Standards of quality, productivity and exports in Colombian manufacturing firms

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2020

Summary This paper is a research of the relationship between the quality standards, productivity, and exports of Colombian manufacturing firms. This product presents an analysis between 2007-2018 with the Annual Manufacturing Survey, Development Survey, and Technological Innovation at the firm level. Different types of quality variables, including certifications, firm productivity, and input and product prices, are analyzed. Results show that product quality certificates, process improvements, and investment in STI have a positive effect on TFP and prices of firm goods and inputs.

*This document was financed with resources from the National Planning Department for the mission of internationalization.

Contents

1 Introduction

Accumulation of capital, growth of the labor factor, and technological change are determinants of economic growth, as is the contribution of innovation (in processes, products, services, and/or in forms of organization). Meanwhile, the role of the quality of goods, services, or processes is recognized as a cardinal element of business competitiveness. In particular, the quality of a good / service is a property that represents well-being for the consumer (and society). That is, with the quality, the competitiveness of the productive unit is reinforced[1].

However, the production of quality goods and the fulfillment of a good service does not necessarily constitute a contribution to economic growth, as long as it is not framed within an adequate production process. In this sense, a production process that manufactures products without defects, or derives in the provision of services that meet a minimum of specificities and satisfy the consumer, constitutes a practice that generates sustainable benefits over time: quality correlates with growth and greater dynamics of international trade.

Export dynamics can also be affected by the quality of the different products in the manufacturing sector that the country trades with the rest of the world. The different qualities of the products make the goods considered differentiated goods, so measuring this quality becomes fundamental when analyzing the country's international trade. However, there are several difficulties in performing this measurement. Colombia ranks among the countries with the highest export costs in terms of obtaining, preparing, and sending documents needed for transport, inspection, and clearing of products, both for the country of origin, the country of destination, and the transit costs for 2020 (Figure 1)[2].

In this sense, it is very important to analyze the international performance of Colombia, which relies heavily on the export of hydrocarbons and agricultural products such as coffee, bananas, and flowers, and to a lesser extent in the manufacturing sector. This limits the creation and contribution of employment and added value OECD (2019). evidenced by the difference between the added value generated by the manufacturing sector. It was three times less than its gross production for 2018 (94.4 vs 260.3 trillion pesos) respectively DANE (2019).

It is clear that not only does economic growth depend on the abundance of labor and capital factors but also on the productivity with which they apply to product generation. Besides, a key component of the before-mentioned productivity is the development of technological knowledge of innovation, as well as the concomitant dissemination, in which standards play a decisive role, which repre-

[1]Evidently, here quality is understood as compliance with specifications set by the client.

[2]In particular, Colombia ranks eighth in the region with the highest export cost, tied with Peru and a large gap concerning Bolivia and El Salvador that have the best performance. This shows the problems the country faces on foreign trade issues.

sents benchmarks for trade, quality, safety, and others. In this regard, standards are a mechanism for the dissemination of technical knowledge, and therefore, a key element of productivity. However, the positive correlation results between Total Factor Productivity (TFPs) and economic growth are just indicators of the role of standards or standards within the economy DIN (2011); for that matter, standards regarding quality standards.

Today, the international scenario has a kind of self-regulation that establishes legislation on issues related to the quality of goods and services traded, so that it is exercise facilitates and stimulates international trade. In this regard, given the high heterogeneity of quality standards between countries, international bodies such as the International Organization for Standardization (ISO) have made efforts to standardize quality standards in such a way as to reduce uncertainty among actors in matters relating to the quality of goods and/or services.

The said standardization does not establish an international standardization on minimum specific parameters to be met by tradable goods and services. But rather determines international quality standards that companies must observe within their production processes so that the quality of the goods or services produced is effectively achieved. Compliance with ISO 9000 implies the obligation to have a quality management procedure in production processes.

In the meantime, having certification or certifications of the ISO 9000 family means additional advantages for companies that are not held by those lacking such. To get started, consumers usually associate the ISO 9000 family of standards with high-quality products or services. Also, the acquisition of the ISO Certificate is an enabling requirement to be able to do business with many companies at the international level or to contract with the State (in some countries).

Others variables that can be used like quality proxies are the export goods and input prices that can be considered as a way to observe the variability of quality. However, it should be noted that a fraction of the price difference may be due to production costs or inefficiencies, rather than product quality.

On the other hand, the ratio of the products quality and their production capacity is closely related to the level of development of each country. Cusolito and Maloney (2018). Krishna et al. (2020) show a positive correlation between the level of development of the countries and the level of quality in the products (Figure 2).

The objective of this document is to evaluate and analyze the effect of the different quality variables and certifications through the EDIT with the AMS as a direct approximation to exports to high-income countries using input and product prices. This contributes to literature, not only by the use of crossovers of different databases at the firm level, including foreign trade, but also by estimating and using direct quality variables for each of the firms in the Colombian manufacturing sector, taking into account their various characteristics, which makes it a fundamental approach in terms of what kind of elements can contribute further by increasing the possibility of countries exporting to high-income countries and, at the same time, because of a better allocation in resources, can increase their size depending on the different existing measures. In this document, section 2 shows the literature review on these topics, followed by the section 3 explaining the data and measurements used. Section 4 discusses the results obtained, and the last section will describe the conclusions and recommendations.

2 Literature Review

In the context of international trade, there have been several approaches and various fields to be studied. One of them is the importance of the quality of goods in exports and whether this characteristic plays an essential role in a country's exports (Alessandria et al., 2020). Hallak (2006) empirically shows how the quality of products actually plays an important role in the behavior of countries' international trade.

In the case of Portugal, Bastos and Silva (2010) finds that firms with high productivity tend to export more products and at a higher price, especially to rich countries, being consistent with better product quality. The firms place higher prices depending on the distance between the countries, therefore, the most expensive products are those sold in the farthest markets. Görg et al. (2010); Baldwin and Harrigan (2011)

Brambilla et al. (2012) look at the relationship between the export destination and the recruitment of qualified labor in companies for Argentina, showing that there is a relationship between these two variables, where the firms that contracted more qualified labor exported to higher-income countries which, in turn, value the quality of the goods more. At the same time, Brambilla and Porto (2016) find for Mexico and Argentina that companies that export to higher-income countries pay higher wages to their workers as a result of being skilled labor, which generates higher quality products. The approach of the Demir et al. (2021) studies the trading relationship between skill-intensive firms.

In the case of the Colombian industry, Carranza et al. (2014) characterize the interaction of exports with domestic production, external demand, and other variables at the product level of each sector. They find that over the period (2000-2010) there is a positive correlation between added value and sectorial exports, highlighting the importance of external markets for the growth of the domestic industry. In turn, Carranza et al. (2020) describes the relationship between the quality of the goods and inputs of Colombian manufacturing companies and the level of revenue in their export markets. They show that there is a positive correlation between measures of product and input quality and per capita income measures in export markets.

Other variables that influence the quality of products and their exports, such as the development of the economy and the size of companies. Kugler and Verhoogen (2011) do this analysis for the Colombian case in the period 1982-2005, finding that using quality inputs produces quality products, but conditioned on the size of the companies, so a positive correlation between the prices of the products and the inputs concerning the size of the firm is generated. While, Manova and Zhang (2012) comes to similar results for China industry, stressing that major exporters use better quality raw materials to produce higher quality goods.

On the other hand, according to literature and data about companies with quality management systems, not all production units have any certification from the ISO 9000 family of standards (especially many SMEs). This lack is due to several reasons, such as the costs involved in the implementation of a quality system, it is assembly and implementation of a quality system, as well as the lack of awareness on the part of managers and staff about the benefits involved in the establishment of an adequate quality management system, in particular, increased productivity, increased opportunities and reputational improvement, among others.

Likewise, according to Martincus et al. (2010), the company-level export performance for Argentina during the period 1998-2006 ensures that ISO certification has effectively helped Argentine companies expand their exports, along the extensive margin, mainly in terms of destination countries, as well as along the intensive margin. For their part, Goedhuys and Sleuwaegen (2016) states that certification plays an important role in reducing transaction costs in international markets while maintaining and increasing efficiency.

Adams (1999), from a logistic regression model, with 1994 cross-cutting data for New Zealand, finds that ISO accreditation was positively related to company size, set of investment opportunities, and market segmentation. Likewise, Castagnino (2006), states that firms that have been certified some international quality standards show, together, a relative better relative performance in international markets. As well, that permanence in international markets is associated with the state of certification (companies that register quality certifications have been exporting for more years).

According to Peñaloza (2016), quality certifications have a significant impact on the internationalization of companies, and, quantitatively, the implementation of these increases by 20% the likelihood that the company will be internationalized. This, according to the author, demonstrates that international certification is a strategy that generates differentiating competitive advantages between companies and contributes to greater insertion of international markets.

