Determinants of Technical Efficiency in Small Firms

Roberto Alvarez
Gustavo Crespi

ABSTRACT. There is evidence that small firms are less productive than larger ones. This phenomenon could be explained by several factors. In this paper, using plant survey data and non-parametric deterministic frontier methodology, we explore what factors can explain the observed differences in technical efficiency. In the case of Chilean manufacturing firms, we found that efficiency is positively associated with the experience of workers, modernization of physical capital and innovation in products. In contrast, other variables such as outward orientation, owner education and participation in some public programs do not affect the efficiency of the firms.

1. Introduction

Small firms are a sector of great concern for government policies. During the last few years, the Chilean Government has developed several instruments for increasing the productivity of these firms and has spent a significant amount of resources to achieve this objective. This has been justified not only from an economic efficiency standpoint, but also from an income distribution perspective, because this group of firms is a very important source of employment in the economy. Chilean small firms represent more than 70% of total employment, however, they only generate 1.5% of the exports and about 17% of total sales. These figures show its high importance in employment and its very low levels of productivity.

The low productivity of small firms has been explained by some factors that could affect their performance. Among them, their inability to take advantage of scale economies, the difficulties they face in getting access to credit for investment, the lack of resources in terms of qualified human capital, and the informality of contracts with clients and suppliers. Nevertheless, although the literature suggests a number of explanations to this phenomenon, in the Chilean case there has not been any recent empirical studies validating or rejecting these hypotheses. An exception is Meller (1976), who concluded that the extent of technical inefficiency of small plants with respect to their relevant efficiency frontiers is much greater than for large firms. However, he does not investigate the determinants of this evidence.

In this sense, the empirical evidence is very important in identifying the factors that threaten the productivity of these firms and in generating information for designing of support policies for the small firms. Also, as this article suggests, there are significant differences in the productivity level of firms throughout the sectors and these differences have not been analyzed sufficiently in recent years.

Based on these considerations, the aims of this paper are to determine the level and to identify the factor that affect the efficiency of small firms, particularly in manufacturing industries. In order to do that, we use data from a special survey collected between April and July, 1998 with a sample of 1,091 small firms in the manufacturing industry.

The article is structured as follows. In Section

Final version accepted on November 11, 2001

Roberto Alvarez
Department of Economics
University of Chile
Diagonal Paraguay 257, Oficina: 1604
Santiago
Chile
E-mail: ralvarez@anderson.ucla.edu

Gustavo Crespi
Science and Policy Research Unit – SPRU
University of Sussex
Mantel Building
Brighton
U.K.
and
Department of Economics
University of Chile
Chile
E-mail: G.A.Crespi@sussex.ac.uk

Small Business Economics **20**: 233–244, 2003.

2, we describe the source of the data, the distribution of firms by size and business sector, and show some of the differences among firms. In general, we found that larger firms have better performance than smaller ones in aspects such as productivity, fixed capital intensity, owner education, credit access, technological innovation, outward orientation, and workers skill. In Section 3, we present the main methodological aspects of technical efficiency estimation. In Section 4, we show results by size and sector, and identify the determinants of technical efficiency. We found that there are significant differences in efficiency throughout the economic sectors. In addition, econometric results suggest that owner characteristics, such as education or job experience, are not related to efficiency. But input quality variables, such as workers experience and capital modernization, increase efficiency. One interesting result is that the more innovative firms, that introduce new products, get higher efficiency than more traditional firms. Finally, the main conclusions and policy implications are presented in the last section.

2. Data source and characteristics of firms

The sampling framework for this study comes from a general survey applied to micro, small and medium firms carried out by the Central Bank of Chile and the National Institute of Statistics (INE) during 1996. The aim of the fieldwork was to collect information from the micro, small and medium firms in order to upgrade the National Account System Statistics. In order to avoid any bias towards formal firms in the sampling selection, it was decided not to use the Tax System Directory following instead a searching procedure. In order to do this, the INE used the sampling frame applied in the National Employment Survey and a new set of questions was introduced in the questionnaire. Each employed worker detected in the employment survey was asked to identify the name of the company where he/she was working, the corresponding address, and an estimation of its workforce size. By this procedure it was possible to build a sampling framework of around 7,000 firms covering the whole country and business sectors.

In 1998, the Ministry of Economics, the National Development Corporation (*CORFO*), the Technical Cooperation Service (*SERCOTEC*), and the University of Chile decided to use this sampling framework in order to carry out the project "*Strategic Behavior and Competitive Performance of the Micro and Small Chilean Firm*". The objectives of this project were: (i) to determine at sector and regional level, the competitiveness of small firms in the manufacturing industry; (ii) to design a mechanism to analyze the evolution of competitiveness through time, and (iii) to evaluate support policies in this sector.

In order to fulfill the requirements for this study a special questionnaire was designed to capture information about competitiveness and innovation in small firms. With the good of getting comparable results with international standards, the questionnaire was structured following the design recommended by the OECD (1996) – the Oslo Manual.

