"Drivers of Technological Capabilities in Developing Countries: An Econometric Analysis of Argentina, Brazil and Chile"

Molina María Alejandra

University of Rome III

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Abstract

This paper introduces the concept of technological knowledge and innovation as key concepts not shared equally among firms. The Evolutionary approaches to the issues of technology in developing countries have assigned a central role to the need to create indigenous technological efforts in mastering new technologies, adapting them to local conditions, improving and exploiting them. Efficiency in setting up, operating, diversifying, and expanding an industrial operation requires specific knowledge and skills in technology, that may be called "capabilities" of the firm. Technological Capabilities (TCs) are then examined here on the perspective of Lall's (1992) definition as a "complex array of skills, technological knowledge, organizational structures, required to operate a technology efficiently and accomplish any process of technological change". TCs, then, embody the resources required to manage and actualize the generation of technical change. The purpose of this work is to propose a methodology for obtaining econometrical estimates of TCs in Argentina, Brazil and Chile. Based on the World Bank's Investment Climate database, as a result of firms' surveys made in each of the mentioned countries, the study covers firms from different industrial sectors. This work applies Wignaraja's Technology Index (TI) in an attempt to provide a preliminary analysis for measuring Technological Capabilities (TCs) and their determinants, and to identify the reciprocal causality relation between them and firms' economic performance. Supported by TI, the study proceeds with the econometric analysis developed through Simultaneous Equations. Endogeneity tests are also run to test the robustness of TI. Although this study does not explicitly examine TCs over time it offers a glance of the relationship between TCs, export share and other micro level factors in a certain moment in Argentina, Brazil and Chile.

Introduction

The Evolutionary approach to the issues of technology in developing countries has assigned a central role to the need to exert indigenous technological efforts to master new technologies, adapt them to local conditions, and then improve and exploit them.

The extent to which the firms differ in technological effort may vary by industry, by size of firm or market, by level of development, or by trade or industrial strategies pursued. But, they also may vary depending on countries. These factors motivate more accurate weighing of the differences between the countries analyzed.

The three Latin American developing countries selected for this study are Argentina (2006), Brazil (2003) and Chile (2006) based on the last World Bank "Investment Climate" available survey. Brazil and Argentina first and third respectively- has been chosen as two of the top developing country manufacturers in Latin America and the Caribbean. Chile is Latin America's outstanding case of fast-growing middle income countries in this region[1] . Small and medium enterprises' productive modernization and technological development have been a high priority of senior level Chilean public policy. In fact, Chile has specialized its niches market production in boosting initiatives and activities in the development of methods, and in the implementation of competitiveness and productivity strategies in the production private sector.

The output and exports of Brazil, and above all those of Argentina, have been predominantly natural resources-based. Brazil has evolved through high-tech industry and invested much more than Argentina in RD in absolute values. In both countries, in RD expenditures, the greatest share has gone to the purchase of machinery and equipment.

This study will also examine how firms build and accumulate their capabilities. Macro and meso determinants influence business behavior. However, it cannot be deduced that the strategic behavior of firms is solely in response to macroeconomic incentives. It is also owed to its own ability to change structures, and to absorb methods and technologies (Hoffman, 1989; Katz, 1987) which allow the firm to produce and increase its capacities. The process of mastering technology is neither passive nor without cost. The empirical literature (Lall, 1992; Katz, 1997; Bell and Pavitt; 1993, Pietrobelli, 1998; Wignaraja, 1998; Romijn, 1999; Figueiredo, 2002), on Technological Capabilities (TCs) in developing countries draws on the evolutionary theory of technical change. Central to this approach is the idea that firms cannot be assumed to operate on a common industry-wide production function.

This analytical framework will explain the dynamics of TCs in the process of industrialization in these countries. This issue is examined here and the objective is to construct the Wignaraja's Technology Index [2](TI) at firm level that may allow us to understand the reciprocal causality

[1]UNIDO, Industrial Development Report 2009 "Breaking In an Moving Up: New Industrial Challenges for the Bottom Billion and the Middle-Income Countries"

[2]Wignaraja (1998) and other successfully technology studies tested an overall Technology Index and one for production against firm-level characteristics (size, foreign equity, technical manpower and technology imports)

relation between TCs and the firm's export performance. The econometric analysis will be run employing Simultaneous Equations.

Indeed, this paper shows how some factors such as foreign ownership, firm size, age in production and in exporting, human capital skills, and training, among others, may be the cause improving the TI . It also analyses the relationship between TI and firms' export performance.

The article proceeds as follows. In the second section, we briefly introduce the theory on innovation and technological framework in Latin America, in the third section we describe the nature and determinants of TCs. Then, we analyze different methods of measuring TCs in the fourth section, and in the next section we explain our own methodology. In the sixth section we propose the empirical illustration and the econometric analysis for measuring the three countries' TCs and their impacts on exports. In the seventh section, the paper concludes.

for a sample of 27 garment and engineering enterprises in Sri Lanka. After that in 1999 with Ikiara for Kenyan enterprises. In 2002, he tested the TI with Mauritius enterprises and in 2008 TI in Sri Lanka clothing exports

I. Innovation and technological framework in Latin America

Technological Capabilities (TCs) are examined here on the perspective of Lall's (1992) definition as a "complex array of skills, technological knowledge, organizational structures, required to operate a technology efficiently and accomplish any process of technological change". These TCs embody the resources required to manage and update the generation of technical change. These resources are accumulated and embodied in skills, knowledge experience and organizational systems (Bell, Pavitt, 1993).

Considering specifically Latin America, the process of Technological Capabilities (TCs) building has been made more complex by the extreme uncertainty and instability of the macroeconomic framework. This has negatively influenced firms that, in some cases, were not prone to innovate.