Similarly, there is a lot of empirical evidence to support the positive relationship between economic performance (product growth) and quality management in the production process. For the individual, studies such as that of DIN (2011) for Germany, and that of AFNOR (2009) for France, among others, indicate positive impacts on economic growth, effects that are corroborated by the inspection of the evolution of the TFP and elements related to quality management.

3 Data and Measurements

To study the relationship between the quality of products and inputs with export destinations, and the relationship between productivity and quality, three databases containing the information were obtained at the firm level and establishment of the manufacturing sector in Colombia. The first database to use firm-level information is the National Administrative Bureau of Statistics (DANE) Annual Manufacturing Survey (AMS) for the period 2000-2018 where firm characteristic variables such as the number of workers hired, workers' wages, total income, and the value of the firm's intermediate consumption are located. The ISIC classification is used to group what each firm specializes in, allowing the focus to be taken on manufacturing companies, eliminating those that are engaged in processing commodities [3]. With several establishments per firm, the value of the establishments was added to obtain the annual value of the firm.

This aggregation by the establishment was made for all variables except those that give information about the characteristics of the firm, such as the department or the identification number of the company. For this process, an aggregate variable was built, which contains the sum of the values per company of its different establishments, in this way to obtain the overall value of the firm. In turn, the percentage variable of sales abroad was modified to leave it in such a way that it was indeed in percentage terms since for this variable the DANE has handled it with different methodologies over the years, being the percentage of sales abroad until 2007. After this year the variable is handled as the continuous value of sales abroad rather than the percentage it represented on its sales. For the last few years, it was divided by the value of the company's total sales.

For quality improvement and innovation variables, the Technology Development and Innovation Survey(EDIT-DANE) is used for the period 2007-2018 which contains variables such as worker training, improvements in production processes, product line innovations, quality certifications, among others. This survey is found biennially, i.e. we found two different years in the same survey, starting in 2007 and 2008 at first base and last 2017-2018, to obtain the annual values, the entire base was doubled and in this way, we can have an annual value for each year and in this way no longer appears a basis for 2007 and 2008, but can have the basis of

[3](CIIU 230 & 270)

2007 and 2008. In addition to variables that mediating the impact of quality in null, medium, or high, they were re-coded so that when they take the value of 1 it is null, 2 an average effect, and 3 a high effect.

For international trade information, DANE and Directorate of National Taxes and Customs (DIAN) data are obtained. These international trade databases include the dollar values of firms' exports and imports and their volume in kilograms. It details the information on the country of destination and origin of the country according to the Nandina classification. This international trade data was an aggregation per year for each firm. Besides, information on the income of countries obtained from the World Bank was added to classify and order the countries of destination of exports. Classifying countries by income level using the World Bank's Atlas method[4]. This establishes whether it is a low-, medium-low, medium-high, or high-income country according to countries' per capita income for 2013. Finally, a firm-level crossing takes place for the years 2015-2018.

The role of quality certificates in products and processes is one of the most recognized elements in the ability to export firms so their characterization with firms is fundamental [5]. For the Colombian case, the table 1[6] shows that the ratio of quality certificates in products increases with the size of the firm through the number of employees. In particular, on average between 2007 and 2018, medium- and large-sized firms had a percentage of 9.2% and 16% with at least one certification, respectively, reinforcing the argument found in the literature, where a larger size of the firm implies a higher quality of the product Kugler and Verhoogen (2011).

Similarly, it can be seen that for the period 2015 and 2018 large firms have an average export price higher than the rest. On the other hand, the table 2[7] shows that on average the ratio of the quality association to products with a larger size of the firm is not necessarily preserved using as a categorical variable the percentage sold abroad. This shows that the firms that concentrate the most certificates and export are the medium-sized ones with an average of 12% on average between 2007 and 2018.

In addition to the size of the firms by the number of workers, the table 3 is

[4]The groups according to income are: Low income USD $1,035 or less; medium-low USD $1,036 - 4,085; medium-high USD $4086-12,615 and high income USD $12,616 or more.

[5](See Martincus et al. (2010); Goedhuys and Sleuwaegen (2016); Adams (1999); Castagnino (2006); Peñaloza (2016); Chen et al. (2006); Clougherty and Grajek (2014); Hudson and Jones (2003))

[6]Defining a microenterprise as one that has no more than 10 employees, small business if it has between 10 and 50 employees, medium-sized company has more than 50 and fewer than 200 employees and the large company is the one with 200 or more employees

[7]The size per export was defined by the percentage it implies about its sales, being a small exporter if only 30% of its sales are exported, average if it exports more than 30% and less than 70% and a large exporter if it exports more than 70% of its sales

on the same line, in this case sorting the firms by their value in sales[8], being on average for the period 2007-2018 only 14% of medium-sized firms have quality certificates in their products, compared to micro-enterprises that only 2% have a quality certificate in the products. Also, the dynamics of a large difference between firms' FOB prices are maintained, where medium-sized enterprises have a higher average FOB price. To calculate the percentage of companies that hold certificates, the number of firms that had at least 1 quality certificate by their size and year was divided into the total number of companies of that size according to their classification for each year.

For certificates in the procedure, it can also be seen in the table 4 as the relationship between size by the number of employees and certificates is greater as the size of the company increases. Seeing that on average for the period 2007-2018 medium and large enterprises have a 21% and 33%, respectively, of having at least one quality certificate in the procedure. During 2015 and 2018, medium and large enterprises had more than 10% and 20% of having at least 1 certificate. While if companies are analyzed by their export capacity in the table 5, you can see how medium-sized enterprises have the most certificates on average for the years 2007-2018, with an average of 21% of companies with at least one certificate, it can be observed that there are not a large number of medium-sized or large exporting companies.

Utilizing the size of the companies by their sales value in the table 6 you can understand why there are not so many exporting companies, since concerning the size by sales the medium-sized companies are the ones that have an average of 29% of having a certificate in their procedures, strong contrast with small companies that only have 5% and are the majority of companies. All these results show the existing relationship between larger company size and higher quality in firm procedures. As with product quality, to find the percentage of companies that have quality certificates on their processes, all companies that had at least one process certificate were taken and divided among the total number of companies in size per year. Maintaining the dynamics that medium and large companies have the highest percentage of process quality certificates, despite fewer firms being those in these categories.

In examining the descriptive statistics of the different productivity estimates, it is observed in the table 7 that the OP specification reports values well higher than the TFP than the others, this is because if the firms expand production through intermediate consumption since this term is not included in the equation, the productivity proxy would be overestimated since the uninsured productivity

[8] This classification was made based on Decree 957 of 2019 of the Chamber of Commerce, where it stipulates the size according to the sales value. Microenterprise less than or equal to 23,563 UVTs, small business is greater than 23,563 UVTs and less than or equal to 204,995 UVTs and the median company that has more than 204,995 UVTs and a value of less than or equal to 1'736,565 Tax Value Units'

would be correlated with the other variables. The LP and Wooldridge methods would correct this bias by producing unused productivity values when shocks occur that lead firms to expand production to maximize their usefulness.

4 Econometric Analysis

This section presents the main results and analysis of regressions performed with the database built for Colombian manufacturing firms about the different quality variables that affect the prices of inputs and products.

4.1 Quality of inputs

4.1.1 Wages

To measure the quality of work, literature uses the average wage that each firm pays its workers so that higher wages can increase the export capacity of firms. Specifically, the quality-of-work measure at the firm level is the average wage q_{it}, where:

$$q_{it} = \beta_0 + \beta_1 HI_{it} + \beta x'_{it} + \theta_{1i} + \theta_{2t} : \theta_{3i} + \epsilon_{it} \quad (1)$$

This equation relates a price measure of the input q_{it} in the firm i and the year t with a quality indicator that increases these prices and in turn the export capacity of the firm, HI_{it}. This in turn includes controls for the characteristics of the firm x'_{it} and a fixed effect of θ_{it} which varies across specifications.

For this case, different estimates were made with different salary measures on different quality variables of the EDIT. The tables 10, 12, 14 y 15, summarize the different estimation results performed for different types of the average wage, the first corresponds to the average salary of all permanently employed staff, the second for the average wage of permanent technical workers, the third to the average wage of permanent workers and the latter corresponds to the average wage of permanent administrative workers[9].

These dependent variables were estimated with different quality variables such as improved quality of goods and services, increases in productivity due to the improvement of significantly improved goods, reduction of labor costs due to significant improvements in goods and services or improvements in production processes, reduction in the use of raw materials due to the improvement of goods and services or improvements in production processes, among others. In particular, these measurements with these quality variables due to their construction allow measuring the effect of the change of state on the dependent variable[10]. For example, in the case of improvement in the quality of goods or services firms must report whether this improvement was null and void corresponding to 1, 2 and high corresponding

[9] Temporary employees are not included since they do not necessarily show the structure of the firms but rather seasonal elements.

