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Imported Intermediates, Technological Capabilities and Exports: Evidence from Brazilian Firm-Level Data

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Abstract

This paper explores how technological capabilities influence the relationship between imported inputs and the export performance of firms. We apply threshold regression techniques to a representative dataset of Brazilian firms and find a strong positive influence of innovation skills on the relationship between imported intermediates and export revenues. We further find that the complementarities between importing and exporting are stronger for firms that export products with a higher scope for quality differentiation. We also observe that technological capabilities are directly correlated with export performance, confirming the view that innovation positively influences firms' international competitiveness. This relationship is not found to be significant for firms that export products with a low scope for quality differentiation and that export to lower income non-OECD markets. Overall, our results suggest that technological capabilities and the quality of imported inputs not only benefit firms directly but also complement each other in enhancing export competitiveness.

Keywords: imports; exports; productivity; innovation; technological capabilities
JEL Codes: F14, O30

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1. Introduction

A large theoretical and empirical literature has emerged addressing how access to imported inputs affects the performance of domestic firms. Initial studies demonstrated that imports not only increased competitive pressure on local markets, forcing firms to become more efficient, but could also influence their performance by expanding the availability of foreign intermediates (Amiti & Konings, 2007; Kasahara & Rodrigue, 2008; Topalova & Khandelwal, 2011). The literature that followed quickly indicated that the channels that mediate the effect of imported inputs on firms' performance relate not only to reductions in the cost of inputs, but also to the superior embodied technology, quality and variety of many imported intermediates (Bas & Strauss-Kahn, 2014; Bas & Strauss-Kahn, 2015; Halpern et al, 2015; Kasahara & Lapham, 2013, Goldberg et al, 2010).

The international trade literature suggests that if access to imported intermediates increases firms' performance it will also positively impact their exports. More productive firms 'self-select' into exporting, as they are the ones able to afford the relatively higher fixed-costs of entering foreign markets (Clerides, Lach, & Tybout, 1998; Melitz, 2003; Wagner, 2007). However, evidence also indicates that imported intermediates facilitate firms' efforts to upgrade their product portfolios and meet the requirements of foreign buyers, thus increasing demand in foreign markets and boosting the intensive and extensive margins of exports. Empirical studies have shown that there is strong connection between imports and both the variety and quality of exports – usually proxied by their prices or origin/destination – at the firm level. (Bas & Strauss-kahn, 2015; Bas & Strauss-Kahn, 2014; Fan, Li, & Yeaple, 2015; Feng, Li, & Swenson, 2016a; Kugler & Verhoogen, 2009, 2012; Manova & Zhang, 2012; Wagner, 2016).

In this context, we focus this paper on the role of firms' technological capabilities and their influence on the relationship between imported inputs and the export performance of firms.

We test how firm capabilities condition the correlation between imported inputs and export performance applying threshold regression techniques to the most representative available dataset of Brazilian firms. The main results are as follows: first, we observe that more capable firms benefit more in terms of export performance from imported intermediates originating in OECD countries – to which we attribute a higher quality; second, the type of exported product conditions complementarities between input quality and firm capability, with the export of customized products – which offer greater scope for differentiation – significantly intensifying these complementarities; third, we find an indication that lower quality imports are relevant for access to new markets at all levels of firm capability; finally, we observe that technological capabilities are directly correlated with export performance, but this relationship is significantly stronger for products with a higher scope for quality differentiation. Overall, our results indicate the existence of complementarities between imported inputs and firms' technological capabilities, with these complementarities driven by the import of higher quality intermediates.

We orient our empirical analysis by first revisiting the Kugler & Verhoogen (2012) model that studies the role of firm heterogeneity in explaining the relationship between the quality of imports and exports. As with other related works in the international trade literature (Bastos, Silva, & Verhoogen, 2018; Demir, 2013; Hallak & Sivadasan, 2013; Johnson, 2011; Manova & Yu, 2017), this model develops a framework in which high-capability firms have a comparative advantage in producing high-quality goods. Moreover, firms depend on complementarities between internal capabilities and the quality of their inputs to increase the quality of their own final products. This description of the quality production process summarizes the most important aspect of our empirical results, i.e. that firms' export performance depends on innovation-related factors, which in turn depend on their internal technological capabilities and external technology obtained through imported inputs.

