is chosen. To adjust for differences in productivity between the groups, labour input is defined in efficiency labour units, where the number of employees is computed in blue-collar workers' equivalents.[60] This is done by combining the data on the total wage cost for blue-collar workers (W_B) and the average number of blue-collar workers during the year (L_B) with the data on total wage cost for white-collar workers (W_w) and home workers (W_H). We then define labour input as

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[59] All firms which reported zero value of machines and equipment are considered as non-responders.

$$L = L_B + L_B(W_w / W_B) + L_B(W_H / W_B)\,. \tag{14}$$

The assumption behind this measure is that blue-collar workers are identical for all firms, while the quality of white-collar and home workers is reflected in their relative wages. The difference in wages between the two ownership categories is much higher for white-collar workers than for blue-collar workers, which may support this assumption.[61]

All variables are deflated to 1990 prices using 4-digit sector-specific price indices. Output price-deflators were constructed directly from average-price indices obtained from Statistics Chile. Deflators for capital and raw materials were constructed from sectoral output prices using the 1986 Chilean input-output table. Each energy input was deflated by its own deflator, constructed from reported physical volumes and values. Summary statistics of output and inputs are presented in Table 1.

Table 1. Summary statistics of output, capital, and labour.

Variables	Mean	St. Dev.	Minimum	Maximum
Output*	1009	2869	6.4	44043
Capital*	265	761	0.3	6422
Labour	207	309	9.9	3365

*Million Chilean pesos in 1990 prices.

Technical inefficiency is assumed to be a function of ownership and the input levels. The inefficiency model (3) is specified as

$$u_{it} = \delta_0 + \delta_F F_{it} + \delta_{KD} \ln K_{it} D_{it} + \delta_{LD} \ln L_{it} D_{it} + \delta_{KF} \ln K_{it} F_{it} + \delta_{LF} \ln L_{it} F_{it} + \sum_l \eta_l S_l + w_{it} \tag{15}$$

where K is capital, L is labour, F is a dummy for foreign ownership, D is a dummy for domestic ownership, and S is the sector dummy defined in (13). F equals one if 50

[60] See Griliches and Ringstad (1971).

[61] Wage payments per employee are, on average, 67% higher for blue-collar workers and 98% higher for white- collar workers in foreign owned plants.

percent or more of the plant is foreign-owned and D equals one if more than 50 percent of the plant is domestic-owned. To allow the marginal effects of inputs on efficiency to differ according whether a plant is foreign- or domestic-owned, the slope coefficients include "product" dummies for foreign and domestic ownership.

Factor productivity measures shown in Table 2 indicate that foreign firms are more productive than domestic ones, in terms of both labour and capital. The large difference in the output-labour ratio may be partly explained by the fact that foreign plants use less labour-intensive techniques. Comparisons of partial productivity measures within each size class reveal that small domestic plants are more productive with both inputs, while foreign medium-sized plants have a higher labour productivity and a lower capital productivity compared with domestic plants belonging to the same size class. Foreign large plants, however, are more productive with both inputs. Interpretations of partial productivity ratios between size classes are straightforward: The higher the scale in production, the higher the productivity in both capital and labour. This result holds even when looking at productivity differences between size classes within each ownership category. The capital-labour ratio is higher for the foreign plants also within each size class and increases with size independently of ownership. The difference in mean plant-size between the groups is remarkable: On average, foreign plants are more than four times as large as domestic plants.

Table 2. Factor productivity, capital intensity and mean plant size by owner category and size.

Category	N	Output-labour ratio	Output-capital ratio	Capital-labour ratio	Mean plant size*
Foreign	138	7.05	3.24	2.17	2726
Domestic	564	3.57	2.55	1.40	588
Small	350	1.81	1.65	1.10	108
Medium	176	3.18	2.32	1.37	623
Large	176	6.16	3.19	1.93	3186
Foreign small	18	1.52	0.91	1.67	122
Domestic small	332	1.83	1.73	1.06	107
Foreign medium	35	3.77	1.92	1.96	709
Domestic medium	141	3.04	2.46	1.24	601
Foreign large	85	7.71	3.47	2.22	4109
Domestic large	91	4.62	2.81	1.64	2324
All	702	4.84	2.88	1.68	1009

* Value added, million Chilean pesos in 1990 prices.