Analyzing Argentina, Brazil and Chile from 1990 there are alternative periods of expansion and retraction in GDP in these countries that can be seen on Tables A1, A2 and A3 (Appendix A) that show the evolution of Gross Domestic Product (GDP), Exports and Imports in absolute values and growths rates in the same period. The same occurs for industry evolution, considering GDP on Graphic 1 but with increasing differences between the three countries:

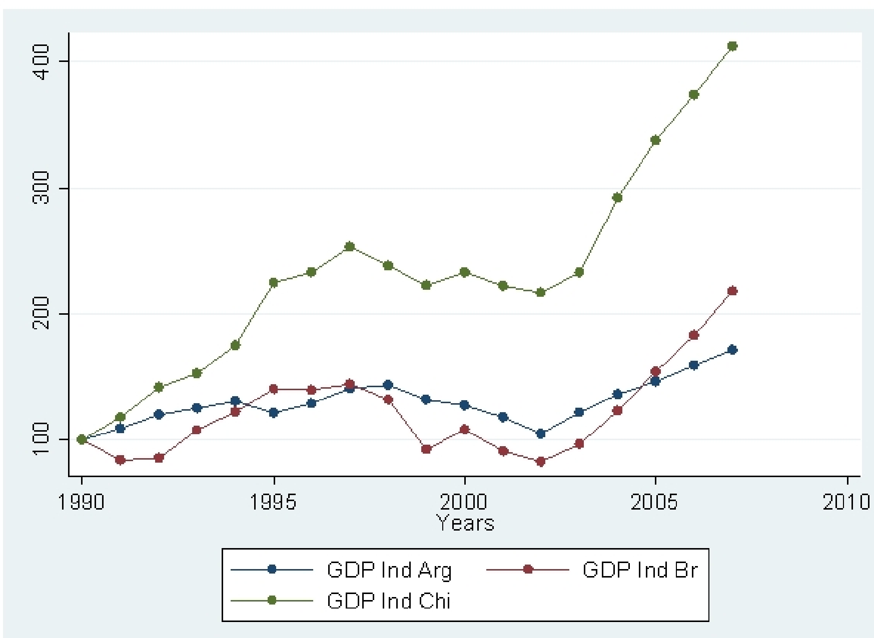

Figure 1: Graphic 1. Industry evolution from 1990-2007 in Argentina, Brazil and Chile by GDP considering 1990=100 - Source:ECLAC

Cimoli and Katz (2002) emphasize that the best way to describe the 1970-2000s period in Latin America is the Schumpeterian metaphor: the "creative destruction". The new regime caused the disappearance of some enterprises, accompanied by changes in trade and in market behavior, among other structural changes. Unfortunately, the macro slant on this debate, has sometimes forgotten the huge impact of these reforms on nature and importance of the meso and micro phenomenon. The three aspects evolve pari pasu and in an interrelated way. The "survivors" firms of the destructive impact finally returned to invest and to risk.

On behalf of the "creation" aspect of the metaphor, it is important to introduce the Pack and Westphal (1986) definition of industrial development as the process of building TCs through learning and translating them into product and process innovations in the course of continuous technological change. This means that a single innovative firm's TCs building process may contribute to the rate of sector's -and a country's- technological progress.

II. Nature and determinants of TCs

As a matter of fact, the learning process that allows firms to build TCs, has two important elements that are extremely interrelated: existing knowledge base and intensity of effort (Cohen and Levinthal, 1990). The former contribute to strengthen the latter through the spiral process of technology learning. Education, skills and quality, enhances people's ability to receive, decode and understand information and that information process and interpretation is important for performing or learning to perform many jobs (Nelson and Phelps, 1996).

As stated by Linsu Kim (2002, p:9) "Technological Capabilities (TCs) refers, to the ability to make effective use of technological knowledge in production, engineering and innovationIt also enables a firm to create new technologies and to develop new products and processes in response to their changing economic environment. Technological learning is the process of building and accumulating TCs".

Hence, technological knowledge is not shared equally among firms, nor it is easily imitated by or transferred across firms. Transfer necessarily requires learning because technologies are tacit, and their underlying principles are not always clearly understood. Thus, simply to gain mastery of a new technology requires skills, effort and investment by the receiving firm, and the extent of mastery achieved is uncertain and necessarily varies by firm according to theses inputs (Lall, 1992). And these movements affect also the other firms of the industry's sector and the whole influenced sector may contribute to more TCs building, as in a loop.

Focusing on the intra-firm dimension, Barney (1991) argues that the resource-based model of the firm examined the implications of two assumptions for the analysis of firm competitive advantage: firms may be heterogeneous with respect to the strategic resources[3]

[3] Firms resources are strengths that firms can use to conceive of and implement their strategies (Learned, Christensen, AndrewsGuth, 1969; Porter, 1981; Barney, 1991)

they control and these resources may not be perfectly mobile across firms. Then heterogeneity may be long lasting as also stated by Dosi (1988) when underlying that there is a "permanent existence of asymmetries among firms, in terms of their process, technologies and quality of output".

However the resource-based strategy explained part of these asymmetries. There are also different innovative capabilities, that is, different degrees of technology accumulation and different efficiencies in the innovative search process. Teece and Pisano (1994) referred that "this strategy is often not enough to support a significant competitive advantage". Then they emphasizes the crucial role of dynamic capabilities to keep the pace of innovation when it is accelerating. They define dynamic capabilities as "the subset of competences which allow the firm to create new product and processes and to respond to changing market circumstances".

This study agrees that firms asymmetries may be explained by Technological Capabilities (TCs) -as one of intra-firm crucial factor for enterprises' success- and also that these capabilities need to be dynamic for properly adapting, innovating and changing while the environment evolves.

Then, in-house technological effort seems to be essential for firms' performance, starting from investment, production or linkages, as suggested by Lall's taxonomy[4] (1987). This means that firms should have their own capabilities required for the various activities from setting up to operating an enterprise.

Investment capabilities are the skills needed to identify, prepare, and obtain technology to design, construct, and equip an expansion or a new facility. They include capital costs of the project, the selected technology and equipment, and the understanding gained by the operating firm of the basic technology involved.

Production capabilities start from the last step of the first typology: basic technology skills, like quality control, operation, and maintenance to more advanced ones like adaptation or improvement to research, design, and innovation. This implies in some way technology mastery and in others, minor or major innovation.

Linkages capabilities are the skills needed to transmit information, skills, and technology to receive knowledge from component or raw material suppliers, consultants, service firms, and technology institutions. Consequently, they affect not only the firm but the whole industrial structure. They also include the access to external technical information and support (from foreign technology sources, local firms and consultants, and the technology

[4]"The Lall taxonomy of technological capabilities has been successfully used by case study research to assess levels of firm-level technological development in developing countries (for a selection see Lall, 1987, Lall, Barba-Navaretti, Teitel and Wignaraja, 1994, Wignaraja, 1998; and Romijn, 1997). Subsequently, a technology index (TI) based on the Lall taxonomy (or its variants) has been developed for econometric testing in several developing countries (see, for instance, Westphal et al. 1990; Romijn, 1997; Wignaraja 1998, 2002 and 2008a and 2008b; and Wignaraja and Olfindo, forthcoming)" Wignaraja (2008, Appendix I, p. 14)

infrastructure of laboratories, testing facilities, standards institutions and so on); and access to appropriate "embodied" technology in the form of capital goods from the best available sources, domestic or foreign.