In the model, consumers obtain utility not only from the quantity but also from the quality of the products they consume. Firms decide both prices and the quality level of the varieties they offer. However, higher quality inputs are more expensive and increase the price of final products, creating a trade-off for producers: in order to upgrade quality it is necessary to increase production costs, which might translate into more expensive final products. In equilibrium, more capable firms export more, use higher quality inputs and produce higher quality goods, with this relationship becoming stronger in markets with a higher scope for quality differentiation.

We concentrate on firms' export revenues as a measure of export performance but also look at the number of country-product pairs exported. These approaches connect our empirical framework also to studies that investigate the effect of imported intermediates on firms' overall performance and variety in exports. Goldberg et al (2010) provide evidence that a wider variety of imported intermediates had a sizable effect on the scope of products supplied by Indian firms in the internal market. Several studies find compatible evidence also for external markets, demonstrating a significant impact of input tariff reductions on the use of imported intermediates and their impact on firms' overall export performance (Aristei et al, 2013; Bas, 2012; Edwards et al, 2018), as well as the connection between input variety and the number of export destinations and product varieties (Bas & Strauss-Kahn, 2014; Manova & Zhang, 2012; Wagner, 2016). These results are related to the existence of imperfect substitution between inputs, which – in the presence of increased access to imported intermediates and input diversity – result in a more efficient use of production factors.

Our analysis is also connected to the literature that focuses on innovation and "technology gaps". The relationship between imports and innovation has long been recognized in this literatures in the context of capital goods (Abramovitz, 1989; Gerschenkron, 1962) and more in the context of imported intermediates (Castellani & Fassio, 2019), the latter of which shows the positive effect of new imported products for firms that start exporting a new product variety for the first time. Our study complements this work by demonstrating that the effect of imports is conditioned by the presence of innovation capabilities within the firm. This is in line with the notion that imported intermediates have a strong impact on firms' technological choices, therefore suggesting that the extent to which firms will benefit from the higher quality/technology of foreign intermediates – or simply from the increased variety of inputs – in terms of innovation must also depend on their capacity to properly understand and manage technology. In that context, many authors have previously emphasized the importance of technological capabilities, i.e. the skills, knowledge and institutional structures necessary for firms to manage technology and develop technological change (Bell & Pavitt, 1993; Lall, 1992; Morrison et al, 2008); and the dual role of R&D and human capital for both generating and absorbing external sources of knowledge (Aw et al, 2007; Cohen & Levinthal, 1989).

Finally, our work is also connected to studies on the relationship between innovation and export competitiveness. Flach (2016) directly associates quality improvements in firms' exports to product innovations, while other studies have shown that technology influences exports through channels that consistently remain important even after controlling for self-selection based on productivity. This is usually the case for R&D investments (Aw et al, 2007; Barrios et al, 2003; Caldera, 2010) and for innovation outputs, such as process and product innovations (Becker & Egger, 2013; Caldera, 2010; Cassiman et al, 2010; Damijan & Kostevc, 2015; Dosi et al, 2015). Since the introduction of new products will likely be preceded by investments in the accumulation technological capabilities, the latter should also have a direct effect on firms' export performance. We recognize this possibility in the empirical analysis by allowing technological capabilities to directly impact upon exports.

Unlike most work exploring the role of quality in exports and imports (Bas & Strauss-kahn, 2015; Fan et al., 2015; Kugler & Verhoogen, 2012; Manova & Yu, 2017), our analysis does not assume that firm capability is completely unobserved. We take advantage of having access to Brazilian labour market administrative data registering the functions performed by employees to construct a direct proxy for the presence and intensity of technological capabilities. This variable captures the presence of advanced internal capabilities related to innovation and the management of technological change (Lall, 1992), and allows us to create a simple framework capable of testing both the direct effect of capabilities on firms' export performance and the indirect effect related to complementarities between capabilities and inputs.

We contribute to the literature in three main ways. First, to the best of our knowledge this is the first framework providing evidence of complementarities between the quality of imported inputs and firms' technological capabilities by using direct proxies for both variables. Second, we revisit the relationship between technological capabilities and export performance and qualify previous results by highlighting the influence of exported product types in this relationship. Third, we complement recent evidence (Castellani & Fassio, 2019) on the differential effects of imported intermediates and imported capital goods, demonstrating how capabilities increase the importance of the former more intensively. Our results demonstrate that the benefits of trade tend to be asymmetrical and much more intense for a minority of more capable firms that can take full advantage from accessing high quality inputs.