In this paper we use some results from the project mentioned above. As the interest was focused only on the manufacturing sector, the sampling framework was reduced to 2,657 observations (from more than 7,000 in the original framework). From this framework, we selected a stratified random sample using as strata each industrial sector according to ISIC three digits. The sample allocation was non-proportional but with the restriction of allowing for a maximum sampling error of 10% in each strata.[1] The final sample size was then 1,091 observations covering all industrial sectors in Chilean Industry, which guarantees an error sampling for the whole sample of 2%. The sample observations were expanded to the population.

The response rate was 75%. The main reason for not responding was the lack of time by firm managers. Only a small part of the non-response was due to closed plants.[2] We did not find any particular bias in the non-response across the different sectors. Thus, we can assume that missing observations are completely at random, conditional on the firm observable ISIC code.

Since the database from which the sample originated only had historical information, and in some sectors lacked the variable sales, there were a considerable number of companies in the survey that, as measured by level of annual sales, cannot be considered as small firms, but rather as medium sized ones. In order not to lose information and to be able to make some comparisons, we opted to maintain these observations.

There are several ways of classifying firms by size. Employment and sales are the most common ones in Chile. For the purpose of this paper, we used sales. The classification of firms by annual sales is shown in Table I. The distribution of firms in the survey, according to this definition of size and by economic sector, is shown in Table II.

TABLE I
Firms size by sales

Size	Annual sales (in U.S. dollars)
Micro	0–70,000
Small	70,001–740,000
Medium	740,001–1,500,000

Note: Given that this classification is made in Chilean pesos, we transform these figures using the average exchange rate in the year 2000. For the rest of the paper, we use all figures in Chilean pesos.

Some characteristics by size of firms are shown in Table III. We have found that there is consistency between classification by sales with respect to employment levels. In fact, micro firms have an average employment of around 4 workers, small ones around 17 workers and medium ones around 30 workers. Although, average capital per worker is similar among sizes, we found significant differences in sales per worker. Micro and small firms reach only about 21% and 57%, respectively, of medium size sales per worker. In terms of owner educational level, we have found evidence that it is positively related with firm size. In fact, 55.1% of the owners in medium firms have a bachelor's degree. This figure is 42.1% in small companies and only 20.8% in micro ones. A similar result is found in the case of technological innovation; larger firms are more innovative than medium and small ones. In relation to credit access, we have found that it is higher in larger firms. The percentage of firms with some type of bank loan is 31.2% in micro firms, a number that increases to 48.6% in small firms and 60.0% in medium firms. In the case of outward orientation, there is a positive relationship between size and exports. In fact, no micro size firms significantly sells to foreign markets. This figure is 1.0% for small firms and increases to 2.9% for medium ones. In addition, there are huge differences in qualification of workers. Only about 9% of workers in micro sized firms have finished college. This percentage increases to 14% and 21% in small and medium firms, respectively. In

TABLE II
Distribution of firms by economic sector and size

Sector	Micro	Small	Medium	Total	Percentage
Agroindustry	8	49	18	75	6.9
Bakeries	5	55	4	64	5.9
Beverages	2	17	2	21	1.9
Textiles	16	47	9	72	6.6
Apparel	23	62	8	93	8.5
Footwear	4	50	11	65	6.0
Timber products	2	60	12	74	6.8
Furniture	29	41	5	75	6.9
Printing and publishing	13	54	6	73	6.7
Industrial chemicals	3	43	11	57	5.2
Plastic products	3	52	8	63	5.8
Non-metallic mineral products	18	46	2	66	6.0
Metallic products	13	93	9	115	10.5
Machinery, electric	6	43	13	62	5.7
Machinery, except electrical	2	37	16	55	5.0
Transport equipment	5	34	4	43	3.9
Professional and scientific equipment	5	13	0	18	1.6
Total	157	796	138	1,091	100

TABLE III
Some firm characteristics by size

Variable	Description	Micro	Small	Medium
Employment	Average workers	3.7	16.8	30.3
Capital per worker[a]	Index: Medium = 100	90.8	99.5	100
Sales per worker[b]	Index: Medium = 100	20.8	57.3	100
Owner education	Percentage of owners that finished college	10.2%	42.1%	55.1%
Technological innovation[c]	Intensity index: 0 (does not innovate) to 4 (high innovation)	1.1	1.6	1.9
Credit access	Percentage of firms with bank loans	31.2%	48.6%	60.0%
Outward orientation	Percentage of firms that sells mainly to foreign markets	0.0%	1.0%	2.9%
Qualification of workers	Percentage of workers that finished college	8.9%	14.2%	21.4%
Machinery age	Years	10.1	10.1	9.5
Equipment age	Years	5.4	5.3	5.0
Vehicle age	Years	4.3	4.4	4.4
Use of development programs[d]	Percentage of participating firms	18.5%	24.5%	26.8%

Source: Author's research.
Notes: [a] Fixed capital in Chilean pesos; [b] Annual sales in Chilean pesos; [c] This variable is measured as an average of the scores about intensity in technological innovation in processes and products. According to Oslo Manual for technological innovation surveys, the interviewee had five alternatives to answer, 0 = Does not innovate, 1 = low innovation, 2 = moderately low innovation, 3 = moderately high innovation and 4 = high innovation. [d] It is measured as a percentage of firms that have participated in some public development program, specifically in two of them, PROFO and FAT, that are explained in Section 4.

the case of capital goods vintage, we do not find any significant difference by size. This result together with the fact that capital labor ratios are similar by size leads to the hypothesis that probably the main driving force behind the differences in firm performance has to be found in labor skills and managerial capabilities. Finally, the survey reveals some focalization problems in government programs. The participation in technological development programs has been higher in larger firms than in smaller ones.