4 Estimation Results

The translog frontier production function (13) and the inefficiency model (15) have been estimated using the likelihood function given in Battese and Coelli (1993).[62] The parameters of the model are estimated such that the variance parameters are expressed in terms of γ and σ^2_s, which are defined by $\gamma \equiv \sigma^2_w / \sigma^2_s$ and $\sigma^2_s \equiv \sigma^2_v + \sigma^2_w$.

A number of generalized likelihood tests are performed to investigate the importance to efficiency of ownership, input levels, and size. The null hypotheses and the test results are presented in Table 3. The first null hypothesis, which implies that technical efficiency is absent from the model, is rejected. Hence, the traditional average response function is not an adequate representation for the data.

The second null hypothesis, that the parameter for the foreign ownership dummy is equal to zero, is also rejected. This result implies that the intercepts of the inefficiency model differ between foreign- and domestic-owned plants.

[62] The estimates were obtained using the computer program FRONTIER Version 4.1, written by Coelli (1994).

Table 3. Hypothesis tests for parameters of the inefficiency model.

Test	Null Hypothesis	lnL(H_0)	Test statistic	Critical value	Decision
1	H_0: $\gamma=\delta_0=\delta_F=\delta_{KD}=\delta_{LD}=\delta_{KF}=\delta_{LF}=\eta_1=\eta_2\ldots=\eta_9=0$	-701.44	109.51	25.69*	Reject H_0
2	H_0: $\delta_F=0$	-655.86	15.66	3.84	Reject H_0
3	H_0: $\delta_{KD}=\delta_{LD}=\delta_{KF}=\delta_{LF}=0$	-653.32	10.58	9.49	Reject H_0
4	H_0: $\delta_{KD}=\delta_{LD}=0$	-653.30	10.54	5.99	Reject H_0
5	H_0: $\delta_{KF}=\delta_{LF}=0$	-648.05	0.04	5.99	Accept H_0
6	H_0: $\delta_{KD}+\delta_{LD}=0$	-652.26	8.42	3.84	Reject H_0

* As suggested by Coelli (1995), the critical value for the generalized likelihood-ratio test of the first null hypothesis, with $\gamma=0$, is obtained from Table 1 of Kodde and Palm (1986).

The third null hypothesis testing the specification of the non-neutral effect, was rejected at the 5 percent level. This result suggests that the marginal rate of technical substitution changes when the unit isoquant shifts with variation in efficiency, or, equivalently, that variations in efficiency relate to variations in input levels. The fourth null hypothesis, that non-neutral effects are absent for domestic plants, is also rejected. The fifth null hypothesis, that non-neutral effects are absent for foreign plants, can however not be rejected. Thus, variations in input levels explain some of the variations in technical efficiency for domestic plants, while technical efficiency is independent of input levels among foreign plants. Finally, the last null hypothesis, that technical efficiency is unaffected by a proportional increase in inputs for domestic plants, is rejected. Thus, an increase in size along a factor ray will influence technical efficiency for domestic plants.

The maximum-likelihood estimates for the parameters in the restricted model, with the restriction $\delta_{KF}=\delta_{LF}=0$, are given in Table 4. The coefficients for the input variables in the translog stochastic frontier are not directly interpretable. However, the estimates of the coefficients for the inefficiency variables are of particular interest in this study.

Table 4. Maximum likelihood estimates for parameters of the stochastic frontier model.

Variable	Parameter	Estimates	t-ratio
Stochastic frontier			
Constant	α_0	-0.328**	-2.056
Capital	β_K	0.289***	5.166
Labour	β_L	0.910***	10.700
Capital^2	β_{KK}	0.056***	2.847
Labour^2	β_{LL}	-0.100*	-1.906
Capital × Labour	β_{KL}	-0.026	-1.007
Capital × Year	β_{KT}	0.023	1.369
Labour × Year	β_{LT}	-0.078***	-3.223
Year	β_T	0.203*	1.814
Year^2	β_{TT}	-0.062	-1.427
Industry dummies:			
Basic industrial chemicals	α_1	0.791***	5.232
Synthetic resins, plastic materials and pesticides	α_2	0.967**	2.297
Paints, varnishes and lacquers	α_3	0.401***	3.320
Drugs and medicines	α_4	0.742***	6.559
Soap and cleaning preparations, perfumes and cosmetics	α_5	0.561***	4.547
Chemical products not elsewhere classified	α_6	0.674***	5.434
Products of petroleum and coal	α_7	0.193	0.801
Tyre and tube	α_8	0.191	1.561
Rubber products not elsewhere classified	α_9	0.144	1.070