The remainder of this paper is organized as follows. In Section 2, we develop the theoretical framework that orients our empirical analysis based on a version of the main model of this literature. In Section 3, we explain our empirical methodology, whereas data sources and the construction of variables are presented in Section 4. In section 5 we present our empirical results, while conclusions and areas for future research are discussed in Section 6.

2. Theoretical Framework

2.1. The Model Set-Up

We illustrate our main propositions by relying on the model of Kugler & Verhoogen (2012) and the more recent version developed in Bastos et al (2018), which we slightly alter to maintain the original monopolistic competition environment. We inherit all simplifying assumptions of this model, including the "partial-equilibrium" set-up in which firms' decision to enter each market is assumed as given. There are K countries and each firm supplies a single product in each market but with different quality levels. There is a separate production line for each market, which allows firms to choose the quality level of intermediates according to the chosen level of product quality. We index each product and country with subscripts i and k, respectively. Since each firm produces a single product, firms can also be indexed with subscript i, whereas product lines or product-quality pairs are identified by subscripts ik.

Consumer willingness to consume quality is strictly positive but differs by country. A common assumption of the literature is that consumers in wealthier countries are more willing to pay for quality than in poorer nations. The representative consumer maximizes a standard CES utility function augmented by quality and a parameter $d_k > 0$ determining consumers' willingness to pay for quality in each country k:

$$\mathrm{U}_k = \left(\int_{i \epsilon \Omega} \left(q_{ik}^{d_k} x_{ik} \right)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \quad (1)$$

where x_{ik} and q_{ik} represent respectively the quantity demanded and the quality of product variety produced by firm i for country k, and $\sigma > 1$ is the elasticity of substitution between varieties. The maximization problem results in a demand function for product-quality pair ik of the following form:

$$x_{ik}[Y_k, P_k, q_{ik}, po_{ik}] = \frac{Y_k}{P_k} \left(q_{ik}^{d_k}\right)^{\sigma-1} \left(\frac{po_{ik}}{P_k}\right)^{-\sigma} \quad (2)$$

where Y_k is aggregate income and P_k is the quality-adjusted price index[3] in each country, which are both exogenous to the firm producing variety i under monopolistic competition, and po_{ik} is the final price of the product-quality pair. As such, demand is increasing in quality – in proportion to the quality preference parameter – and decreasing in price.

Inputs are sourced exclusively from the local market. This is a clear simplification to maintain tractability, as our empirical analysis of firms' sourcing behaviour is based on imported intermediates. However, as demonstrated by Demir (2013), similar results can ensue in a fully open economy set-up, although at the cost of losing the closed form solutions we obtain here. As in Kugler & Verhoogen (2012), there is an intermediate-input sector that transforms l labour-hours into heterogeneous intermediates of quality c. The cost of production directly depends on the quality of the intermediate good, with the production function in this sector being simply $F_I[l, c] = {}^{l}/_{c}$. We assume perfect competition in the market for intermediates and normalized homogenous labour costs in all markets. The input price will therefore equal the marginal cost of production of intermediate suppliers, $p_i[c] = c$.

Each producer of final goods receives a capability draw $\lambda_i > 1$, which will affect both its production costs and its ability to produce quality. There is a fixed cost to produce for each destination, f_k, and the usual iceberg cost for shipping the product, τ_k. Production of physical units of the final good is given by $F_i[n] = n\lambda_i^a$, where n is the number of inputs used and $a > 0$ is the parameter describing how capabilities affect production efficiency. The marginal

[3] This is the usual price index adjusted by the quality of each variety, i.e. $P_k = \left(\int_{i\epsilon\Omega} \left(\frac{p_{ik}}{q_{ik}^{dk}}\right)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$.

cost of a product serving each destination is therefore equal to $\frac{c_{ik}\tau_k}{\lambda_i^a}$, where c_{ik} is the desired level of input quality firm i chooses to supply to market k.

As in the original models of Bastos et al. (2018) and Kugler & Verhoogen (2012), production of quality, q_{ik}, in the final good sector is determined by a CES combination of firm capability and input quality:

$$q_{ik}[\lambda_i, c_{ik}] = \left(\mu\left(\lambda_i^b\right)^\theta + (1-\mu)\left(c_{ik}^\gamma\right)^\theta \right)^{\frac{1}{\theta}} \quad (3)$$

where $\theta < 0$ indicates the scope of complementarity between capability and input quality, b indicates the scope for quality differentiation, γ is a similar parameter for input quality and μ is a multiplicative weight between the two inputs. The more negative θ is, the higher are complementarities between the two inputs. The scope for quality differentiation (b) is assumed to be positive and can be thought as sector-specific – a possibility we explore later but simplify away here by assuming it to be the same for all firms. We interpret the quality function (3) as a simplified product innovation production process by which firms upgrade and adapt their products for each market.