III. **Alternative methods for measuring TCs**

There have been different approaches to the challenge of measuring inter-firm differences in TCs. Romijn (1997) for Pakistan, demonstrated that the qualitative case study approach is not the only feasible method for analyzing how firms build TCs. In fact he considered that it was possible to develop satisfactory and objective measures for evaluating TCs and its underlying learning process using both information about intra-firm activities as well as information of the interaction with the environment of the firm. He focused only on production capabilities and considered this, as an important limitation of his work that can be justified only by the fact that his sample included only fairly small firms. He proposed a production capability indicator that captured also the manufacturing complexity of products by allowing to quantify the level of production capability incorporated in each product. He also differenced between "in-house" manufacturing and "vendor operations" (subcontracted to other firms). He proceeded under a strong assumption: firms can only differ in terms of the degree of user-capability, obtained with the same equipment. Then, his "capability score" was an "unadjusted" one. As a second step, he "adjusted" it, upward or downward in order to consider differences in in-house production. This product score was used to construct several variables, measuring complexity of the firms. The question was studied under a cross-section analysis calculating simple correlations and running OLS regression. He concluded that, the variation in the set of explanatory variables, were important mechanisms of learning and consequently they explained the differences in the capability levels.

Another significant contribution was given by Wignaraja's (2001, 2002, 2008) empirical work, following the pioneering work of Westphal (1990) on Thailand, Gosen (1995) on Mexico and Romijn (1999) on Pakistan. He preferred to rank firms TCs and performed and statistical analysis of their determinants. He created an enterprise score as a summary measure of capabilities. He selected technical functions -regarding investments, production and linkages activities performed by the firms in developing countries- to manage imported technology and assigned a given enterprise a score, for each technical function, indicating also its level of competence. These scores were gathered in an overall capability score. After constructing this score called "Technology Index" (TI), he run OLS regressions to check the influence of specific firms characteristics on this index. Finally -for instance in Mauritius case study- he controlled also the importance of the TI and other relevant firms characteristics on firms' export performance.

Another type of TCs' measure was preferred by Figueiredo (2008) in his Brazil's case study. On the basis of a Lall type of taxonomy, he distinguished between "routine" production capability and "innovative" TCs. In this study he focused specifically on two groups of firms: electro-electronic firms and suppliers, and bicycle and motorcycle firms and suppliers. He measured TCs by the type of activity (process) a firm was able to do on its own, at different points in time, identifying not only the manner and level of difficulty, but also the time-scale that each firm needed to reach a higher capability level. He introduced, then, another important issue that was "time" needed for capability accumulation.

Also other authors have examined other empirical evidence of TCs at the firm level in Latin American countries. For instance, Crespi and Katz (1999) studied the accumulation of knowledge in Chilean manufacturing industry. Pietrobelli (2000) did an empirical analysis based on a sample of 338 industrial enterprises from Chile, studying firms with different levels of technological complexity. Costa and Robles Reis de Queiroz (2002), based on proxies by means of innovation survey database, proposed TCs classification and the distinction between generation and use of knowledge. Ianmarino et al. (2008) -examined the electronic industry in two Mexican regions- combined the analysis at micro and meso levels.

Received literature about TC and different methods of calculating TI were an important source of information for the present work. As already targeted in the mentioned empirical evidences, the core of our study is to construct a quantitative measure -unfortunately constrained by lack of information that implies not considering the time-scale- for firms TCs. The attempt is to determine if a firm, undertaking certain functions -such as certifying ISO, introducing new products or processes, investing in RD, etc.- may demonstrate to be able to set up and operate technology. And once obtained this indication, to understand which are the factors that contribute to favor this process (firm size, foreign ownership, training, etc) in each of the selected country.

IV. The methodology

The empirical part of this work is based on data from the World Bank Investment Climate Survey. The surveys were conducted on a sample of representative (about a thousand) enterprises in Argentina (2006), Brazil (2003), and Chile (2006). The samples of firms were stratified by size, sectors and location. Argentina and Chile country data were matched to a standard set of questions. As Brazil's survey was done before than the others surveys, it was made with another standard set of questions. Nevertheless surveys are highly comparable and the format allows cross-country comparisons and analysis.

These surveys covered mainly manufacturing[5] and certain services for registered firms. Other sectors were covered on a smaller scale, except for the banking sector[6] , that was

[5]The level of sector's analysis has been given by the same survey and are two or three digits ISI codes based on the 1987 Standard Industrial Classification (SIC) and referred after as 1987 ISI codes

[6]In a stratified random sample, all population units are grouped within homogeneous groups and simple random samples are selected within each group. This method allows computing estimates for each of the strata with a specified level of precision while population estimates can also be estimated by properly weighting

not considered. For the purpose of our work, we decided to work only with manufacturing enterprises. The samples did not cover the same sectors for the three countries, as different countries were focused on different industrial activities. Argentina's and Chile's surveys covered Food Processing, Textiles, Garments, Chemicals, Non Metallic Mineral Products, Machinery and Equipment, Other Manufacturing and Electronics (only for Argentina). Brazil's survey considered Autoparts, Chemical, Food Processing, Electronics, Furniture, Garments, Machinery, Shoe and Leather Products and Textiles sectors. Regarding size, firms were divided in small (less than 20 employees), medium (20-99 employees) and large (more than 100 employees). Nevertheless the surveys were not conceived for analyzing TCs, we found in them some useful questions for evaluating firms technical functions.

Based on Wignaraja's TI, this analysis starts from the information on these functions performed within a given enterprise to compute a TI for each firm. In line with Lall (1987, 1992), TCs are classified as production and linkages capabilities (Table 1). A future work may also analyze investment capabilities: the skills needed to identify, prepare, and obtain technology. This information was not available in our databases.

For functions related to production, Wignaraja focused on twelve technical activities, among production and linkages activities. Beginning from the easiest ones -like internal reject rates and ISO 9001 quality certification-, to the most complex ones such as improving products, processes and productivity. For functions related to linkages he considered two types of relationships: with subcontractors and with overseas buyers of output. Constrained again by the lack of information, we propose to work on only seven production and linkages functions, similar to the ones selected by Wignaraja (see Table 1).

We selected these functions for calculating an overall TI, as indicators of firms' indigenous efforts. Certifying quality implies to accomplishing processes in a certain way. The buy new equipment function was selected to demonstrate the incorporation of new technologies. Lastly the other two functions related to production -to improve process or products- confirm firms' decision to diversify and expand industrial operations.