3. Methodological issues

In this paper, we use non-parametric deterministic frontier methodology to calculate the efficiency for each firm. As we have data of firms in different economic sectors, we estimate the best practice frontier for each one. This frontier represents the maximum production level that a firm can reach, given a certain level of inputs.

For this purpose, we use the methodology of linear programming developed by Farrell (1957) and extended to technologies with variable returns to scale by Forsund and Hjalmarsson (1974, 1979 and 1987). Given that we use cross-sectional data, our analysis is static. The firm efficiency is only obtained for the current time period, thus we can only investigate efficiency by sectors and size, but not over time. A dynamic approach is used by Fare et al. (1994), who compute productivity index and decompose productivity growth in changes in technical efficiency and technological progress over time.

According to related literature, there are two broad methodologies for measuring technical efficiency. The firm efficiency may be obtained econometrically specifying a stochastic production function, which assumes that the error term is composed of two elements. One is the typical statistical noise, generally assumed to follow a normal distribution. The other one represents inefficiency and it is supposed to follow some one-sided distribution, which reflects shortfalls of the firms from the best practice frontier (Caves and Barton, 1991).

The linear programming methodology that we use in this paper and known as data envelopment analysis (DEA), has some advantages in comparison with the stochastic frontier methodology. First, it is not necessary to assume some functional form for the production function. Second, it makes no *a priori* distinction between the relative importance of outputs and inputs considered as relevant in firm decision-making process. Third, DEA is relatively insensitive to model specification, the efficiency measurement is similar if it is estimate oriented to inputs or oriented to outputs. However, DEA is not costless. One problem is that it infers the best practice production function from the reported input-output combinations of some small number of the most efficient firms. For this reason, the results may be highly sensitive to measurement errors in outputs and inputs. A second problem is originated when a high number of inputs is considered. Given enough inputs all or most of the firms may be rated as efficient (Leibenstein and Maital, 1992).

Both problems related to DEA are minimized in this paper. First, we use sales as output, which generally has less measurement errors in surveys. Second, we only use two inputs, labor and capital. Thus, we minimize potential measurement errors in inputs and we reduce the probability of rating most of the firms as efficient. However, the most important advantage of this approach is that we do not need to specify a production function, and to assume some probability distribution for the errors.

The DEA approach is illustrated in Figure 1, where points *A*, *B*, *C* and D represent different productive units and geometrical locus *OBG* and *EABCF* represent production functions with constant and variable returns to scale, respectively.

Consider one firm located in *D*, with a production of *H* and a quantity *N* of input. With variable returns to scale, efficiency in the use of inputs is defined as:

$$E_1 = \frac{HJ}{HD}$$

And efficiency in production is defined as:

$$E_2 = \frac{ND}{NL}$$

However, efficiency estimated this way does not consider that the size of the plant may be different from an optimal one. Considering production scale, efficiency of using inputs is defined as:

$$E_3 = \frac{HI}{HD}$$

In the same way, efficiency of production is:

$$E_4 = \frac{ND}{NG}$$

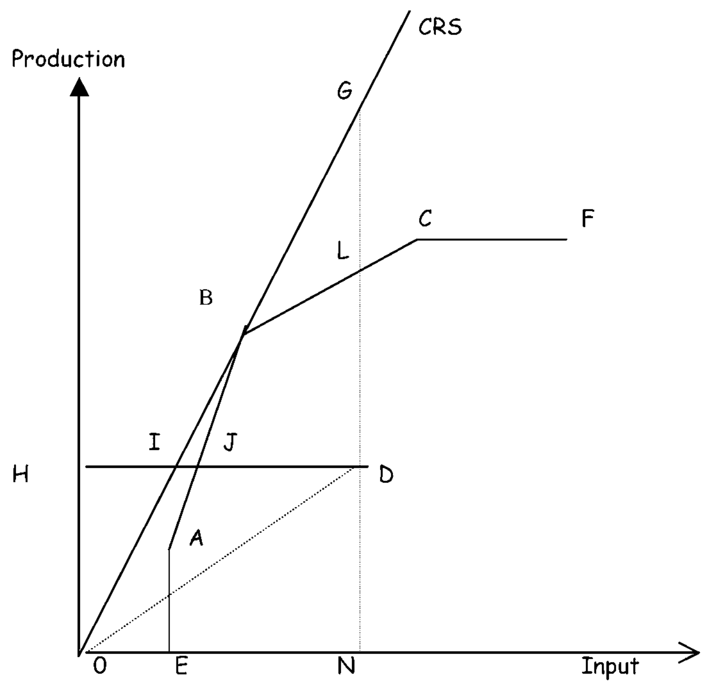

Figure 1. Efficiency measurement.