[10] Independent variables are constructed at a lag of one year.

to 3[11]. This defines the change from 1 to 2 or from 2 to 3 as a change in the state of the quality variable over its independent variable.

Table 10 shows the relationship between the average salary of the firms and different quality measures. Columns 1 and 3 show how the improvement in the quality of goods or services maintains a positive and significant relationship with the average wage, being under random effects for column 1 and with fixed effects with the second control variables for column 3, specifically changing state in the improvement of the quality from null to medium or medium to high increases the average salary by 2%, leaving everything else constant. Column 2 shows that by including the first control variables this quality variable loses significance. Columns 4, 5, and 6 note how the number of quality certificates of firm processes under fixed effects are significant including or not including the different control variables. Unlike the number of product quality certificates, in which you already lose significance by including the second control variables as can be seen in column 9. Investment in science, technology, and innovation, columns 10, 11, and 12, is also significant for average wages under fixed effects including or not including control variables.

For the average technical salary, the table 12 shows in columns 1 and 3 that having new or significantly improved projects has a positive and significant effect on the average salary of technicians under fixed effects and with the second control variables. Causing an increase of 10% or 9% respectively on wages and leaving the rest constant.

The reduction of labor costs resulting from the introduction or improvement of goods or the implementation of new or improved processes becomes a significant variable and that positively affects this average salary under the control variables and with fixed effects, except for the case without variable control in column 4, being significant and positive, but with random effects. In column 7 we observed how the reduction in material costs thanks to the introduction of an improvement of goods is significant and positive only for the model without control variables, increasing the salary by 7% and leaving everything else constant. While obtaining a quality certificate for the signing process is only positive and significant if you are included with the first control variables under fixed effects, so if the company obtains a quality certificate, the salary is increased by 9%.

In the case of the average wage of workers in the table 14 only the number of quality certificates of the processes that the firm has, column 2, including the control variables, is significant and positive. Therefore, when the number of certificates increases by 1%, the average wage of workers increases by 5%.

[11] Question in particular: Point out the degree of importance of the impact, which it had on the following aspects of your company during the period 2014 - 2015, the introduction of significantly improved services or goods, and/or the implementation of new or significantly improved processes, new organizational methods, or new marketing techniques.

In the case of the average salaries of the administrative ones, the table 15 shows how the increase in production, the reduction of labor and material costs, together with the CTI, have a positive and significant effect on the average administrative salary. In column 2 you can see if there is indeed an increase in productivity, the salary will increase by 4%, while the reduction in labor and material costs will only have an effect of the 2% increase for salary, column 5 and 8 respectively. While investing 1% more in CTI only increases by 0.8% of the average administrative salary.

4.1.2 Intermediate consumption and raw materials from abroad

Another measure of impact on quality and exports is intermediate consumption or raw materials that firms import to produce their goods. Tables 17 and 18 show the relationship between raw materials purchased abroad with intermediate consumption and the relationship between raw materials purchased abroad concerning raw materials purchased in total.

In columns 1 and 3 of the table, 17 shows how the number of certificates in the quality of the firm processes positively affect this relationship by 0.1%, keeping the rest constant, as well as in the number of product quality certificates in column 5. For the reason between raw materials from the outside and the total, the table 18 also affects the quality certificate, both in processes and product, affects the reason by 0.1%, regardless of the control variables used. In this way, showing the relationship between the quality of the product and the processes with the raw material used, showing that an increase in the quality certification of products and processes implies an increase in the number of raw materials from abroad.

4.2 Product quality

Because the relationship between quality and exports of firms is direct, quality variables are expected to have a positive impact. The table 8 summarizes the results shown in column 1 that the effect of undertaking projects to improve the goods produced or production chains can increase the percentage of sales abroad by 0.3%, keeping the other constant. Now, in columns 4, 7, and 10 you can see as expected, the importance of quality certificates regarding the percentage of sales abroad, since obtaining a certificate of quality of processes increases the percentage of sales by 0.5%, while increasing by 1% the number of quality certificates of processes and products increases the percentage of sales abroad by 0.9% and 0.3% respectively. A curious result is that for the number of product quality certificates if we add the control variables, it is no longer significant for sales abroad, columns 11 and 12.

For quality in products, the variable of interest is the export price of the firm's goods

$$uv_{ijkt} = \beta_0 + \beta_1 HI_k + \theta_{1,t} + \theta_{2,j} + \epsilon_{ijkt} \tag{2}$$

where uv_{ijkt} is the FOB value per kilogram j put by the firm i for the destination country k in the year t, HI_k is the dummy variable for the firm quality variable, θ_{1t}, and θ_{2j} represent a vector of fixed effects per year and per product, and ϵ_{ijkt} is the term error.

In this case, two estimates were made for both dollar FOB prices and FOB peso prices. For the first, the table 20 in column 1 shows that the reduction in the cost of raw materials, the result of improving processes or products, have both a positive and significant effect. On the other hand, from columns 3 to 6 variables related to quality certification in products show a significant effect on the export prices of firms. Similarly, column 7 shows that investment in CTI positively impacts prices as the quality output on products. In the same sense, the table 21 which shows the effect of quality variables on FOB prices in pesos confirms the previous results for the reduction of raw material costs and quality certifications on products.

4.3 TFP Quality Standards

There are numerous sources of bias when you want to estimate the TFP using added value (or gross production) and production factors. Traditionally the TFP has been estimated as the residue of an estimate of the Cobb-Douglas function. However, productivity shocks are highly correlated with production factors: capital and labor. Also, it is logical to think that there is a problem of endogeneity since production factors determine the level of production, but it explains the variation of those: the growth of the product and the TFP allow to vary the work and capital according to the short and long term needs respectively. The endogeneity problem has been addressed through estimates incorporating fixed effects at the firm level, instrumental variables, or control function functions. In the latter case, the endogeneity issue is corrected by modeling it in the error term.

The concurrency problem and endogeneity bias overestimate the parameters of the Cobb-Douglas function, so at the same time, the true value of the TFP can be underestimated. This problem essentially occurs when there are unmeasured productivity shocks, which, by not being treated properly - solving the above problems – TFP estimates are sought. For example, firms increase production factors when there is a productivity shock, but this cannot be observed in the data. In return there is a bias in TFP estimates: concurrency bias.

There is also a selection bias. Firms facing negative productivity shocks can exit the market and when they are no longer observed, the selection bias occurs. The probability of exit is negatively correlated with capital stock, as large firms have sunken costs that make them withstand productivity shocks longer. As a result, the capital parameter is seated downwards and the TFP is up.

Concurrency problems can be solved by using the reversal as a proxy for shocks not observed in productivity, while the selection bias can be controlled using the survival probabilities observed in the data (Olley and Pakes, 1996). However, firms may respond to the increase in production, generated by shocks not observed in productivity, by expanding intermediate consumption (Levinsohn and Petrin, 2003). The argument of these authors is based on the fact that investment decisions are slower to respond to the productivity shock by suggesting that you econometrically obtain consistent parameters when using intermediate consumption or other more flexible inputs as a proxy. The estimates of these authors are based on a two-stage method where the proxy variable is first estimated and then incorporated into the production function (see subsection 6.3)

Another approximation suggests replacing the two-stage method with the Generalized Moments Method (GMM). This results in robust standard errors that may be being overestimated by using instrumental variables, because of the serial correlation and heteroscedasticity issues that are common in the panel data.

Once the results of the TFP ϕ_{it} where obtained, using annual firm information, data model pane was estimated to find the existing relationship with different quality measures C_{it}. The quality variable was used lagging since once the firm adopts such a process, the expected results in productivity occur in the future:

$$\phi_{it} = \delta_i + C_{i,t-n}\theta + \mu_{it} \tag{3}$$

The estimation of the coefficients by using the AMS-EDIT panel is traditionally done under different assumptions of the coefficient δ_i. The fixed-effects model allows this parameter to be correlated with the quality variable allowing for a limited form of endogeneity that is likely to exist. In return, the random-effects model assumes that the above correlation is non-existent and the parameter is orthogonal to the quality variable. While each of the above assumptions has advantages or disadvantages, the appropriate model is chosen by a Hausman test using the covariance matrices of the estimated residuals. The test indicates which of the models used produces consistent estimators, so for each estimate, the equation was verified and reported. The models also used robust and grouped errors to find standard errors without heteroscedasticity overestimation.

Looking at the relationship between TFP variables and quality in Colombia's manufacturing firms in the table 22, it is found that the variables of lagging quality and technical efficiency of firms have a positive relationship. Besides, there is a strong and positive relationship between productivity and the quality processes that firms adopt, therefore, those firms that adopt quality improvements have higher productivity, compared to firms that do not apply these improvements.