Regarding linkages functions and, without having information about the relationship with providers (key channel to acquire TCs), subcontractors and buyers, we introduced functions such as technology licensed from foreign buyers, the investment on inputs supplied by foreign companies and RD contracting a third party, to highlight that technology needs to come from outside the firms.

individual observations. Weights take care of the varying probabilities of selection across different strata. Under certain conditions, estimates' precision under stratified random sampling will be higher than under simple random sampling (lower standard errors may result from the estimation procedure). The 2006 Latin American have weights for the estimates of the aggregate indicators in order to account for the random stratified sample design (/www.enterprisesurveys.org/Methodology)

Then, each firm is evaluated over these two groups of functions. Each of the technical activities is graded in three different ways , which we considered as more accurate. The first way is to normalize[7] the variable and this method is used for the "bought new equipment in the last year" and also "investment in RD contracting a third party" variables. This means that the variables are divided between their maximum ranged value, so that in these cases the variable becomes 1 and, in other cases, less than 1. The second way for grading other variables, is to give them two (0,1) alternative levels and the third case is to give them three alternatives (0, 1 and 2). In our analysis the third alternative is used to represent different levels of the "inputs supplied from foreign companies" variable. The enterprise with highest grades would have a maximum of 8 points, obtained as the sum of maximum grades on each function. For better comparison between enterprises, a simple average is created and this new value is attributed to the each firm. The procedure implies that the original grading is divided between the maximum grading -that is 8- assigning the same relative importance to each of the seven functions -based on the assumption that they are of similar importance- and obtaining a more comparable value. This straightforward procedure was preferred and implied a linear transformation[8] , simply dividing the variable by 8. This new value -based on the overall "Capability Score" (Wignaraja, 2002, p.94)- is then, essentially, a summary technology score for each firm in the Argentina, Brazil and Chile samples. Hence, TI is a normalized variable, that ranges between 0 and 1. The following table represents different values of variable TI: simple average TI score for the whole sample in each country and simple average TI related to firm size, both of them with their respective standard deviation. TI variable is also analyzed over its maximum range in the whole sample:

[7]Sometimes to "normalize" a variable means a "transformation" that will result in a variable that is nearer to a normal (Gaussian) distribution. Then, the resulting variable cannot range between 0 and 1, as a normal distribution ranges between minus infinity and plus infinity. In other cases the term "normalize" is used for "standardization", then a common method is to subtract the mean and divide by the standard deviation. The results are sometimes called z-scores. Again the resulting variable will not range between 0 and 1.

[8]" the Capability Scores are biased estimates with respect to the measurement of capabilities cum capacities per se. The degree of bias depends on the respective weights placed on capability and sophistication in the researcher'scoring. Unfortunately, it is not possible to state these weights.." Westphal et al. (1990)

Table 1. Production and linkages functions to measure capabilities

FUNCTIONS RELATED TO PRODUCTION	
PROCESS FUNCTION	
ISO 9000/QS 9000/ISO TS 16949 STATUS	
No accreditation	0
Accreditation	1
Bought new equipment in the last year	
Normalized variable, values between 0 and 1	1
Introduced new or improved production processes	
No	0
Yes	1
PRODUCT FUNCTION	
Introduced new or Improving existing products	
No	0
Yes	1
FUNCTIONS RELATED TO LINKAGES	
OTHER FUNCTIONS	
Technology licensed from foreign buyers	
No	0
Yes	1
Percentage of Inputs supplied from foreign companies	
0 a 20%,low	0
20% a 60, medium	1
60% or more, high	2
Investment in R&D contracting a third party	
Normalized variable, values between 0 and 1	1

Table 2. Mean and maximum TI values for Argentina, Brazil and Chile

TECHNOLOGY INDEX	ARGENTINA 2006	BRAZIL 2003	CHILE 2006
Simple Average:			
All firms	0,30 (0,16)	0,23 (0,14)	0,32 (0,18)
Small Firms (5-19 employees)	0,27 (0,15)	0,18 (0,12)	0,26 (0,17)
Medium Firms (20-99 employees)	0,31 (0,16)	0,22 (0,13)	0,33 (0,18)
Big firms (> 99 employees)	0,45 (0,16)	0,28 (0,15)	0,42 (0,16)
Maximum Range of every firm	0,88	0,75	0,75

Note: Standard Deviation in brackets

As expected and confirming different studies -for instance Romijn (1999), Wignaraja and Ikiara-, that emphasize that size matters for technological performance, TI is positively related with firms' size[9] . The evidence shows that bigger enterprises have higher TI.

Brazil's mean TI is the lowest among the three countries. It is due to the fact that the normalized variables -composing TI- are affected by two big outliers that invest huge amounts in new equipment and RD. This contribute to diminish each firm score and consequently also, the whole mean TI.

The maximum TI's range in Argentina belongs to a big national Food Process firm. The most outstanding characteristic is that this enterprise has also the highest investment in RD in the country. Considering Chile, the maximum TI's range belongs to a medium completely foreign owned Chemical firm that -as the Argentina's one- undertakes every selected TI's function and has the 70% of its inputs of foreign origin. The same for Brazil: the highest TI's range comes from a big completely foreign owned Autoparts firm that undertakes every TI's selected function and has the 80% of its inputs of foreign origin. These results are coherent and confirm which it is mostly known about the three countries' industry.

On the following Graphics 2, 3 and 4, the relationship between TI and foreign ownership is shown, for each country. The reason of considering this aspect in the current analysis is an attempt to check the role of foreign affiliates in host economies. TI's behavior seems very similar in the three countries: in the three cases the presence of 100% of foreign capital is not indispensable for having a high TI. Consequently also national firms have the similar and also high ranges of TI. In the middle zone, firms partially owned by no-nationals, exert middle levels of TI.