We use the Data Envelopment Analysis (DEA) approach for estimating these measurements of efficiency, where each plant is represented by vectors of products (y_i) and inputs (x_i). The efficiency of this plant is then defined as the ratio between products and inputs:

$$\frac{\mu' y_i}{\nu' x_i}$$

Where μ and ν are weights obtained by solving the following linear programming problem:

$$\max_{\mu,\,\nu} = \left(\frac{\mu' y_i}{\nu' x_i}\right)$$

s.a.:

$$\frac{\mu' y_j}{\nu' x_j} \leq 1, \quad j = 1, 2, \ldots, N.$$

$$\mu, \nu \geq 0$$

Solving the previous problem allows finding values for μ and ν, such that the efficiency of firm "i" is maximized, subject to the restriction that efficiency for the rest of the firms is smaller than or equal to 1. A problem with this specification is that it has infinite solutions. To avoid this, the next restriction is imposed: $\nu' x_i = 1$. So, the maximization problems is:

$$\max_{\mu,\,\nu}\ (\mu' y_i)$$
s.a.:
$$\nu' x_i = 1$$
$$\mu' y_j - \nu' x_j \leq 0, \quad j = 1, 2, \ldots, N.$$
$$\mu, \nu \geq 0.$$

Using the duality in the linear programming, the equivalent maximization problem is:

$$\min_{\theta,\,\lambda}\ \theta$$
s.a.:
$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0.$$

Where θ is an efficiency parameter and $\theta\lambda$ is a vector of constants.

In this paper, we use efficiency defined as E_1, because this has some advantages in comparison to others previously defined. In the first place, an efficiency measurement is obtained without the need to assume that the plant is operating at its optimal scale or minimum average cost. This is especially true in the case of small firms, because, in general, they are operating with a production scale lower than optimal. Thus, in this paper, we measure inefficiency that is caused only by an excessive use of inputs and not by inadequate plant size. There are several explanations for this "X-Inefficiency", but the typical one is related to the market structure and the competitive pressures it has on firms (Frantz, 1992). However, in the context of small firms we also have several new plants which are in their first steps of their learning curves and they are trying to discover their real capabilities in order to compete in a context of noisy market selection (Acs and Audrestch, 1990).

However, although efficiency measurement may be different assuming variable or constant return to scale, empirically in our case we do not find significant differences. The correlation coefficient between both measurements is relatively high. Considering the entire sample is 0.85, and within the sectors the correlation is ranging between 0.74 and 0.90.

Second, we focus on the space of inputs because it allows a simpler programming problem solution, and the results do not differ significantly from the alternative focus on space of products. In addition, given the serious measurement problem with production variables, the output variable is annual total sales. The inputs used are labor and fixed capital.

4. Empirical results

4.1. *Efficiency by sector and size*

Using the efficiencies estimated for all firms, we found that the average efficiency of the sample is 65%. These results are consistent with some previous papers such as Alvarez and Fuentes (1999), which, using data for the Chilean manufacturing industry and stochastic frontier methodology, found that the average efficiency in manufacturing industries has fluctuated between 60% and 70% during the period 1979–1994.

In the Table IV, we show average efficiency in the productive sectors under study. An interesting result is that there is large heterogeneity among sectors. There are some with higher efficiency, for example, professional and scientific equipment (91%), non-metallic mineral products (81%),

TABLE IV
Average efficiency by economic sector

Productive sector	Average efficiency
Professional and scientific equipment	0.91
Non-metallic mineral products	0.81
Beverages	0.79
Transportation equipment	0.77
Footwear	0.74
Industrial chemicals	0.72
Machinery, except electrical	0.71
Plastic products	0.68
Machinery-electric	0.67
Bakeries	0.66
Metallic products	0.65
Wood products	0.65
Printing and publishing	0.63
Furniture	0.62
Apparel	0.60
Agro-industry	0.49
Textiles	0.34

Source: Author's research.

beverages (79%) and transport equipment (77%). However, in some sectors average efficiency of firms is very low, for example, agro-industry (49%) and textiles (34%).

This evidence implies that inefficiency is not an intrinsic problem in micro and small firms. There are many sectors where smaller firms are closer to the production frontier. There are some factors related to sectors affecting the efficiency of all firms, as is the case in agro-industry and textiles. In order to reinforce this implication, we show in Table V, average efficiency by size. The results suggest that we can not conclude that there is a positive relationship between efficiency and size. In fact, the smallest firms, classified as micro, have an average efficiency of 67%, which is higher than the efficiency of 62% estimated for small firms. However, these levels of average efficiency are lower than the efficiency of medium size firms, which is 84%.

TABLE V
Average efficiency by size

Size	Average efficiency
Micro	0.67
Small	0.61
Medium	0.83

Source: Author's research.