Table 4 (continued)

Variable	Parameter	Estimates	t-ratio
Inefficiency Model			
Constant	δ_0	-2.648	-1.291
Foreign	δ_F	-2.519**	-2.034
Capital × Domestic	δ_{KD}	0.692***	3.178
Labour × Domestic	δ_{LD}	-0.320*	-1.918
Industry dummies:			
Basic industrial chemicals	δ_1	2.061**	2.162
Synthetic resins, plastic materials and pesticides	δ_2	4.087***	2.470
Paints, varnishes and lacquers	δ_3	-4.984	-1.443
Drugs and medicines	δ_4	1.322**	1.997
Soap and cleaning preparations, perfumes and cosmetics	δ_5	-0.577	-0.674
Chemical products not elsewhere classified	δ_6	0.331	0.634
Products of petroleum and coal	δ_7	-0.327	-0.300
Tyre and tube	δ_8	-7.200	-1.319
Rubber products not elsewhere classified	δ_9	-0.083	-0.125
Variance Parameters			
	σ_S^2	2.442**	2.216
	γ	0.927***	26.507

Note: * International Standard Industry Classification Rev. 2.

The estimate for the foreign ownership dummy is negative. This implies that, at mean input levels, a foreign-owned plant is expected to be less inefficient than a plant with domestic ownership belonging to the same sector.[63] The estimated coefficient for the product dummy between capital and domestic ownership is positive, which indicates that increased uses of capital among domestic-owned plants increase inefficiency. Further, the estimated coefficient for the product dummy between labour and domestic ownership is negative, which implies that increased uses of labour reduce the inefficiency of production for domestic plants.[64]

[63] Since inputs are scaled by their sample mean, the log of inputs equals zero at mean.
[64] The parameter is however only significant at the ten percent level.

The sum of the product dummies is positive. This suggests that an increase in size originating from a proportional increase in inputs increases technical inefficiency among domestic plants. A labour-biased increase in size may, however, reduce inefficiency.

Table 5 shows means of returns to scale (RTS) and its components direct effect on RTS corresponding to the non-neutral specification and the indirect effect on RTS from variations in inefficiency, together with direct elasticities corresponding to movement along the production function and indirect elasticities corresponding to a shift in the production function due to a change in efficiency from a change in input. Mean RTS is greater than one for small and medium-sized plants, indicating increasing returns to scale, while the large plants category, on average, exhibits decreasing returns to scale. The effect on RTS by the decrease in efficiency from a proportional increase in inputs is low. On average, a proportional increase in input of, for example, 10 percent decreases efficiency and, hence, output in only 0.13 percent among domestic plants. Also the individual indirect elasticities are rather low compared to the direct elasticities.

Table 5. Mean of returns to scale (RTS), output elasticities , direct and indirect elasticities, technical efficiency, by ownership and size categories.

Category	N	RTS	Direct RTS	Indirect RTS	Direct capital elasticity	Direct labour elasticity	Indirect capital elasticity	Indirect labour elasticity
Foreign	138	1.042	1.042	0	0.338	0.703	0	0
Domestic	565	1.115	1.128	-0.013	0.273	0.855	-0.024	0.011
Small	351	1.186	1.199	-0.013	0.251	0.948	-0.024	0.011
Medium	176	1.050	1.058	-0.008	0.296	0.762	-0.016	0.007
Large	176	0.982	0.988	-0.006	0.343	0.645	-0.011	0.005
Foreign small	18	1.185	1.185	0	0.295	0.890	0	0
Domestic small	333	1.186	1.200	-0.014	0.249	0.951	-0.026	0.012
Foreign medium	35	1.079	1.079	0	0.334	0.745	0	0
Domestic medium	141	1.042	1.053	-0.011	0.287	0.766	-0.020	0.009
Foreign large	85	0.996	0.996	0	0.349	0.647	0	0
Domestic large	91	0.969	0.981	-0.012	0.338	0.643	-0.021	0.010
All	703	1.101	1.111	-0.010	0.285	0.826	-0.019	0.009

In Table 6 arithmetic averages of technical efficiency (TE) are presented. Higher efficiency among foreign firms confirms the conclusion drawn from factor productivity analysis: The average level of efficiency for domestic plants is 0.65, compared to 0.69 for foreign plants. However, small and medium-sized domestic-owned plants are on average more efficient than foreign plants belonging to the same size group. This may be explained by the fact that domestic-owned plants belonging to these size groups operate with a more labour-intensive technique than do large domestic plants (see Table 2).