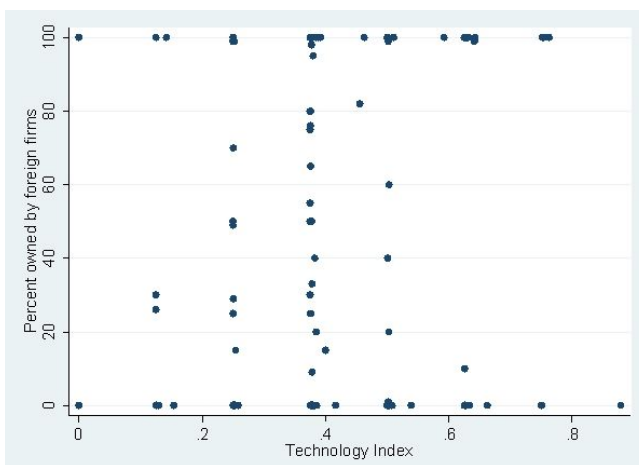

Figure 2: The relationship between TI and Foreign Ownership in Argentina

[9]In our study size is measured as the number of employees of the firms

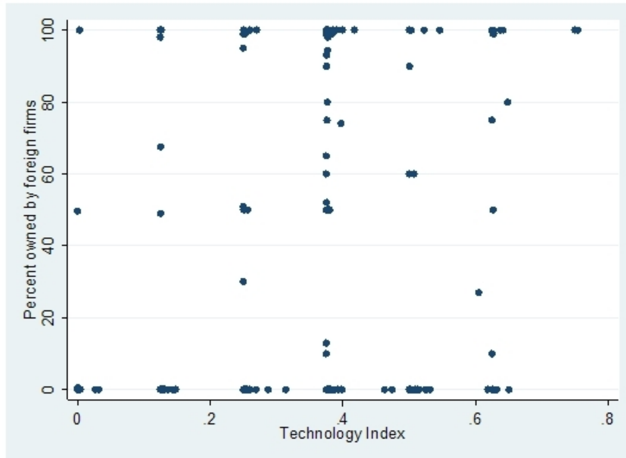

Figure 3: The relationship between TI and Foreign Ownership in Brazil

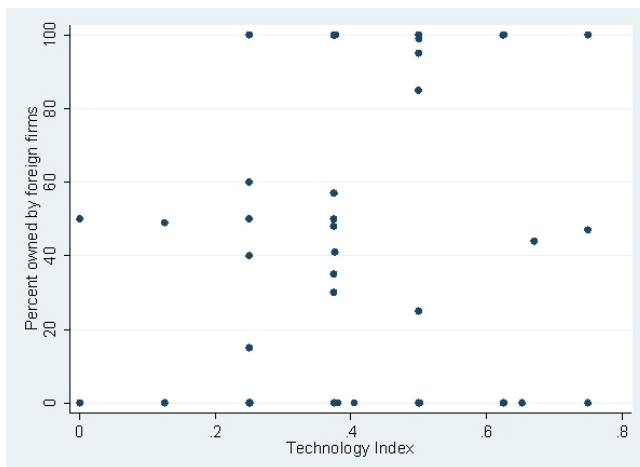

Figure 4: The relationship between TI and Foreign Ownership in Chile

On the following graphics we propose a glance over mean TI and its relationship with firms' sectors:

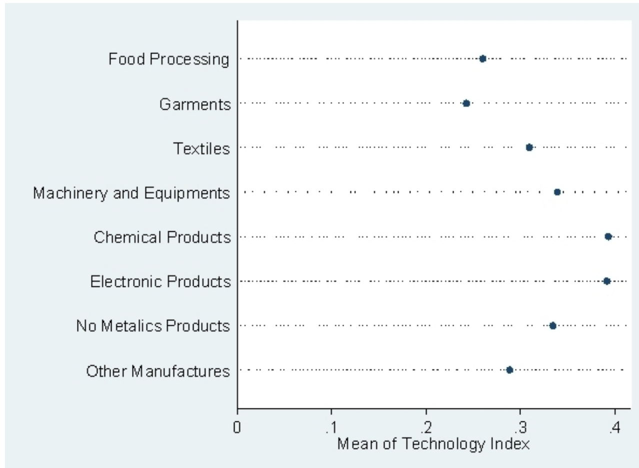

Figure 5: Mean TI over sectors in Argentina in 2006

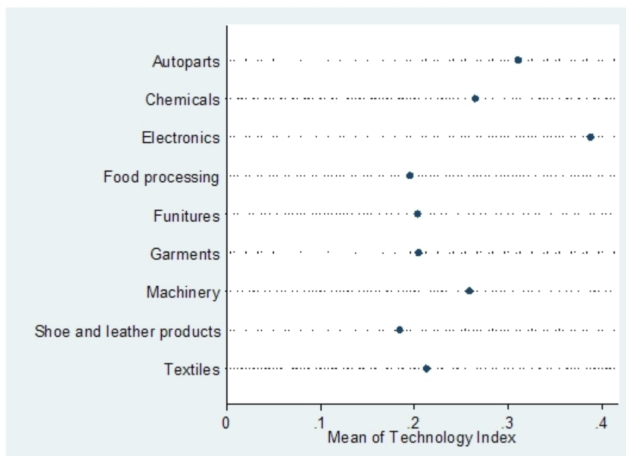

Figure 6: Mean TI over sectors in Brazil 2003

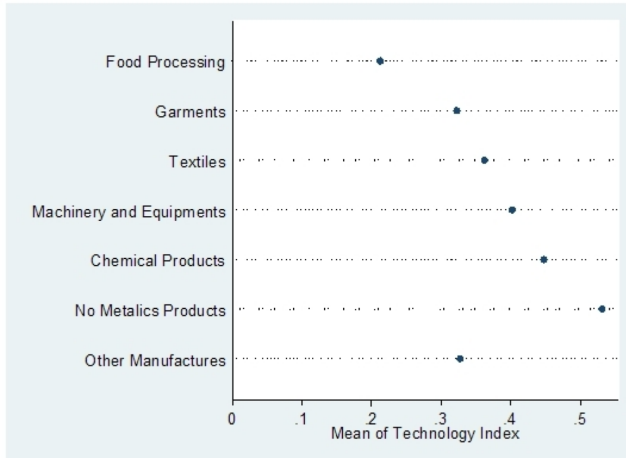

Figure 7: Mean TI over sectors in Chile 2006

The results show that different sectors have different TI in the three analyzed countries. Nevertheless Brazilian sectors seem to be more homogeneous and to have very similar average TI.