4.2. Determinants of efficiency; econometric results

Given the efficiency estimated for each firm, we proceed by identifying the determinants of this variable. We try to answer the following question: why are some firms more efficient than others? In general, the empirical approach in the Chilean case has mainly explored the relationship between free trade and efficiency of productive sectors. The central hypothesis has been that openness, which increases competition, would raise efficiency levels in the productive sectors. In the case of Chile, some empirical evidence of positive relationship between efficiency and openness has been found and discussed by Tybout et al. (1991), Marshall (1992), Fuentes (1995) and Alvarez and Fuentes (1999).[3]

However, one issue that has not been sufficiently researched is what causes the heterogeneity observed among the firms. In fact, firms in the same sector have very different efficiency levels. Therefore, we focus the analysis on those characteristics of the firms that can explain this phenomenon. Some of them are: credit access for investment, labor skills, experience and education level of firm owners, variance in sales, firm capital, type of products sold by the firm, orientation to international markets, and impact of programs designed to increase the competitiveness of micro and small firms.

In relation to these variables, we expect that the experience and education of the owner positively affect technical efficiency. Less experience in the activity and lower educational levels could be related to the inability to manage the firm, higher principal agent problem, and to maximize output given the used inputs. In the case of input quality, we postulate that efficiency would depend positively on human capital and the experience of workers. In contrast, older capital (machinery, equipment and vehicles) would reduce efficiency. The credit access has been indicated as one of the most important variables affecting performances on micro and small firm performance. The argument is that relaxation in credit restrictions would let these firms increase investment in physical or human capital and, in this way, reach higher efficiency levels. Thus, we expect that firms with some banking loan were more efficient.[4]

Following the literature that studies the relationship between trade openness and efficiency, we expect that firms mainly oriented towards international markets would be more efficient than those mainly focused on domestic markets. The theoretical basis is the known self-selection hypothesis, which implies that only the most productive firms survive in the highly competitive export market. If the fixed costs for selling in the export market are higher than those in the domestic market or if output prices are lower, only high productivity firms will find it profitable to enter the export market. For the same reason, exporters whose productivity declines will be forced to exit. Empirical evidence on this is provided by Aw, Chung and Roberts (2001) for firms in Taiwan and the Republic of Korea, and Bernard and Jensen (1999) for American firms.

Given the existence of several programs managed by government, we study the impact of the two most important, called FAT and PROFO. A PROFO (Associative Support Project) is a public enhancement tool that finances joint actions undertaken by a group integrated for at least five firms coming from the same sector and region. These actions are designed to achieve common goals to the group. Its objective is to improve the competitiveness of firms by solving not only administrative and managerial problems, but also commercialization failures that, for their nature or magnitude, they can be approached better in a joint manner. A PROFO is only partially financed by public resources, up to 80% of total cost in its stage of preparation (diagnostic and working plan) and up to 70% of total cost in the first year of implementation. This financing is reduced by 10 percentage points every year, with a maximum term of 4 years.

A FAT (Technical Assistance Fund) is a public instrument directed towards small firms for financing the hiring of consulting services in specialized areas such as finance, design, production process, marketing and strategic planning. This instrument may be used in two ways. The individual FAT finances consulting for one firm in a specific area after an external review by an agent. The collective FAT finances consulting for a group of at least three firms in common areas. A previous external diagnostic is also required. A FAT finances up to 50% of the total consulting costs.[6]

In general, these instruments have followed earlier experience in developed countries. In OECD countries, there are similar technology development and diffusion programs supporting small firm activities. These may be classified in five types: financial assistance, technology incubators, technical assistance, technology networking, demonstration programs, training and organizational change. Among these, FAT follows a similar approach to OECD programs in technical assistance. For example, the Industrial Research Assistance Program in Canada has a similar objective, which is to assist small firms in diagnosing technology needs and solving problems. In the case of PROFO, this follows a similar approach to the Manufacturing Extension Partnership implemented in the U.S., whose objective is to support smaller manufacturing firms in becoming globally competitive. It provides information, decision support and implementation assistance so that small firms may adopt new, more advanced technologies, techniques and business best practices (OECD, 2000).

Although, our empirical approach is not a formal evaluation of these support instruments, we test if its utilization is positively correlated to firm performance. Given that the objectives of FAT and PROFO are to increase small firms' competitiveness, we expect a positive relationship between efficiency and participation in these public programs.[6]

In addition, we control for the effect on efficiency of some variables like capital per worker, variability of sales and product differentiation, whose a priori correlation is ambiguous. Dummy variables by sector (ISIC, three digits) and by size are included in the regressions.

We estimate the following equation:

$$Ef_i = \alpha + X_i\beta + \varepsilon$$

Where *Ef* is the estimated efficiency for firm "*i*", *X* is a vector of firm characteristics and ε is an error term.

As the values of dependent variable, technical efficiency, are bounded to take values between 0 and 1, estimation by Ordinary Least Squares would provide biased estimates. To avoid this problem, the Tobit maximum likelihood method is used in estimating the regression coefficients. We also use the consistent sandwich variance estimator, suggested by White (1982), for taking into account heteroskedasticity.