Similarly, when other quality measures are used, such as the number of certifications acquired by firms, the TFP increases by 0.037 for each of the certifications obtained and 0.039 when the likelihood of staying on the market is taken into account. Finally, when estimated by the logarithm of investment in CTI, where quality improvements are assumed when adopting technological innovation processes, the relationship was found to be strong and positive when using OP assumptions and remains positive, but at a lower level of significance, when LP assumptions are used.

5 Conclusions and Recommendations

This document discusses the relationship between quality and innovation variables with different indicators and measures of greater export capacity and increases in firm productivity. These results can be analyzed individually as the result variable changes, however, they can also be analyzed together through the characteristics of the firm.

In the first instance, on the export side, it can be seen that, although there is consensus in the literature on the different proxies of quality prices in exports, there are also a number of their quality variables that give a better approximation to the possibility of exports of the firm and that influence these prices. It is found that with an interaction of certifications and taking into account the characteristics of the firm, the prices of the products and inputs are positively affected either with the fact of having a single certification or accumulating certifications over time since, for example, obtaining ISO quality certifications are twice as high as other types of certifications. Similarly, the results show that undertaking projects that improve the quality of processes and products, just as investing in CTI, has a positive effect on both input and export prices.

It is important to note that on average for the period 2007-2018 to the larger the size of the firm, by employee number, the value of sales, and percentage sold abroad, certificates play a fundamental role in exporting to high-income countries. In this way, these certifications, quality improvements, and investments in CTI are fundamental in the export capacity of firms and their prices that are proxy variables of export indicators to high-income countries. So it becomes necessary to incentivize these actions in companies, encourage investment in CTI and generate programs or aids that allow an improvement in quality and innovation of firms that help increase the quality certification of both their products and their procedures.

Likewise, the relationship between a larger size of the firm greater number of quality certificates is obtained, being a two-way size-quality ratio, reflected in the higher export price used by larger companies, maintaining an average FOB price much higher than that of small enterprises, so it is essential to look at the size of domestic companies and make them grow. By improving the size and obtaining of certificates, it will lead to an increase in its export capacity with higher added value in its products, resulting in a greater export relationship with high-income countries and higher export revenues, thus gradually shifting the large export dependence on primary products and starting the process of exporting more higher added value manufacturing goods.

On the other hand, the effect of quality measures on productivity can be analyzed in two parts. The first corresponds to the different types of productivity measurement since each has different assumptions which can generate variations in the results. In this sense, this relationship between quality and TFP should be modeled by trying to avoid the possible endogeneity biased that this mechanism can generate, for example, the equation 3 can be estimated with different control variables and better treating underlying problems in the data panel. On the other hand, a strong relationship between TFP and quality variables was evident. In this sense, the coefficients range from 6% to 10% of a standard deviation indicating that it is a key policy variable for increasing firm productivity, especially those that have significant limitations in adopting these standards.

This in turn shows that it is essential to recognize the virtuous circle between quality, productivity, and the ability for firms to expand their markets. In turn, this mechanism may operate oppositely, i.e. firms that have limitations in adopting these quality standards have restrictions on access to certain markets, therefore limiting their ability to grow, and in turn their ability to absorb aggregate productivity shocks which leave them at risk of exiting the market. This high turnover of companies and low life cycle destroys the investment in the physical and human capital of companies and workers which makes it part of the explanation of the country's low export level.

References

Adams, M. (1999). Determinants of iso accreditation in the new zealand manufacturing sector. *Omega*, 27(2):285–292.

AFNOR (2009). The economic impact of standardization – technological change, standards and long-term growth in france.

Alessandria, G. A., Arkolakis, C., and Ruhl, K. J. (2020). Firm dynamics and trade. Technical report, National Bureau of Economic Research.

Baldwin, R. and Harrigan, J. (2011). Zeros, quiality and space: Trade theory and trade evidence. *American Economic Journal: Microeconomics*, 3(2):60–88.

Bastos, P. and Silva, J. (2010). The quality of a firm's exports: where you export to matters. *Journal of International Economics*, 82(2):99–111.

Brambilla, I., Lederman, D., and Porto, G. (2012). Exports, export destinations, quality and wages. *American Economic Review*, 102(7):3406–3438.

Brambilla, I. and Porto, G. (2016). High-income export destinations, quality and wages. *Journal of International Economics*, 98:21–35.

Carranza, J., González, A., and Serna, N. (2014). La relación entre la producción y el comercio exterior de la industria manufacturera colombiana(2000-2010). *Borradores de Economía*, (806).

Carranza, J. E., González-Ramírez, A., and Pérez, A. (2020). The quality and the destination of the colombian manufacturing exports. *The Journal of International Trade & Economic Development*, 29(3):247–271.

Castagnino, T. (2006). Estándares internacionales de calidad y desempeño exportador: Evidencia a nivel de firma. *Revista deL CEI. Comercio Exterior e Integración*, (7):93–105.

Chen, M. X., Otsuki, T., and Wilson, J. S. (2006). *Do standards matter for export success?*, volume 3809. World Bank Publications.

Clougherty, J. A. and Grajek, M. (2014). International standards and international trade: Empirical evidence from iso 9000 diffusion. *International Journal of Industrial Organization*, 36:70–82.

Cusolito, A. P. and Maloney, W. F. (2018). *Productivity revisited: Shifting paradigms in analysis and policy*. The World Bank.

DANE (2019). Boletín técnico encuesta anual manufacturera 2018.

Demir, B., Fieler, A. C., Xu, D., and Yang, K. K. (2021). O-ring production networks. Technical report, National Bureau of Economic Research.

DIN (2011). The economic benefits of standardisation: An update of the study carried out by din in 2000.

Goedhuys, M. and Sleuwaegen, L. (2016). International standards certification, institutional voids and exports from developing country firms. *International Business Review*, 25(6):1344–1355.

Görg, H., Halpern, L., and Murakozy, B. (2010). Why do within firm-product export prices differ across markets? *Kiel Institute for the World Economy*, (1596).

Hallak, J. C. (2006). Product quality and the direction of trade. *Journal of international Economics*, 68(1):238–265.

Hudson, J. and Jones, P. (2003). International trade in 'quality goods': signalling problems for developing countries. *Journal of international Development*, 15(8):999–1013.

Krishna, P., Levchenko, A. A., and Maloney, W. F. (2020). Growth and risk: A view from international trade.

Kugler, M. and Verhoogen, E. (2011). Prices, plant size, and product quality. *Review of Economic Studies*, 79:307–339.

Levinsohn, J. and Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *The review of economic studies*, 70(2):317–341.

Manova, k. and Zhang, Z. (2012). Export prices across firms and destinations. *The Quarterly Journal of Economics*, 127:379–436.

Martincus, C. V., Castresana, S., and Castagnino, T. (2010). Iso standards: A certificate to expand exports? firm-level evidence from argentina. *Review of International Economics*, 18(5):896–912.

Mollisi, V. and Rovigatti, G. (2017). Theory and Practice of TFP Estimation: the Control Function Approach Using Stata. CEIS Research Paper 399, Tor Vergata University, CEIS.

OECD (2019). *Estudios Económicos de la OCDE: Colombia 2019*.

Olley, G. S. and Pakes, A. (1996). "the dynamics of productivity in the telecommunications equipment industry." econometrica 64 (6): 1263–1297https://doi.org/10.2307/2171831.

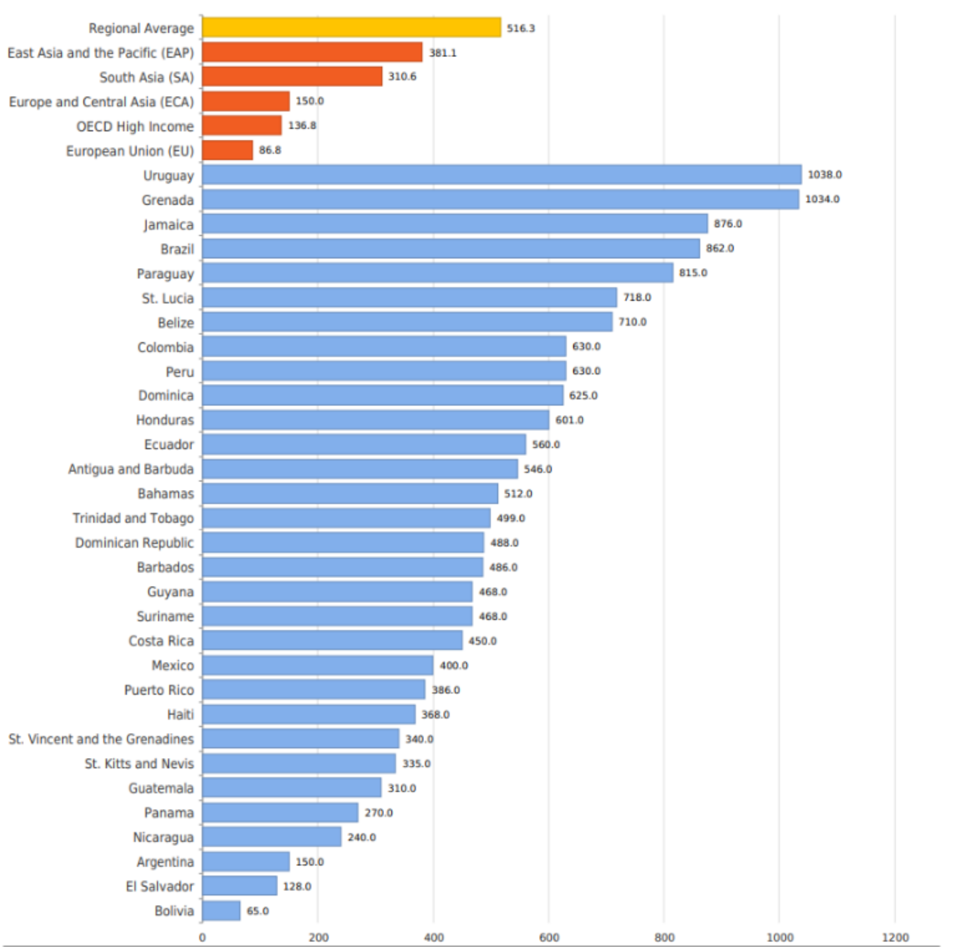
Peñaloza, H. A. B. (2016). Las certificaciones de calidad y la internacionalización de las firmas industriales colombianas. *Suma de Negocios*, 7(16):73–81.