V. The econometric analysis

Different authors, such as Westaphal et al. on Thailand, (1990), Lall et al. on Ghana (1994), Wignaraja (1998) on Sri Lanka, Latsch and Robinson on Zimbawe (1999) Deraniyagala and Semboja (1999) on Tanzania ran multiple OLS or Tobit regressions were run relating export achievements to particular firms' characteristics (including capital intensity, skill intensity, firm size, foreign ownership, RD, and technological capabilities). Indeed export achievements are correlated with deeper capability level and highly innovative capabilities. Some of these econometric studies report interesting findings linking positively TCs -measured by TI- with firm size. Others consider also the role of foreign ownership for building indigenous capabilities. Both aspects have already been analyzed with descriptive statistics and are now subject to econometric tests. Special firms' characteristics, such as firms' age, entrepreneur's education level and skills have been, for instance, were tested by Deraniyagala and Semboja in Tanzania(1999) as influent on TCs. Wignaraja (1998) checked in Sri Lanka the same firms' characteristics -adding technical manpower and technology imports- and in Kenya -adding employee training- for constructing a Technology Index (TI). Based on the mentioned technology studies on developing countries, we selected to test for the influence of a common group of variables for the three countries: foreign equity, size and training programs. Following the findings available in the literature, we expected these variables to be positively related with TCs and Export Share. The measure of the TI as a proxy for TCs and its link with exports share , is expected to provide some empirical support for the hypothesis that both TCs and export share are related by a mutual-two-way causality relationship. As stated by

Figueiredo (2008) "exporting firms are more exposed to specific needs of the international markets they supply, they need to respond quickly to and/or anticipate the changes and trends in such markets. This, in turn, appears to be reflected on the speed at which they adapt and upgrade their process and production organization capabilities to meet new requirements of product design. This further suggests that exposure to foreign competition is relevant for firms' innovative capability building". TI is then, expected to be positively related to export performance: the process of acquiring TCs is the outcome of improving and creating experience and skills, that are dramatically important for exporting. On the opposite hand however, exporting should be a great incentive and motivation for creating TCs, and may open the way to useful learning opportunities. The purpose now is to use an alternative econometric methodology: Simultaneous Equations run by the Three-Stage Least-Squares Regression[10] checking for reciprocal causality relationship between these firms' characteristics with exports. As stated before, we believe that there is a loop, where there is permanent feedback within the firm, between TI and exports. We proposed the following econometric model for evaluating the three countries. The variables' selection was based on their influence on the process of building TCs and increasing exports, on the validity for the econometric regressions and also on the availability of information. The econometric model under 3SLS was run over the following equations:

$$\boxed{TI = b0 + b1\ FE + b2\ TRAIN\ PROG + b3\ EXSH + Sector\ Dummies} \tag{1}$$

$$\boxed{EXSH = b0 + b1\ SIZE + b2\ TI/med} \tag{2}$$

Then, equation (1) was the regression with TI as the dependent variable and export share and other variables as the explanatory ones. Equation (2) represents Export Share as function of TI and other variable, where:

TI: reflected the level of TCs in enterprises. As affected by several variables, it was not just a simple function of years of experience, but of conscious investments in creating skills and information.

FE: the share of foreign equity calculated as the percent owned by private foreign individuals, companies or organizations.

TRAIN PROG: is a dummy variable that studied if the firm has internal formal training programs.

[10] The available methods of estimating Simultaneous Equations vary on the basis of their treatment of information, and their use of different estimators (Maximum Likelihood versus Instrumental Variables). Single equation methods, like Two Stage Least Squares (2SLS), and limited information Maximum Likelihood (LIML), estimate the model parameters of each equation at a time, whereas full-system estimators, like Three Stage Least Squares (3SLS) and full information maximum likelihood (FIML), estimate all the parameters at once. As suspected the presence of endogeneity, 3SLS method was preferred -a full system estimator-. Because it is likely that it has an efficiency advantage over the single equation methods, such as 2SLS

EXSH: as already mentioned, the export share was calculated as the percentage of sales that were exported directly and indirectly.

SIZE: was measured by the number of full-time permanent workers at the end of last fiscal year.

TI/med: is a new variable generated to capture the size effect, within the database. The reason is that firms' export share has an enormous range between the sampled firms. Then, an econometric resource was needed to capture this variability and better explain the studied phenomenon. The procedure was to multiply TI by the dichotomous "medium" variable, that refers to medium size enterprises (20 to 99 employees). The benefit was to create a subgroup inside the variable with similar characteristics, as variability was reduced within the group. In this case -for both countries- the medium size group was the one with less variability within the group regarding TI.

As suggested by Geroski's (1990) we agree that firms may face different technological opportunities in different industries, hence we decided to control for sectoral effects including in (I) also (n-1) sectoral dummies (for n sectors).

The selection of the variables for the regressions was made considering Wignaraja's model. At a first glance, we expected these micro level factors to be significant and positively related with TI. Nevertheless if deepening the analysis the conclusions may be quite different for some variables.

For instance some firms characteristics such as foreign equity, skilled trained employees, and export share were expected to be significant and have a positive sign as already checked in several case studies (Wignaraja, 2002,008; Figueiredo, 2008). Several studied confirmed that TCs, skilled employees and skilled trained employees have positive impacts on Export Share (Pietrobelli, 1998; Kim, 2000).

However, in other cases, -specifically for Brazil- Costa and Robles Reis de Queiroz, (2002), found that although higher than domestic firms, foreign affiliates' scores on the systematic effort index are still low, suggesting that their local TCs accumulation is relatively restrained. Then, the expectations for the foreign equity variable, were not completely clear. We included in the regressions sectoral dummies. We intended to control for sectoral effects as agreeing with Geroski (1990) that firms face different technological opportunities in different industries.

Table. 3 illustrates the results arising from the OLS regressions for Brazil 2003 database, run with the Three States Least Squares method.

The results demonstrated that Technology Index and Export Share reciprocally explained each other, within the cross section analysis. The R-squared obtained was low but acceptable for a cross section model.

Table 3. BRAZIL 2003 – Simultaneous Equations Estimates – 3SLS

Equation	Obs	Parms	RMSE	R-sq	chi2	P
Technology Index	1628	10	0,1260448	0,1567	380,75	0,000
Export Share	1628	2	3,16E+07	0,157	347,26	0,000

Technology Index	Coef.	Std. Error	z	P>z	[95% Conf. Interval	
Foreign ownership	0,0015	0,0002	8,3	0,000	0,0011	0,0018
Training programs	-0,0437	0,0064	-6,85	0,000	-0,0562	-0,0312
Export Share	0,0000	0,0000	4,11	0,000	0,0000	0,0000
Constant	0,2976	0,0161	18,52	0,000	0,2661	0,3290

Export Share	Coef.	Std. Error	z	P>z	[95% Conf. Interval	
Size	2,21E+07	5301573	4,18	0,000	1,18E+07	3,25E+07
TI/medium	50015,1	2.685,923	18,62	0,000	44750,79	55279,42
Constant	-4128091	1076995	-3,83	0,000	-6238964	-2017219

Notes: sectoral dummies not included

Tests of endogeneity of TI for EXPORT SHARE

H0: Regressor is exogenous			
Wu-Hausman F test:	74,82494	F(1,631)	P-value = 0.00000
Durbin-Wu-Hausman chi-sq test:	71,67438	Chi-sq(1)	P-value = 0.00000

For Brazil it was verified that firms' characteristics such as foreign equity and export share, had significant and positive (with low coefficients) impacts on TI in Brazil. This means that as expected, these parameters contributed to create "skills" within firms, reflected in-house efforts, and may be a cause of building TCs.