The variables included in the Tobit regressions are described in Table VI. In relation to the characteristics of the firm owner, average years in the activity are 22.4, and about 40% of the owners have a bachelor's degree. With respect to employment, 14% of workers are qualified and average experience in the firm is around 3 years. Machinery has an average age of 10 years, higher than age of equipment and vehicles. The degree of product differentiation is relatively low, only about 4% of the firms sell a product that they think is unique in the market. With regards to financing, 47% of the firms have a bank loan. These firms are preferentially oriented towards domestic markets, only 1% of them sell mainly to international markets. The participation rate in government programs for increasing productivity is around 8%.

The results of the estimates are shown in Table VII. In relation to variables related to the characteristics of the firm owner, we found that experience does not significantly affect technical efficiency, but higher education level affects negatively. We tested alternative definitions of owner education, and the results are the same.

Apparently more formal education does not induce higher efficiency. This controversial result may be explained by assuming that control activities are the result of knowledge, effort and time monitoring the labor force. This assumption is in the sense of a single entrepreneur with a fixed amount of calendar time as proposed by Oi (1983). Thus, owners with higher education probably have a higher opportunity cost for monitoring and they focus less efforts in these activities. However, this is also a hypothesis that requires further research in developing countries.

With respect to labor quality, the evidence suggests that worker experience, measured by years of service in the firm, led to an increase in its efficiency, but the impact of skilled workers although positive is not significant. In the case of fixed capital, the most important quality variables are the age of machinery and vehicles. Given both parameters are negative, we conclude that firms with older machinery or vehicles have lower efficiency than firms with more modern equipment.

The results for the relationship between capital per worker and efficiency show that it is positive, but only significant at 10%. When we control for participation in FAT, significance of capital per worker is reduced. This may be explained by the fact that participation in these kinds of public programs may be correlated to some firm characteristic, for example, capital per worker.

One interesting point is that the variable access to credit is not significantly related to efficiency. However, the effect of this variable should be incorporated in variables age of capital and the

TABLE VI
Summary statistics of explicative variables

Variable	Description	Mean
Expact	Experience of the firm owner: number of years in the activity.	22.4
Educ	Dummy equal to 1 if owner has university education	0.39
Varvent	Variability of sales: ratio between higher and lower monthly sales	4.8
Kh	Human capital of workers: share of qualified labor to total employment	0.14
El	Experience of workers: average months in the firm	33.8
Am	Machinery age (years)	10.0
Ae	Equipment age (years)	5.3
Av	Vehicles age (years)	4.4
Kw	Capital per worker	367.2
Dif	Dummy equal to 1 if product sold is only in the domestic market, 0 if not.	0.036
Cred	Dummy equal to 1 if firm has a banking loan, 0 if not.	0.47
Exp	Dummy equal to 1 if firm sells mainly to the international markets, 0 if not.	0.01
Profo	Dummy equal to 1 if firm has participated in a technological development program, 0 if not.	0.076
Fat	Dummy equal to 1 if firm has participated in a technical assistance fund, 0 if not.	0.084

TABLE VII
Tobit econometric results

Variable	(1)	(2)	(3)	(4)
Expact	–0.00 (–0.03)	–0.00 (–0.10)	–0.00 (–0.02)	–0.00 (–0.05)
Educ	–0.054 (–1.96)*	–0.056 (–2.02)*	–0.057 (2.05)*	–0.057 (2.06)*
Varvent	–0.001 (–0.64)	–0.001 (–0.56)	–0.001 (–0.61)	–0.001 (–0.56)
Kh	0.082 (1.38)	0.073 (1.24)	0.072 (1.21)	0.069 (1.16)
El	0.06 (3.29)**	0.058 (3.32)**	0.061 (3.46)**	0.06 (3.41)**
Am	–0.06 (–5.12)**	–0.06 (5.17)**	–0.06 (5.19)**	–0.06 (5.20)**
Ae	0.021 (1.56)	0.023 (1.68)	0.022 (1.59)	0.023 (1.68)
Av	–0.026 (–1.84)	–0.028 (–2.02)*	–0.029 (–2.06)*	–0.03 (–2.12)*
Kw	0.00 (1.92)	0.00 (1.93)	0.00 (1.79)	0.00 (1.84)
Dif	0.094 (1.60)	0.094 (1.60)	0.094 (1.60)	0.094 (1.60)
Cred	–0.017 (–0.61)	–0.019 (–0.70)	–0.021 (–0.77)	–0.021 (–0.79)
Exp	0.093 (0.76)	0.102 (0.84)	0.101 (0.83)	0.106 (0.87)
Profo	–	0.081 (1.71)	–	0.065 (1.41)
Fat	–	–	0.064 (1.42)	0.04 (0.93)
Small	–0.091 (–1.80)	–0.094 (–1.86)	–0.095 (–1.87)	–0.096 (–1.89)
Medium	0.255 (4.25)**	0.253 (4.23)**	0.254 (4.23)**	0.253 (4.22)**
Constant	–0.816 (–1.92)	–0.823 (–1.93)	–0.912 (2.11)*	–0.882 (2.04)*
Observations	1062	1062	1062	1062

Dummy variables by sector (ISIC, three digits) were incorporated, but not reported.
* Significant at 5%; ** Significant at 1%.
Robust *z*-statistics in parentheses.

ratio of capital per worker. In fact, without access to credit, firms invest less in capital. This is reflected in a lower capital per worker and older machinery. Alvarez et al. (1999) give evidence supporting this in the Chilean small firms. They show that the investment rate for small firms is lower than that for larger ones because small firms face liquidity constraints.