Wooldridge, J. M. (2009). On estimating firm-level production functions using proxy variables to control for unobservables. *Economics Letters*, 104(3):112–114.

6 Annexes

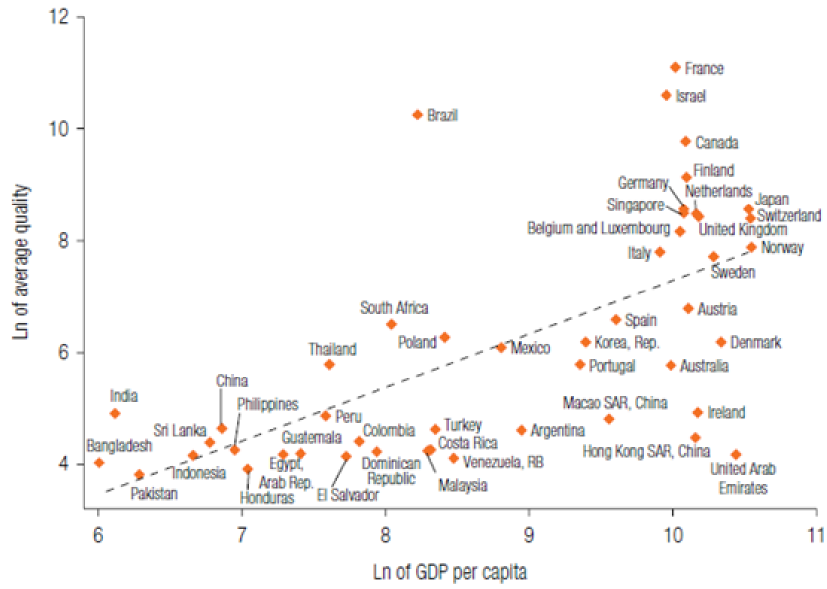
6.1 Figures

Figure 1: Export costs (USD)



Source: Doing Business database.

Figure 2: The average quality of a product increases with the level of development



6.2 Tables

Table 1: Quality certificates in the products and size of the firms per number of employees

		Number of firms			
year	**Size per employee**	Certificates	**Total**	%	FOB Dollars (mean)
2015	**Micro-enterprise**	10	6137	0,2%	$ 21.155
	Small	75	3651	2,1%	$ 17.218
	Median	109	1747	6,2%	$ 18.134
	Big	58	510	11,4%	$ 24.708
2016	**Micro-enterprise**	13	6105	0,2%	$ 16.490
	Small	66	3563	1,9%	$ 15.917
	Median	111	1724	6,4%	$ 16.794
	Big	62	523	11,9%	$ 71.526
2017	**Micro-enterprise**	2	6489	0,0%	$ 17.147
	Small	75	3634	2,1%	$ 26.152
	Median	107	1864	5,7%	$ 18.582
	Big	59	568	10,4%	$ 39.550
2018	**Micro-enterprise**	2	6620	0,0%	$ 33.680
	Small	57	3239	1,8%	$ 20.149
	Median	80	1670	4,8%	$ 22.386
	Big	53	528	10,0%	$ 64.954
2007-2018	**Micro-enterprise**	24	5661	0,5%	
	Small	124	3855	3,1%	
	Median	156	1703	9,2%	
	Big	82	511	16,1%	

Note: Relationship between the size of firms per number of employees and the average quantity of product quality certificates for companies of that size for the different years, the number of companies of that size for that year, and the average FOB value dollars of company products for each size.

Table 2: Quality certificates in products and size of firms by percentage of exports

		Number of firms			
year	**Size per exports**	**Certificates**	**Total**	**%**	**FOB Dollars (mean)**
2015	**Small**	147	5022	3%	$ 16.282
	Median	20	156	13%	$ 17.802
	Big	6	120	5%	$ 42.849
2016	**Small**	166	5057	3%	$ 28.449
	Median	20	188	11%	$ 22.774
	Big	7	127	6%	$ 58.433
2017	**Small**	168	5132	3%	$ 18.565
	Median	18	203	9%	$ 29.446
	Big	4	130	3%	$ 64.617
2018	**Small**	137	4508	3%	$ 30.663
	Median	10	183	5%	$ 20.002
	Big	5	122	4%	$ 97.356
Mean 2007-2018	**Small**	244	5194	5%	
	Median	26	201	12%	
	Big	10	127	8%	

Note: Relationship between the size of the firms by export capacity and the average number of product quality certificates for companies of that size for the different years, the number of companies of that size for that year and the average FOB dollar value of the companies' products for each size.

Table 3: Quality certificates in the products and size of the firms per sales value

		Number of firms			
year	**Size per sales value**	**Quality**	**Total**	**%**	**FOB Dollars (mean)**
2015	**Micro-enterprise**	131	9668	1%	$ 19.408
	Small	69	1816	4%	$ 15.025
	Median	52	561	9%	$ 26.395
2016	**Micro-enterprise**	111	9205	1%	$ 15.439
	Small	74	2004	4%	$ 14.240
	Median	67	706	9%	$ 73.679
2017	**Micro-enterprise**	113	9786	1%	$ 23.853
	Small	70	2030	3%	$ 13.955
	Median	60	739	8%	$ 46.019
2018	**Micro-enterprise**	90	9549	1%	$ 19.163
	Small	47	1819	3%	$ 15.869
	Median	55	689	8%	$ 78.947
Mean 2007-2018	**Micro-enterprise**	211	9360	2%	
	Small	104	1805	6%	
	Median	73	565	14%	

Note: Relationship between the size of the firms by the total value of sales and the average number of product quality certificates for companies of that size for the different years, the number of companies of that size for that year and the average of the FOB dollar value of the companies' products for each size.

Table 4: Quality certificates in the procedures and size of the firms by number of employees

		Number of firms			
year	**Size per employee**	**Quality process**	**Total**	**%**	**FOB Dollars (mean)**
2015	**Micro-enterprise**	29	6137	0%	$ 21.155
	Small	215	3651	6%	$ 17.218
	Median	321	1747	18%	$ 18.134
	Big	139	510	27%	$ 24.708
2016	**Micro-enterprise**	35	6105	1%	$ 16.490
	Small	204	3563	6%	$ 15.917
	Median	316	1724	18%	$ 16.794
	Big	148	523	28%	$ 71.526
2017	**Micro-enterprise**	21	6489	0%	$ 17.147
	Small	156	3634	4%	$ 26.152
	Median	258	1864	14%	$ 18.582
	Big	127	568	22%	$ 39.550
2018	**Micro-enterprise**	15	6620	0%	$ 33.680
	Small	138	3239	4%	$ 20.149
	Median	230	1670	14%	$ 22.386
	Big	116	528	22%	$ 64.955
Mean 2007-2018	**Micro-enterprise**	40	5661	1%	
	Small	281	3855	7%	
	Median	351	1703	21%	
	Big	168	511	33%	

Note: Relationship between the size of the firms by the number of workers and the average number of quality certificates in the procedures for companies of that size in the different years, the number of companies of that size for that year and the average of the FOB dollar value of the companies' products for each size.