We expected the same results for the variable training programs as agreeing on the importance of "continuously improving". As affirmed by the evolutionary theory of Nelson and Winter (1982) and his followers, each firm requires purposeful learning. But unexpectedly, the variable referred to having training programs in firms in Brazil, was negatively related with TI level. Such negative effects may be due, for instance, to the lack of efficiency with which mastery is achieved or to the fact that trained labor become productive only when it is combined with other technological efforts to master and improve technology (Lall, 1991). Then, training employees under these particular circumstances, may not give the firm the expected positive impact on TI.

Again, confirming the initial hypothesis, exportation variable positively contributed to TI and stimulated the continuous building of TCs.

As a second step, analyzing the impact of TI/med and the variable size on export share, size, skilled, -as expected- they had positive impacts on exports in the studied countries. Considering the size variable, it was confirmed that the scale of production was relevant for exporting: for instance, more large firms than SMEs had moved into modern quality management systems by adopting ISO 9000 standards, especially relevant for exports, already included as one of the functions related to production, within TI score.

Finally, after the regressions -and for the three countries-, the Durbin-Wu-Hausman (DWH) Test -for evaluating the potential endogeneity of TI- was run. The test confirmed that the selected estimation method, that is the Three Stages Least Squares was correct. Consequently under the null hypothesis this is an appropriate estimation technique. The Chi-square statistic reported was correct, with degrees of freedom that also supply correct p-values. The hypothesis being tested is that the variable TI -being challenged- could be treated as exogenous in order to derive consistent estimates. As the model treated the variable as exogenous, the estimators that were found were robust.

The databases for Argentina and Chile were more recent and also different from the Brazilian one. The three surveys were made with the same objectives, but different questions were included in both types of databases. The procedure described before for calculating TI was used also for Argentina and Chile. The regressions were also run under Simultaneous Equations with 3SLS with the same model.

If analyzing the variable foreign ownership, in both countries as expected, we found significant and positive -but low- coefficients. This may mean that not every foreign partners help to improve indigenous TCs. It depend -for example- on how much local firms had access to new technologies and how much foreigner firms outsourced their activities to local enterprises and facilitated local affiliates access to international capital and technology (Mendona de Barros and Goldestein, 1997; Moreira, 1998, Costa and de Queiroz, 2002).

As in Brazil, the variable referred to having training programs in firms in Brazil, was negatively related with TI level. We assume that the motivations in these countries are the same as the Brazilian ones.

Also in these cases R-squared was low but acceptable for a cross section analysis. Again as in Brazil, the other selected variables were expected to contribute to explain TI. For example, variables such as high percentages of training programs and export share, were positively related with TI in both countries.

In a second step evaluating TI and size influence over export share, as expected both positively influenced export share -like in Brazil-. Specifically for size, this was the return form of capability acquisition: exports were higher when firms were large. The results, may be seen in this way: TCs and human capital are important determinants of export advantage in the three selected countries. On the other hand, exporting firms need to build TCs for continuously improving and exporting -as a requisite to satisfy foreign markets-.

Brazil and Chile have higher R-squared in their regressions that demonstrate higher goodness of fit of the proposed model. We assume then, that more firms in these countries -within the industrial sectors- invest export thanks to investing in technological functions measured by TI.

Finally, we are conscious that there are important differences between sectors and that this is one of our study's limitation as we are considering only one year. Indeed, there are specific sectors in each of the three countries which develop high levels of technology (TI) and reach the world markets while others are able to export having medium levels of TI.

On Graphics 8, 9 and 10 we present the relationship between TI and Export Share.

Table 4. ARGENTINA 2006 – Simultaneous Equations Estimates – 3SLS

Equation	Obs	Parms	RMSE	R-sq	chi2	P
Technology Index	329	8	0,162378	0,0154	138,64	0,000
Export Share	329	2	5,24E+07	0,0289	31,65	0,000

Technology Index	Coef.	Std. Error	z	P>z	[95% Conf. Interval	
Foreign Ownership	-0,10028	0,0167	-5,8900	0,0000	-.1307155	-0,0655
Training Programs	0,00103	0,0003	3,5600	0,0000	.0004656	0,0016
Export Share	1,64E-09	8,30E-10	2,00	0,045	3,55E-11	3,29E-09
Constant	0,43335	0,03687	11,75	0,000	0,361074	0,50564

Export Share	Coef.	Std. Error	z	P>z	[95% Conf. Interval	
Size	12354,48	2.535,505	4,87	0,000	7370,254	17323,97
TI/medium	3,17E+07	1,20E+07	2,64	0,008	8510440	5,51E+07
Constant	-2752791	3355476	-0,82	0,412	-9294502	3823822

Note: sectoral dummies not included

Tests of endogeneity of TI for Export Share

H0: Regressor is exogenous

Wu-Hausman F test: 419340 F(1,383) P-value = 0.04126

Durbin-Wu-Hausman chi-sq test: 418047 Chi-sq(1) P-value = 0.04089

Table 5. CHILE 2006 – Simultaneous Equations Estimates – 3SLS

Equation	Obs	Parms	RMSE	R-sq	chi2	P
Technology Index	637	8	0,169675	0,2054	190,98	0,0000
Export Share	637	2	5,94E+09	0,3092	298,41	0,0000

Technology Index	Coef.	Std. Error	z	P>z	[95% Conf. Interval	
Foreign Ownership	0,00076	0,003172	2,42	0.015	0,001469	0,013901
Training Programs	- 0,6345	0,0104	-6,13	0.000	-0,0861448	0,0443809
Export Share	8,84E-12	1,85E-12	2.25	0.025	5,81E-13	8,51E-12
Constant	0,4708	0,0306	14.48	0.000	0,4102612	0,5387442

Export Share	Coef.	Std. Error	z	P>z	[95% Conf. Interval	
Size	1,58E+07	673872,10	17,21	0,000	1,03E+07	1,29E+07
TI/medium	3,31E+09	1,12E1+9	2,96	0,003	1,12E+09	5,50E+09
Constant	-4,90E+08	2,96E+08	-1,66	0,044	-1,07E+09	9,02E+07