Firms will choose prices and the quality of its inputs in order to maximize profit in each production line according to the following equation:

$$\pi_{ik}[\lambda_i, c_{ik}, po_{ik}] = \left(po_{ik} - \frac{c_{ik}\tau_k}{\lambda_i^a}\right) x_{ik} - f_k \quad (4)$$

where we assume real wages are the same in all countries, ignoring exchange rates[4]. This set-up results in the following solutions for input and output quality, final prices and revenues for each product-quality (firm-country) pair:

$$c_{ik} = \left(\frac{(1-\mu)}{\mu}\,(\gamma d_k - 1)\right)^{\frac{-1}{\theta\gamma}} \lambda^{\frac{b}{\gamma}} \quad (5)$$

$$q_{ik} = \left(\frac{1}{\mu}\,\frac{(\gamma d_k - 1)}{\gamma d_k}\right)^{\frac{-1}{\theta}} \lambda^b \quad (6)$$

[4] Production happens in the home country and is exported to $k-1$ destinations. Therefore, revenues have to be converted to the local currency, as in Bastos et al. (2018).

$$po_{ik} = \left(\frac{\sigma}{\sigma-1}\right) \tau_k \left(\frac{(1-\mu)}{\mu} (\gamma d_k - 1)\right)^{\frac{-1}{\gamma\theta}} \lambda^{\left(\frac{b}{\gamma} - a\right)} \qquad (7)$$

$$r_{ik} = \Gamma_1 \, \Gamma_2 \, \Gamma_3 \, \lambda^{\Gamma_4} \qquad (8)$$

where $\Gamma_1 = \frac{Y}{P^{(1-\sigma)}} \left[\left(\frac{\sigma}{\sigma-1}\right) \tau_k\right]^{-(\sigma-1)} \left[\frac{\mu}{(1-\mu)}\right]^{\frac{-(\sigma-1)}{\gamma\theta}}$, $\Gamma_2 = \frac{1}{\mu}^{\frac{-d_k(\sigma-1)}{\theta}}$,

$\Gamma_3 = (\gamma d_k)^{\frac{\gamma d_k(\sigma-1)}{\gamma\theta}} (\gamma d_k - 1)^{\frac{-(\gamma d_k - 1)(\sigma-1)}{\gamma\theta}}$ and $\Gamma_4 = \left[\frac{(\sigma-1)}{\gamma}\right] [b(\gamma d_k - 1) + \gamma a]$.

Once we assume $\gamma d_k > 1$ to obtain an interior solution, it is straightforward to observe in equations (5)-(8) that all variables are positive functions of firm capability, except for the price of final goods, which will be positive if $\frac{b}{\gamma} > a$ in equation (7). These closed-form solutions also allow us to derive propositions relating firm capability to their selling and sourcing behaviour.

2.2. The Effects of Capability and the Scope for Quality Differentiation

Equations (5) and (8) demonstrate that the quality of intermediates (c_{ik}) and firm revenue (r_{ik}) increase in firm capability $\left(\frac{\Delta c}{\Delta \lambda}, \frac{\Delta r}{\Delta \lambda} > 0\right)$. Considering that c_{ik} summarizes the quality level of a bundle of inputs and, in practice, indicates a more intensive use of higher quality intermediates relative to lower quality ones, we can conclude that more capable firms will choose higher quality intermediates, sell higher quality products and have higher revenues. Therefore, we may define two initial hypotheses as: (i) there will be a positive effect of firms' capability on export revenue; and (ii) that more capable firms will benefit more from using higher quality intermediates compared to lower quality ones.

Moreover, the quality of intermediates (c_{ik}) increases in firm capability (λ) in a non-linear manner. As long as the parameters b and γ of the quality production function are not equal, this relationship will be non-linear and will be increasing (decreasing) in λ if $b \geq \gamma$ ($b \leq \gamma$).[5] This suggests that our choice of a threshold regression model as our preferred empirical strategy in the following sections is consistent with theory.