Another variable that has positive impact, although significant at 10%, on firm efficiency is differentiation of products. This implies that firms that produce goods that are unique in the market become more efficient than others that produce homogenous goods.

In relation to the characteristics of demand, there is no evidence relating a firm having an outward orientation to an increase in efficiency. Although, the parameter of the variable exports is positive, it is not significant. In addition, we do not find any significant relation between efficiency and variability of sales.

Variables that incorporate the impact of public programs like FAT or PROFO are positively related to efficiency, but only the impact of PROFO is significant at 10%. In the case of FAT, there is no significant difference in efficiency between firms that have and have not participated in this program. This provides some evidence against the efficacy of these instruments, although a definitive conclusion requires a more robust analysis on this topic, because participation in the programs may be an endogenous variable. In fact, firms having low efficiency or productivity are more likely to participate.

As suggested by the preliminary results on average efficiency by size, we did not find a strict positive relation between efficiency and the firm size. In fact, as we show in Table VII, the dummy variables for small firms are negative and significant at 10%. In contrast, the dummy variables for medium firms are positive and significant. This implies that, after correcting for sector and other variables, micro firms are more efficient than small firms, but less efficient than medium firms. This evidence is consistent with empirical evidence in Chow and Fung (1997), who find that the largest firms in Shangai, China, have higher technical efficiency, and medium size firms are less efficient than the smallest ones. However, this evidence is controversial in related literature. Patibandla (1998) reports a non-linear relation between technical efficiency and firms size. He finds that medium size firms are more efficient than the smallest and largest ones.

Finally, we have found that, although we control for firm characteristics, there is a sector effect that is significant. In order to save space in Table VII, we do not report parameters for the dummy variables. However, the results show that a positive and significant effect is found in sectors that are in the top of ranking in Table IV. These are professional and scientific equipment, non-metallic mineral products, and beverages. Only in one sector was a dummy variable negative and significant. This is the textile sector, which was at the bottom of efficiency ranking.

5. Conclusions

The results obtained in this paper show that the average efficiency of micro, small and medium firms in the Chilean manufacturing sector only reaches 65%. This implies a production level substantially smaller than they could have achieved if they had used productive factors more efficiently.

Comparing the average efficiency levels by productive sector, we find high heterogeneity in this variable. There are sectors with an efficiency of about 80%, with others having a lower efficiency around 40%. This reveals that there are important factors that reduce efficiency and they are related to sector, rather than size.

With respect to the size of firms, we conclude that there is no absolutely positive relationship between size and efficiency. In fact, micro firms achieve higher average efficiency than do small firms. However, micro firms average efficiency is inferior to the 84% that larger firms achieve, which in this case are those that are defined as medium. This evidence is robust if we control for sector and other firm characteristics in the regression analysis.

Regression analysis allows identification of some determinants of firm efficiency. Owner characteristics, such as experience, are not related to efficiency. But input quality variables, such as worker experience and modernization of capital, increase the efficiency of firms. One interesting result is that efficiency is positively related to the degree of product differentiation. More innovative firms, that develop new goods, get higher efficiency than more traditional firms. With respect to demand variables, we do not find a relation between either sales variability or exports and efficiency.

One of the most important results that arise from our analysis is the existence of highly heterogeneous efficiency levels among productive sectors. Even if we control for some firm variables, there are elements inherent to some sectors that make them more or less efficient. In terms of policy implications, this evidence shows that traditional resource allocation may be not the best way to increase efficiency or productivity. It would better to design intervention strategies targeted toward specific sectors.

Our results suggest that there are several factors that could be affected by the current public instruments. These factors are related to input quality, specifically modernization of capital and technological innovation. According to this, government policies should be aimed to increase and to improve the access of small firms to capital markets. A higher quantity of financial funds would allow them to increase the investment in modern capital, human capital of workers and technological innovation. This kind of policy may be very important in order to increase efficiency and productivity in small firms.

Finally, we can infer that, in general, firm participation in some public programs has had a weak impact on firm efficiency. However, the results are better for PROFO program than FAT program. However, more research including a more suitable control group is required on this topic.

Notes

[1] This restriction avoids getting a very high proportion of homogeneous observations in the sample (such as bakeries, groceries, etc.).

[2] The reason for this low exit rate are a very favorable macroeconomic cycle during these years, and because there is a short time between the sample framework construction in 1996, and the time of this study, 1998.

[3] For a survey of studies about this issue in developing countries, see M. Roberts and J. Tybout (1996).