Note: sectoral dummies not included

Tests of endogeneity of TI and exports share

H0: Regressor is exogenous

Wu-Hausman F test: 939591 F(1,690) P-value = 0.00226

Durbin-Wu-Hausman chi-sq test: 930999 Chi-sq(1) P-value = 0.00228

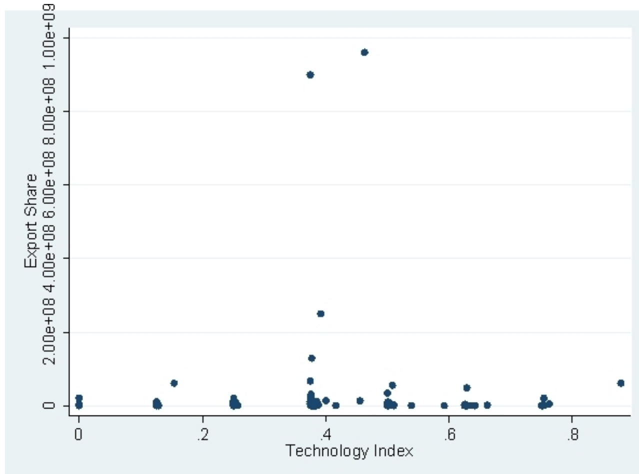

Figure 8: The relationship between TI and Export Share in Argentina

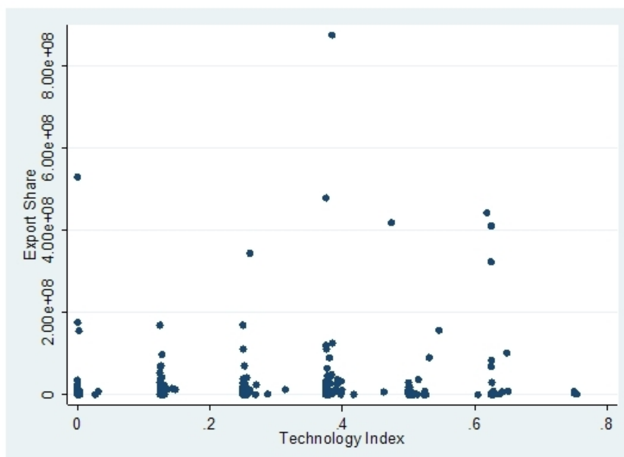

Figure 9: The relationship between TI and Export Share in Brazil

The graphics confirm that there are more firms in Brazil and Chile that reach to export with different TI levels than in Argentina. And between them, Brazil has more firms exporting more, at different levels of TI.

The three countries' industries perform high exportations levels with medium TI. We also found that within each country, most of the firms' export share are similar and low if compared with some few outliers within each country. Nevertheless we recognize another limitation in the fact that only one year has been considered for each country in the present study. It would be very useful to see the evolution of industries in the three selected countries to know more about firms building TCs. However we corroborated that in three countries there are firms that have already reached high levels of TCs while

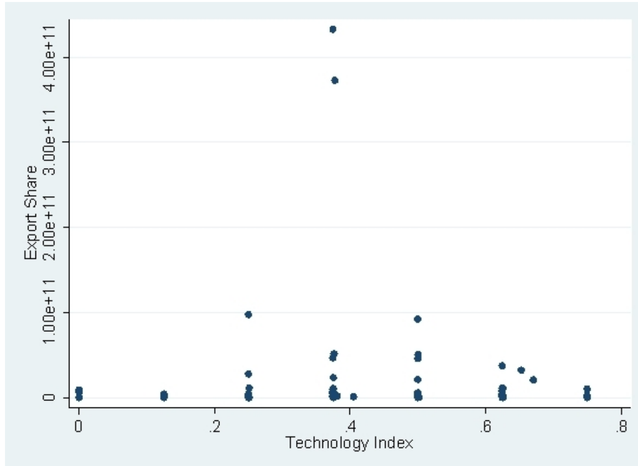

Figure 10: The relationship between TI and Export Share in Chile

others did not meet this condition, reflecting the intra-country diversity of TCs.

VI. Conclusion

This study has compared Argentina (2006), Brazil (2003), and Chile (2006) industrial sectors, based on the World Bank Investment Climate Survey. It started from the concept of Innovation and Technological framework in Latin America (LA) to define the scenario and compare countries' economic performance during almost the last twenty years. This evidenced that the studied period was characterized by uncertainty and instability. The analysis then began under the assumptions that the process of Technological Capabilities (TCs) developing in LA countries had been extremely complicated by the context of uncertainty and instability of the macroeconomic framework. After that, the attention was concentrated on capabilities. TCs, their nature, and their determinants, were defined. The empirical literature on TCs in developing countries has been significantly based on the Evolutionary Theory of technical change. This study agreed with this main line and followed these ideas. Then, it presented different methodology to measure TCs, starting from Romijn and following with Wignaraja and Figueiredo. The three authors' studies were considered extremely important for the present work and we finally focused on using Wignarja's TI -as a proxy- taking account also the others literature's contributions on this field. This paper tried to estimate the costly efforts required to build capabilities and specifically the efforts related to production and linkages. Expecting asymmetries among firms and starting from Lall's taxonomy, we selected from the survey, some questions that reflected these functions, and used them for measuring TCs of the firms in the sample. The empirical analysis allowed us to conclude that:

o The measure of TI -assumed useful in representing firm-level technological activity level- demonstrate that the three countries' average manufacture enterprises evidence similar degree of technical competences.

o As expected the firms' size is relevant for building capabilities. Again, in Argentina, Brazil, and Chile, average big firms have higher TI than medium and small ones.

o Considering the descriptive statistics, foreign ownership is not a crucial factor for building TCs in the three countries. The are one hundred percent national firms that reach almost the same TI than completely foreign firms.

o There are only few firms in specific sectors, which reach high technological levels. They may be seen as outliers, also for having outstanding export share.

o Under the econometric analysis, in each of the selected country it was confirmed that firm's characteristic features, such as foreign equity and export share contribute to build TCs in the three countries. The training programs variable had unexpectedly significant and negative coefficients.

o The estimators were robust and the regressions were correct considering the potential endogeneity. Also as expected, TI and size were positively related to exportation level. The evidence confirmed that TI and exports are mutually influenced in Argentina, Brazil and Chile.

o We can not make generalizations about levels of TI in the three selected countries. There are specific firms, within specific sectors, that have high levels of TI that means different level of accumulation TCs. The same occurs if considering export share, as there are specific outliers in the three countries.

o Brazil is the best performer among the three countries if considering the density of firms exporting . As already stated, they export at different level of TI.

o We recognize that our study has limitations. We have not captured neither changes in TCs as considering only one year nor the role of dynamic capabilities to keep the pace of innovation. As recognizing the importance of inter industries differences, the avenues for further research include also deepening in sector's analysis.

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