Table 5: Quality certificates in procedures and size of firms by percentage of exports

		Number of firms			
Year	**Size by exports**	**Quality process**	**Total**	**%**	**FOB Dollars (mean)**
2015	**Small**	418	5022	8%	$ 16.282
	Median	32	156	21%	$ 17.802
	Big	18	120	15%	$ 42.849
2016	**Small**	478	5057	9%	$ 28.449
	Median	37	188	20%	$ 22.774
	Big	17	127	13%	$ 58.433
2017	**Small**	361	5132	7%	$ 18.565
	Median	32	203	16%	$ 29.446
	Big	13	130	10%	$ 64.617
2018	**Small**	315	4508	7%	$ 30.663
	Median	28	183	15%	$ 20.002
	Big	14	122	11%	$ 97.356
Mean 2007-2018	**Small**	528	5195	10%	
	Median	49	251	21%	
	Big	21	127	17%	

Note: Relationship between the size of the firms by export capacity and the average number of quality certificates in the procedures for companies of that size in the different years, the number of companies of that size for that year and the average FOB value dollars of company products for each size.

Table 6: Quality certificates in the procedures and size of the firms by sales value

		Number of firms			
Year	**Size per sales value**	**Quality Procedure**	**Total**	**%**	**FOB Dollars (mean)**
2015	**Micro-enterprise**	394	9668	4%	$ 19.408
	Small	172	1816	9%	$ 15.025
	Median	138	561	25%	$ 26.395
2016	**Micro-enterprise**	344	9205	4%	$ 15.439
	Small	196	2004	10%	$ 14.240
	Median	163	706	23%	$ 73.679
2017	**Micro-enterprise**	271	9786	3%	$ 23.853
	Small	156	2030	8%	$ 13.955
	Median	135	739	18%	$ 46.019
2018	**Micro-enterprise**	251	9549	3%	$ 19.163
	Small	120	1819	7%	$ 15.869
	Median	128	689	19%	$ 78.947
Mean 2007-2018	**Micro-enterprise**	463	9360	5%	
	Small	223	1805	13%	
	Median	154	565	29%	

Note: Relationship between the size of the firms by the total value in sales and the average number of quality certificates in the procedures for companies of that size in the different years, the number of companies of that size for that year and the average of the FOB dollar value of the companies' products for each size.

Table 7: Descriptive statistics TFP

TFP		(1)	(2)	(3)	(4)	(5)
Mean	Global	4.23	4.48	2.44	2.41	2.32
	Between firms					
	In the time					
Standard deviation	Global	0.39	0.42	0.24	0.24	0.87
	Between firms	0.33	0.36	0.21	0.21	0.84
	In the time	0.13	0.13	0.10	0.10	0.48
Min	Global	3.51	3.74	1.65	1.65	-6.68
	Between firms	3.55	3.76	1.80	1.79	-3.92
	In the time	3.15	3.32	1.68	1.67	-3.52
Max	Global	6.84	7.24	3.95	3.94	6.01
	Between firms	6.61	7.01	3.67	3.66	6.01
	In the time	5.21	5.39	3.53	3.52	6.78
Observations		9,802	9,802	9,380	9,380	11,689

Note: Column 1 shows the results with the Olley-Pakes (OP) estimation method, the second column is the Olley-Pakes Attrition (OPA) estimation. In the third column is the estimate by Levinsohn-Petrin (LP) and in the fourth column the estimate by Levinsohn-Petrin attrition (LPA). In the last column is the Wooldridge GMM methodology

Table 8: Foreign sales and quality

Dependent variable: Export value	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Promarch	0.003**	0.003	0.003**									
	(0.001)	(0.002)	(0.001)									
Obtcetcalproce				0.005**	0.007**	0.005**						
				(0.001)	(0.002)	(0.001)						
Numcalproce							0.009**	0.006**	0.006**			
							(0.001)	(0.002)	(0.001)			
Numcalproduct										0.003***	0.002	0.002
										(0.002)	(0.003)	(0.002)
Control variables	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes	-
Control variables 2	-	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	58,743	27,399	58,743	58,743	27,399	58,743	98,084	43,938	98,084	98,084	43,938	98,084
R-squared	0.005	0.06	0.05	0.009	0.06	0.05	0.007	0.06	0.03	0.002	0.06	0.03

Note: Robustness test between parentheses ** and *** denote a significance level at 5% and 10%, respectively. The dependent variable is the percentage of production sold abroad. Promarch is a dummy variable that takes the value of 1 if the firm has a project to obtain new or significantly improved goods or services or improvement in the production process, 0 otherwise. Obcetcalproduc is a dummy variable that takes the value of 1 if the firm had product quality certifications, 0 otherwise. Also included is Numcalproce, which is the logarithm of the number of quality certificates in the firm's processes, and Numcalproduct, which is the logarithm of the number of quality certificates of the products. All the dependent variables (not including the control variables) have a one-year lag. The control variables are the number of permanent employees, total value of sales as the firm's income variable, intermediate consumption, and TFP. In the second control variables, we exclude the number of employees and TFP to avoid possible problems of collinearity. The models are selected by the Hausman test, between fixed effects (FE) or random effects (RE), placing yes if that model is chosen or - in the other case.

Table 9: Differences: Sales abroad and quality

Dependent variable: ΔExport value	(1)	(2)	(3)	(4)	(5)
ΔNumcalproce	0.008**	0.01**	0.01**	0.008**	0.008**
	(0.05)	(0.003)	(0.003)	(0.002)	(0.002)
Control variables in level	-	Yes	-	-	-
Control variables in differences	-	-	Yes	-	-
Control variables 2 in level	-	-	-	Yes	-
Control variables 2 in differences	-	-	-	-	Yes
FE	-	Yes	-	Yes	-
Observations	66,407	30,314	24,988	66,407	66,407
R-square	0	0.002	0.01	0.001	0.009

Note: Robustness test between parentheses ** and *** denote a significance level at 5% and 10%, respectively. The dependent variable ΔExport value is the value of exports in differences. ΔNumcalproce is the logarithm of the number of quality certificates in the processes of the signatures in difference. All the dependent variables (not including the control variables) have a lag of one year. The control variables both in level and in The difference is the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption and PFT. For the second control variables, both in level and in difference, the number of employees and PFT were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE), so yes if that model is chosen or - in the other case.

Table 10: Average salary and quality

Dependent variable: SM	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mejcal	0.02**	0.006	0.02**									
	(0.01)	(0.01)	(0.01)									
Numcalproce				0.15**	0.09**	0.08**						
				(0.02)	(0.01)	(0.02)						
Numcalproduct							0.07**	0.03***	0.03			
							(0.02)	(0.02)	(0.02)			
CTI										0.008**	0.004**	0.006**
										(0.001)	(0.001)	(0.001)
Control variables	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes	-
Control variables 2	-	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes
FE	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,966	12,537	19,966	108,264	51,584	108,264	108,264	51,584	108,264	30,597	17,318	30,597
R-square	0	0.09	0.1	0.01	0.1	0.1	0.004	0.1	0.1	0.04	0.1	0.1

Note: Robustness test between parentheses ** and *** denote a significance level at 5% and 10%, respectively. The dependent variable is the average salary. Mejcal is a variable that qualifies the impact that an improvement has had on the quality of goods and services, evaluating the effect as null, medium or high. Numcalproce is the logarithm of the number of quality certificates in the firm's processes. Numcalproduct is the logarithm of the number of quality certificates in the product. CTI, which is the amount invested. These variables are lagged by one year. The control variables both in level and in difference are the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption and TFP. For the second control variables, the number of employees and TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE) , so it is placed yes in the case that this model is chosen or - in the other case.

Table 11: Differences: Average salary and quality

Dependent variable: ΔSM	(1)	(2)	(3)	(4)	(5)
ΔCTI	0.002	0.003	0.004***	0.002	0.003
	(0.001)	0.002	(0.002)	(0.001)	0.002
Control variables in level	-	Yes	-	-	-
Control variables in differences	-	-	Yes	-	-
Control variables 2 in level	-	-	-	Yes	-
Control variables 2 in differences	-	-	-	-	Yes
FE	-	Yes	Yes	-	Yes
Observations	19,946	11,678	10,024	19,946	19,946
R-square	0	0	0.001	0	0.001

Note: Robustness test between parentheses ** and *** denote a significance level at 5% and 10%, respectively. The dependent variable δSM is the mean salary in differences. ΔCTI is logarithm of the invested amount. The control variables both in level and in difference are the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption and TFP. For the second control variables, both in level and in difference, the number of employees and TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE), so yes if that model is chosen or - in the other case.