The model also allows us to explore the effect of the scope for quality differentiation – represented in the theoretical model by the parameter b – on firms' sourcing and revenue results. Different sectors and products might offer different opportunities for quality improvements depending on the characteristics of their markets, such as the established level of standardization that firms must follow. This will be further explored in the empirical section by dividing exports into customized and non-customized products.[6] In the model, these ideas can be represented by the derivatives $\frac{\Delta^2 c}{\Delta\lambda\Delta b}$ and $\frac{\Delta^2 r}{\Delta\lambda\Delta b}$ in equations (9) and (10), respectively, which indicate the influence of the scope for quality differentiation on the effects of firm capability:

$$\frac{\Delta^2 c}{\Delta\lambda\Delta b} = \left(\frac{(1-\mu)}{\mu}\left(\gamma d_k - 1\right)\right)^{\frac{-1}{\theta\gamma}} \lambda^{\frac{b}{\gamma}-1}\left(\frac{b}{\gamma}\right)\left(\frac{1}{b}+\frac{\ln\lambda}{\gamma}\right) \tag{9}$$

$$\frac{\Delta^2 r}{\Delta\lambda\Delta b} = \Gamma_1\,\Gamma_2\,\Gamma_3\,\lambda^{\Gamma_4-1} d_k(\sigma-1)(1+\Gamma_4\ln\lambda) \tag{10}$$

It is straightforward to observe that both will necessarily have positive signs, indicating more capable firms will use higher quality inputs and produce higher quality products more intensively if there are more opportunities for quality differentiation. This provides us with an additional hypothesis: (iii) for exports of products with a higher scope for quality differentiation, there will be a stronger positive effect of firms' capability on export revenue; while more capable firms will benefit more strongly from using higher quality intermediates

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5 $\frac{\Delta c}{\Delta\lambda} = \left(\frac{(1-\mu)}{\mu}\left(\gamma d_k - 1\right)\right)^{\frac{-1}{\theta\gamma}} \lambda^{\left(\frac{b}{\gamma}-1\right)}\left(\frac{b}{\gamma}\right)$, which is only constant if $b = \gamma$.

6 We employ the conservative version of Rauch (1999)'s classification of differentiated products, which has become quite popular in the literature as a measure of complexity or 'contract-intensity' of products (Andersson & Weiss, 2012; Antràs & Chor, 2013; Del Prete & Rungi, 2015). His methodology consists of dividing products in three categories: traded in organized exchanges, reference priced in trade publications, and all others. The first two categories indicate homogeneous products traded in dense markets (non-customized), while the residual identifies differentiated products more likely to be traded in networks (customized).

relative to lower quality ones. In other words, hypothesis (iii) suggests that hypotheses (i) and (ii) will be intensified for exports of products with a higher scope for quality differentiation, which is compatible with existing evidence indicating stronger effects of higher quality inputs on firms export performance in the case of sales of customized products (Bas & Strauss-kahn, 2015; Fan et al., 2015).

3. Empirical Methodology

3.1. The Linear Model

Unlike most previous related work, we do not consider firm capability to be completely unobserved and instead rely on a direct proxy for firms' technological and innovation skills. This variable is constructed from information about the functions performed by employees in each firm, which are extracted from Brazilian administrative data and explained in greater detail in Section 4. This approach allows us to develop a simple framework that simultaneously addresses the propositions we advance from the theoretical model. These propositions summarize important aspects of the influence of innovation on firms' export performance and the role of complementarities between technological capabilities and imports.

Initially, we use a linear model for firms' export revenues that allows for both a direct effect of technological capabilities on export revenues and an indirect effect that depends on the presence of complementarities between capabilities and imported intermediates, the latter of which is captured by an interaction term between these variables. We estimate all models with time and firm fixed-effects, further lagging all dependent variables to allow for delayed effects on exports and to reduce the possible simultaneity bias between exporting and importing. Despite this, we do not have a valid instrument for imports that would allow us to control for endogeneity fully in our model, and thus we remain cautious in interpreting our results in terms of correlations and not causal effects.