The results of the inefficiency model suggest that technical efficiency is independent of plant size for foreign plants. For domestic-owned plants, the results imply a positive relation between technical efficiency and a labour-biased increase in size, and a negative relation between technical efficiency and a capital-biased increase in size. Since Table 2 suggests that an increase in plant size is typically capital-biased, one would expect the efficiency-size relation to be negative for domestic plants. However, the mean efficiency scores in Table 6 do not confirm this. The efficiency index increases with plant size, ranging from an average of 0.62 for small plants to 0.72 for large plants. Mean efficiency also increases with plant size within the foreign ownership group. The mean efficiency for domestic medium-sized plants is higher than the mean efficiency for domestic small plants, while there is no significant difference in mean efficiency between domestic medium-sized and large plants. This conflicting result may be explained by the different definitions of plant size. In the efficiency model, input levels measure size, while the size groups in Table 6 are constructed on the basis of the plant's output levels. Since technical efficiency here is defined as the deviation from potential output, higher output levels may reflect higher technical efficiency per se. Thus, output may be a less successful measure of plant size if the relation between efficiency and size is examined.

Table 6. Mean technical efficiency.

Category	N	Technical efficiency			
		Mean	St. D	Min	Max
Foreign	138	0.69	0.18	0.17	0.90
Domestic	565	0.65	0.19	0.04	0.91
Small	351	0.62	0.20	0.04	0.90
Medium	176	0.69	0.18	0.05	0.90
Large	176	0.72	0.13	0.25	0.91
Foreign small	18	0.51	0.17	0.17	0.75
Domestic small	333	0.62	0.20	0.04	0.90
Foreign medium	35	0.63	0.21	0.18	0.90
Domestic medium	141	0.70	0.17	0.05	0.90
Foreign large	85	0.76	0.11	0.25	0.89
Domestic large	91	0.69	0.14	0.32	0.91
All	703	0.66	0.19	0.04	0.91

5 Summary and Conclusions

This paper presents empirical evidence of a positive relationship between foreign ownership and technical efficiency in Chile's chemical industry. A non-neutral specification of the stochastic frontier production function gives results that suggest that increased use of labour inputs improves technical efficiency for domestic-owned plants, while increased uses of capital reduce efficiency. For foreign-owned plants, however, there is no significant relationship between input levels and technical efficiency. This result indicates that the conventional formulation of the error-component stochastic frontier production function (Aigner, Lovell and Schmidt, 1977; Battese and Corra, 1977; Meeusen and van den Broeck, 1977) may not be appropriate. The implicit assumption behind this model is that inefficient firms are equally inefficient in all inputs, and, hence, the marginal rate of technical substitution is independent of efficiency. Present results suggest, however, that the marginal rate of technical substitution does change with the level of efficiency for domestic-owned plants in the Chilean chemical sector.

Average technical efficiency is higher among domestic small and medium-sized plants compared with foreign-owned plants belonging to the same size groups, while large foreign-owned plants are, on average, more efficient than domestic-owned large plants. This result may be explained by the fact that capital-intensity typically increases with plant size in Chile's chemical industry. The high labour-intensity among domestic small and medium-sized plants generates a relatively low inefficiency, while the high capital-intensity among large plants generates relatively high inefficiency among domestic-owned plants.

The results may give support for the hypothesis that the decrease in the relative price of capital, followed by the trade liberalization in Chile, has resulted in the adoption of an unfamiliar capital-intensive technology, with resulting inefficiency. However, no support was found for the hypothesis that foreign-owned plants in the Chilean chemical sector are more efficient in the use of capital, or less efficient in the use of labour, due to greater experience with more capital-intensive techniques in home operations.

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