Table 12: Technical salary and quality

Dependent variable: ST	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Promarch	0.1**	0.07	0.09***									
	(0.05)	(0.05)	(0.05)									
Redcostlab				0.11**	0.06***	0.08**						
				(0.03)	(0.03)	(0.03)						
Redcostmat							0.07**	0.03	0.04			
							(0.03)	(0.03)	(0.03)			
Obtcetcalproce										0.07	0.09***	0.06
										(0.05)	(0.05)	(0.05)
Control variables	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes	-
Variable de control 2	-	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes
FE	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,549	9,581	11,549	5,080	4,351	5,080	5,080	4,351	5,080	11,549	9,581	11,549
R-square	0.02	0.44	0.26	0	0.43	0.26	0.001	0.43	0.27	0.03	0.44	0.26

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable is the average salary of technicians. Promarch is a dummy variable that takes the value of 1 if the firm has a project to obtain new or significantly improved goods or services or improvement in the production process, 0 otherwise. Redcostlab is a variable that qualifies the impact that a reduction in labor costs has had, taking the values of null, medium or high. Redcostmat is the variable that qualifies the impact that the reduction in material costs has had, taking the values of null, medium or high. Obcetcalproce is a dummy variable that takes the value of 1 if the company has obtained at least one quality certificate for its procedures. The variables are lagged by one year. The control variables both in level and in difference are the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption and TFP. For the second control variables, the number of employees and TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE) , so it is placed yes in the case that this model is chosen or - in the other case.

Table 13: Differences: Technical salary and quality

Dependent variable: ΔST	(1)	(2)	(3)	(4)	(5)
ΔRedcostlab	0.07***	0.06	0.04	0.07***	0.07***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Control variables in level	-	Yes	-	-	-
Control variables in differences	-	-	Yes	-	-
Control variables 2 in level	-	-	-	Yes	-
Control variables 2 in differences	-	-	-	-	Yes
FE	-	Yes	Yes	-	-
Observations	3,063	2,564	2,236	3,063	3,063
R-square	0	0.02	0.28	0	0.005

Note:Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable ΔST is the average salary of technicians in difference. ΔRedcostlab is the one variable that measures the impact on labor cost reduction handled in differences. The control variables both in level and in difference are the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption and TFP. For the second control variables, both in level and in difference, the number of employees and TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE), so yes if that model is chosen or - in the other case.

Table 14: Workers salary and quality

Dependent variable: SO	(1)	(2)	(3)
Numcalproce	-0.02	0.05**	0.03
	(0.03)	(0.02)	(0.03)
Control variables	-	Yes	-
Variable de control 2			Yes
FE	Yes	Yes	Yes
Observations	36,522	17,583	36,522
R-square	0.02	0.62	0.28

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable is the average salary of workers. Numcalproce is the logarithm of the number of quality certificates of the firm's processes. These variables are lagged by one year. The control variables are the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption, and TFP. For the second control variables, the number of employees and TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE) , so it is placed yes in the case that this model is chosen or - in the other case.

Table 15: Administrative salary and quality

Dependent variable: SA	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Aumproduc	-0.009	0.04**	-0.003									
	(0.01)	(0.01)	(0.01)									
Redcostlab				0.7**	0.02**	0.06**						
				(0.01)	(0.01)	(0.01)						
Redcostmat							0.04**	0.02**	0.03**			
							(0.01)	(0.01)	(0.01)			
CTI										-0.005**	0.008**	-0.002
										(0.002)	(0.002)	(0.002)
Control variables	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes	-
Variable de control 2	-	-	Yes	-	-	Yes	-	-	Yes	-	-	Yes
FE	-	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,659	12,668	19,659	19,659	12,668	19,659	19,659	12,668	19,659	29,135	17,252	29,135
R-square	0	0.49	0.30	0	0.49	0.30	0	0.49	0.30	0.09	0.49	0.31

Note: Robustness test in parentheses *, ** and *** denote a significance level at 1 %, 5 % and 10 %, respectively. The dependent variable is the. The dependent variable is the mean administrative salary. Aumproduct is a variable that qualifies the impact that the increase in productivity had on the company, valuing it as null, medium or high. Redcostlab is a variable that qualifies the impact that a reduction in labor costs has had, taking the values of null, medium or high. Redcostmat, like redcostlab, qualifies the impact on reducing the consumption of raw materials, evaluating it as null, medium or high. The variables are lagged by one year. The control variables both in level and in difference are the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption and TFP. For the second control variables, the number of employees and TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE) , so it is placed yes in the case that this model is chosen or - in the other case.

Table 16: Differences: Administrative salary and quality

Dependent variable: ΔSA	(1)	(2)	(3)	(4)	(5)
ΔAumproduc	0.04***	0.02	0.02	0.04***	0.04***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Control variables in level	-	Yes	-	-	-
Control variables in differences	-	-	Yes	-	-
Control variables 2 in level	-	-	-	Yes	-
Control variables 2 in differences	-	-	-	-	Yes
FE	-	Yes	Yes	-	-
Observations	12,830	8,351	7,325	12,830	12,830
R-square	0	0.01	0.17	0.001	0.004

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable ΔSA is the mean administrative salary in differences. ΔAumproduct is in difference the variable that qualifies the impact that the increase in productivity had on the company, valuing it as null, medium or high. These variables are lagged by one year. The control variables both in level and in difference are the number of permanent employees, total value of sales as a variable of the firm's income, intermediate consumption and TFP. For the second control variables, both in level and in difference, the number of employees and TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE), so yes if that model is chosen or - in the other case.

Table 17: Ratio of raw materials from abroad to intermediate consumption and quality

Dependent variable: lncv	(1)	(2)	(3)	(4)	(5)	(6)
Numcalproce	0.001**	0.001	0.001**			
	(0.0005)	(0.0008)	(0.0006)			
Numcalproduct				0.0007	0.001***	0.0004
				(0.0007)	(0.001)	(0.0007)
Control variables	-	Yes	-	-	Yes	-
Control variables 2	-	-	Yes	-	-	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	117,037	43,755	92,747	117,037	43,755	92,747
R-square	0.001	0.02	0.005	0.0003	0.02	0.005

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable lncv is the difference in the ratio between intermediate consumption and raw materials purchased abroad from one year to another. The dependent variable lncv is the logarithm of the ratio between the value of raw materials purchased abroad and intermediate consumption. Numcalproce is the logarithm of the number of quality certificates of the firm's processes. Numcalproduct is the logarithm of the number of quality certificates for the firm's product. These variables are lagged by one year. The control variables are the number of permanent employees, the value of raw materials, the value of assets, the value of total sales, the percentage of foreign sales and the TFP. For the second control variables, both in level and in difference, the value of raw materials, the value of total sales and the TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, the which one chooses between fixed effects (FE) or random effects (RE), so yes is placed in the case that that model is chosen or - in the other case.

Table 18: Ratio Raw materials from abroad-Raw materials and quality

Dependent variable: lnvv	(1)	(2)	(3)	(4)	(5)	(6)
Numcalproce	0.01**	0.01**	0.01**			
	(0.001)	(0.003)	(0.002)			
Numcalproduct				0.01**	0.01**	0.01**
				(0.002)	(0.003)	(0.002)
Control variables	-	Yes	-	-	Yes	-
Control variables 2	-	-	Yes	-	-	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	91,191	36,243	75,298	91,191	36,243	75,298
R-square	0.009	0.05	0.04	0.004	0.05	0.04

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable lnvv is the logarithm of the ratio between the value of the raw materials bought abroad and the value of the raw materials bought. Numcalproce is the logarithm of the amount of quality certificates of the firm's processes. Numcalproduct is the logarithm of the number of the company's product quality certificates. These variables are lagged by one year. The control variables are the number of permanent employees, the value of raw materials, the value of assets, the value of total sales, the percentage of foreign sales and the TFP. For the second control variables, both in level and in difference, the value of raw materials, the value of total sales and the TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, the which one chooses between fixed effects (FE) or random effects (RE), so yes is placed in the case that that model is chosen or - in the other case.

Table 19: Differences: Ratio Raw materials from abroad-Raw materials and quality

Dependent variable: ΔInvv	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ΔNumcalproce	0.007**	0.007	0.005	0.008**	0.005					
	(0.002)	(0.005)	(0.006)	(0.003)	(0.003)					
ΔNumcalproduct						0.009**	0.01**	0.01**	0.01**	0.009**
						(0.003)	(0.005)	(0.007)	(0.003)	(0.003)
Control variables in level	-	Yes	-	-	-	-	Yes	-	-	-
Variables de control en diferencia	-	-	Yes	-	-	-	-	Yes	-	-
Control variables 2 in level	-	-	-	Yes	-	-	-	-	Yes	-
Variables de control 2 en diferencia	-	-	-	-	Yes	-	-	-	-	Yes
FE	-	Yes	Yes	-	-	-	Yes	Yes	-	-
Observations	61,716	24,768	18,427	50,552	44,293	61,716	24,768	18,427	50,552	44,293
R-square	0	0.008	0.02	0	0	0	0.008	0.02	0	0

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable *Delta* lnvv is the difference in the ratio between the raw materials purchased and the raw materials purchased abroad from one year to the next. *Delta* Numcalproce is the variable in differences of the logarithm of the number of quality certificates of the processes that the signature has. *delta* Numcalproduct is the logarithm of the number of certificates for the difference signing product. These variables are lagged by one year. The control variables both in level and in difference are the number of permanent employees, the value of raw materials, the value of assets, the value of total sales, the percentage of sales abroad and TFP. For the second control variables, both in level and in difference, the value of raw materials, the value of total sales and the TFP were eliminated to avoid possible collinearity problems.The selected model is chosen through the Hausman test, the which one chooses between fixed effects (FE) or random effects (RE), so yes is placed in the case that that model is chosen or - in the other case.