[4] Also, causality may be reverse if bank are able to identify better firms.

[5] In both instruments, a maximum of public resources for financing a project or consulting is established, and a minimum value that every firm must finance is also deter-

mined. For more details about these public instruments and other ones, see www.corfo.cl.

[6] For a formal evaluation of PROFO program, see Alvarez, Benavente and Crespi (2000).

References

Acs, Z. and D. Audretsch, 1990, *Innovation and Small Firms*, Cambridge, MA: The MIT Press.

Alvarez, R., J. M. Benavente and G. Crespi, 2000, 'Impacto del Instrumento PROFO en la Pequeña y Mediana Empresa Chilena', presented in the Workshop 'Evaluation as a Management Tool in SDE', Interamerican Development Bank (IADB), June, Washington DC.

Alvarez, R. and R. Fuentes, 1999, 'Productividad y Apertura: Quince Años mas Tarde'. Working Paper N° 164, Department of Economics, Universidad de Chile.

Alvarez, R., G. Crespi, D. Naschelski and M. G. Sepúlveda, 1999, 'Impacto de las Restricciones de Liquidez sobre el Desempeño de las Pequeñas y Medianas Empresas (PYMEs)', *Estadística y Economía, Instituto Nacional de Estadísticas* (December), 85–100.

Aw, B. Y., S. Chung and M. Roberts, 2001, 'Productivity and Turnover in the Export Market: Micro-Level Evidence from Republic of Korea and Taiwan', *The World Bank Economic Review* **14**(1), 65–90.

Bernard, A. and J. B. Jensen, 1999, 'Exceptional Performance Exporter: Cause, Effect or Both?', *Journal of International Economics* **47**(1), 1–26.

Caves, R. and D. Barton, 1991, *Efficiency in U.S. Manufacturing Industries*, The MIT Press, Second Printing.

Chow, K. W. and K. Y. Fung, 1997, 'Firm Size and Performance of Manufacturing Enterprises in P.R. China: The Case of Shanghai's Manufacturing Industries', *Small Business Economics* **9**(3) (August), 287–298.

Fare, R., S. Grosskopf, M. Norris and Z. Zhang, 1992, 'Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries', *American Economic Review* **84**(1), 66–83.

Farrell, M. J., 1957, 'The Measurement of Productive Efficiency', *Journal of the Royal Statistical Society* **120**, 253–282.

Forsund, F. R and L. Hjalmarsson, 1974, 'On the Measurement of Productive Efficiency', *Swedish Journal of Economics* **76** (June), 141–154.

Forsund, F. R and L. Hjalmarsson, 1979, 'Generalized Farrell Measures of Efficiency: An Application to Milk Processing in Swedish Dairy Plants', *Economic Journal* **89** (June), 294–315.

Forsund, F. R and L. Hjalmarsson, 1987, *Analysis of Industrial Structure: A Putty-Caly Approach*, Stockholm: Industrial Institute for Economic and Social Research.

Frantz, R., 1992, 'X-Effciency and Allocative Efficiency: What Have We Learned', *American Economic Review* **82**(2) (Papers and Proceedings), 434–438.

Fuentes, R., 1995, 'Openness and Economic Efficiency: Evidence from Chilean Manufacturing Industry', *Estudios de Economía* **22** (Special Number, December), 375–387.

Libenstein, H. and S. Maital, 1992, 'Empirical Estimation and Partitioning of X-Ineffciency: A Data Envelopment Approach', *American Economic Review* **82**(2) (Papers and Proceedings), 428–433.

Marshall, I., 1992, 'Liberalización Comercial en Chile y su Impacto en la Eficiencia Técnica Industrial: 1974–1986', Colección de Estudios, N° 135, CIEPLAN, September.

Meller, P., 1976, 'Allocative Frontiers for Industrial Establishments of Different Sizes', *Explorations in Economic Research* **3**, 379–407.

OECD, Organisation for Economic Cooperation and Development, 2000, *OECD Small and Medium Enterprises Outlook*, Paris, France, October.

OECD, Organisation for Economic Cooperation and Development, 1996, *The Measurement of Scientific and Technical Activities: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: Oslo Manual* (DTSI, OECD, Paris).

Oi, W. Y., 1983, 'Heterogeneous Firms and the Organization of Production', *Economic Inquiry* **21** (April), 147–171.

Patibandla, M., 1998, 'Structure, Organizational Behavior, and Technical Efficiency: The Case of an Indian Industry', *Journal of Economic Behavior & Organization* **34**, 419–434.

Roberts, M. J. and J. Tybout, 1996, *Industrial Evolution in Developing Countries: Micro Patterns of Turnover, Productivity, and Market Structure*. First Edition, World Bank, Oxford University Press.

Tybout. J., J. De Melo and V. Corbo, 1991, 'The Effects of Trade Reforms on Scale and Technical Efficiency: New Evidence form Chile', *Journal of International Economics* **31**, 231–250.

White, H., 1980, 'A Heteroskedasticity Consistent Variance Matrix Estimator and a Direct Test of Heteroskedasticity', *Econometrica* **48**, 817–838.