Table 20: Prices FOB Dollars and quality

Dependent variable: Fodx	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Redcostmat	0.13**	0.20**						
	(0.05)	(0.06)						
Obtcetcalproduc			0.20**	0.01				
			(0.08)	(0.13)				
Numcalproduct					0.39**	0.06		
					(0.18)	(0.33)		
CTI							0.01***	0.002
							(0.009)	(0.01)
Control variables	-	Yes	-	Yes	-	Yes	-	Yes
FE	-	-	-	Yes	-	-	-	-
Observations	2,942	1,698	8,588	5,385	733	343	3,344	1,963
R-square	0.003	0.04	0.001	0	0.007	0.05	0.001	0.03

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable Fodx is FOB prices in dollars. Redcostmat. Obtcetcalproduc.Numcalproduct is the logarithm of the number of certificates for the signature product. CTI is the logarithm of the amount invested in innovation activities and improvement of human capital. These variables are lagged by one year. The control variables are the number of permanent employees, the total sales value, the percentage of foreign sales and intermediate consumption. The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE), so yes is placed in the case that this model is chosen or - in the other case.

Table 21: FOB prices, weights and quality

Dependent variable: Fopx	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Redcostmat	0.13**	0.20**						
	(0.05)	(0.06)						
Obtcetcalproduc			0.20**	0.02				
			(0.08)	(0.14)				
Numcalproduct					0.39**	0.04		
					(0.18)	(0.34)		
CTI							0.01***	0.003
							(0.009)	(0.01)
Control variables	-	Yes	-	Yes	-	Yes	-	Yes
FE	-	-	-	Yes	-	-	-	-
Observations	2,942	1,698	8,588	5,385	733	343	3,344	1,963
R-square	0.003	0.04	0.001	0	0.007	0.05	0.001	0.03

Note: Robustness test between parentheses ** and *** denote a significance level at 5 % and 10 %, respectively. The dependent variable Fopx is FOB prices in pesos. Numcalproduct is the logarithm of the number of certificates for the firm's product. These variables are lagged by one year. The control variables are the number of permanent employees, the total sales value, the percentage of foreign sales and intermediate consumption. The selected model is chosen through the Hausman test, which chooses between fixed effects (FE) or random effects (RE), so yes is placed in the case that this model is chosen or - in the other case.

Table 22

Variable dependiente: TFP	Olley-Pakes	Olley-Pakes Attrition	Levinsonhn-Petrin	Levinsonhn-Petrin Attrition	Wooldridge GMM	FE
Quality improvements	0.0113** (1.95)	0.0127** (2.11)	0.0146*** (3.12)	0.0145*** (3.11)	0.0224 (1.16)	
Improvement processes underway					0.0376* (1.75)	
Obtaining certification					0.0659*** (2.90)	
Number of certifications	0.0370* (1.68)	0.0391* (1.73)				Yes
Ln(Investment in CTI)	0.0038*** (4.44)	0.0040*** (4.56)	0.0011* (1.67)	0.0011* (1.66)		Yes

Estadístico t entre paréntesis.FE: Efectos Fijos; RE: Efectos Aleatorios.Fuente: Dane, AMS, EDIT. Cálculos propios

6.3 TFP estimation using control variables

From now on, the notation presented by Mollisi and Rovigatti (2017), who developed a Stata module will be used to estimate the parameters of the production function using panel data. The authors present different ways to estimate the added value and for the company i at the time t:

$$y_{it} = \alpha + W_{it}\beta + X_{it}\gamma + \omega_{it} + \epsilon_{it} \tag{4}$$

In the above equation, W contains the free variables represented by the job, X the state variables represented by the capital stock, ω is the unobserved productivity, and ϵ is the error term distributed as white noise Mollisi and Rovigatti (2017). Following Olley and Pakes,1996, (OP) expected productivity is a function of productivity and state variables

$$E[\omega_{i,t+1}|\omega_i, X_{it}] \tag{5}$$

The method of these authors is based on the idea that investment decisions depend on productivity and state variables:

$$I_{it} = I(\omega_{it}, X_{it}) \tag{6}$$

The reverse function is used by OP as a productivity proxy:

$$\omega_{it} = I^{-1}(I_{it}, X_{it}) = h(I_{it}, X_{it}) \tag{7}$$

Replacing 7 in 4 we get:

$$y_{it} = \alpha + W_{it}\beta + \phi_{it} + \epsilon_{it} \tag{8}$$

Where $\phi_{it} = X_{it}\gamma + h(I_{it}, X_{it})$ is estimated in a first stage using n order polynomial in I_{it} , X_{it}, and its interactions. The reversal function (ecuación 6) can also include the probability of survival of the firm. Using the conditional hope of the equation (5) and reordering the terms of the equation (8) you get:

$$y_{it} - W_{it}\beta = \alpha + (X_{it} - X_{i,t-1})\gamma + \phi_{it} + e_{it} \tag{9}$$

The function $\phi(.)$, controls unobserved productivity so that consistent parameters are obtained for free variables and state variables because they are not correlated with the error term. However, the selection bias remains dormant. OP proposes to add a term to the equation (9) that allows control by the probability of survival of the firms. If χ_{it} is the probability of staying in the market, then

$$\hat{P}r_{i,t+1} = P(\chi_{i,t+1} = 1|\chi_{it}) \tag{10}$$

The equation is estimated by a logit model with a polynomial based on state and reversal variables. The equation (9) can be transformed to eliminate the selection bias by using the equation (10):

$$y_{it} - W_{it}\beta = \alpha + X_{it}\gamma + g(\phi_{i,t-1} - X_{i,t-1}\gamma, \hat{P}r_{i,t+1}) + e_{it} \tag{11}$$

Therefore, the OP model can be estimated in two stages using the equation (9) (when the probability of survival is not included) or the equation (11) is included.

Since firms make inter-temporal investment decisions, in some years no data are observed to make robust estimates: "Investments are not decided at all times, but are postponed for a few years before all at once" Mollisi and Rovigatti (2017). This can result in the overestimation of the TFP. LP introduces an estimator where intermediate consumption is used as a proxy for productivity shocks because its behavior is smoother and more observable when compared to investment.

Behind this, firms, looking to maximize their usefulness, are supposed to expand intermediate consumption in order to increase production. The LP estimation strategy changes the investment (of the model proposed by OP), to intermediate consumption to obtain unbiased estimates of firm productivity, which solves the concurrency problem explained at the beginning of this section.

In order to use intermediate consumption m_{it} without violating model assumptions, it's necessary that $E[m_{it}, X_{it}] = 0$, which means that unobserved productivity equals:

$$\omega_{it} = h(m_{it}, X_{it}) \tag{12}$$

By replacing (12) ien (4) we get:

$$y_{it} = \alpha + W_{it}\beta + \phi_{it} + \epsilon_{it} \tag{13}$$

Where $\phi_{it} = X_{it}\gamma + h(m_{it}, X_{it})$ is estimated in a first stage by using n order polynomial in n en m_{it}, X_{it},or by a local linear regression. In order to identify the LP parameters, estimate the equation (13) using a lag of intermediate consumption to avoid the correlation of the contemporary variable with the error and by solving the problem of minimizing errors using GMM[12].

OP and LP assume that the firms can adjust their productive capacity in the face of productivity shocks, in the first case through adjustments to investment and in the second case through increased intermediate consumption, without resulting in costs of adjustments at work. If in the first stage of estimation the data have a variability independent of productivity proxies it is possible to find consistent parameters. "If this is not the case, its coefficients would be perfectly colinear in the estimation of the first stage and therefore would not be identifiable." Mollisi and Rovigatti (2017).

In order to avoid this problem in the data of some firms, Wooldridge (2009) proposes to replace the two-stage method with the GMM estimator. In this case, ϕ will be estimated with the laggards of the state variables and intermediate consumption. In this way, we have a wide range of estimates whose efficiency we cannot know a priori.

To start the production function and the productivity level of the firm can be estimated using i) OP; (ii)OP controlling by selection bias; (iii)LP; (iv)LP controlling by selection bias; v) Wooldridge. These five procedures were used in the study without finding large differences in firm productivity values overtime when the last three models mentioned were used.

With this information, we moved on to the next phase of the study where the different TFP measurements (from AMS) were taken and relationships with quality variables (based on EDIT information) were estimated. The next chapter presents the main results.

[12]to facilitate the reading of the document we have not brought all the equations presented in the fore mentioned literature.