The firm-level time-varying controls include firm size (i.e. number of employees), the skill level of labour (i.e. average years of schooling), total factor productivity and capital-intensity. This set constitutes a reasonably complete group of variables that have consistently been found to positively correlate with export activity in the firm-level international trade literature (Bernard & Jensen, 1999, 2004; Greenaway & Kneller, 2007; Wagner, 2007). The effect of firm size is related to performance and several other firm-level characteristics. Controlling for size is also necessary since our equation is estimated in levels, with larger firms being more able to dilute the fixed-costs associated with entering into foreign markets, such as those related to distribution networks and marketing investments (Aristei et al., 2013; Bernard & Jensen, 2004; Pisu & Muûls, 2009; Roberts & Tybout, 1999). Average years of schooling controls for overall skill intensity and contrasts overall differences in the quality of labour from the presence of functions related to technology management by the firm, which are correlated but nevertheless different. The role of human capital is more frequently captured in the literature through average wages, which are conditioned by the skill level of the labour force and usually found to positively affect firms export propensity and performance (Barrios et al., 2003; Dosi et al., 2015; Greenaway, Sousa, & Wakelin, 2004).

The inclusion of total factor productivity as a control is important due to its role in determining firm performance in foreign markets, strongly confirmed in both theoretical models and empirical investigations (Antràs & Helpman, 2004; Melitz, 2003; Wagner, 2007). More productive firms self-select into foreign markets and obtain higher revenues in both local and external markets, even after controlling for size (Hallak & Sivadasan, 2013). Total factor productivity is of course another proxy for capability, especially for capability related more strongly to cost-efficiency, whereas technical and scientific personnel indicate innovation capabilities and skills required to upgrade quality. Despite necessary, this framework can be seen as creating a partition of capabilities of the sort formalized by Hallak & Sivadasan (2013), where two types of firm-specific capability are modelled: one influencing 'process productivity' and the other 'product productivity' or quality production. In the context of the Kugler & Verhoogen (2012) model, such a partition would potentially influence some theoretical predictions, especially those related to prices of final goods, a fact highlighted by the authors in their original version. However, both of these models converge in terms of the expected patterns relating capabilities to export revenues and input quality, therefore we consider this concern to be considerably smaller here.[7]

The resulting estimation equation takes the following form:

$$\ln EX_{it} = \alpha + \beta_1 \ln IM_{it-1} + \beta_2 Tecper_{it-1} + \beta_3 \ln IM_{it-1} \times Tecper_{it-1} + \beta_4 \ln(K/L)_{it-1} + \beta_5 \ln EMP_{it-1} + \beta_6 SCHOOL_{it-1} + \beta_7 \ln TFP_{it-1} + u_i + v_t + u_{it} \quad (11)$$

where $\ln EX$ is the log of exports, $\ln IM$ the log of imported intermediates, $Tecper$ indicates technical and scientific personnel intensity and represents the proxy for firms technological capabilities, $\ln K$ is the log of the capital intensity, $\ln EMP$ the log of employees, $SCHOOL$ is the average years of schooling of workers, $\ln TFP$ the log of total factor productivity, and u_i and v_t are firm and time-specific fixed-effects, respectively. Initially, we assume that imported intermediates are a proxy for higher quality intermediates, later also accounting for the quality of these imports.

3.2. Threshold Effects: Direct and Indirect Effects of Firm Capability

There is no reason to assume that the effect of capabilities on input quality increases linearly and depending on their form, these non-linearities will not be captured properly by the

[7] We could rationalize the effect of cost-related capabilities in the model is by assuming it to be a firm-specific multiplicative parameter reducing cost, in which case it would enter the equations in a way similar to (the inverse of) the iceberg export cost, τ. Our conclusions would not be affected as long as the new parameter is positive. Consequences, however, would be more relevant for export entry in a complete general equilibrium framework.

interaction term. A more flexible way of modelling them is to consider that they represent classes of observations delimited by thresholds that depend on the level of firms' technological capabilities. Hansen (1999) developed a method to estimate unknown thresholds determined by the value of an observable variable in non-dynamic panels with individual specific fixed effects. These thresholds emerge from the sample data and do not depend on specific assumptions regarding the functional form of non-linearities, which is a clear advantage compared to linear interactions. We describe our procedures to estimate thresholds effects in Appendix II. We begin by allowing the parameter associated with imported intermediates to vary discretely depending on the intensity with which firms employ technical and scientific personnel. We adjust this model initially with a single threshold given by the following equation:

$$\ln EX_{it} = \alpha + \delta_1 \ln IM_{it-1} I(Tecper_{it-1} \leq \lambda_1) + \delta_2 \ln IM_{it-1} I(Tecper_{it-1} > \lambda_1) + \beta_2 Tecper_{it-1} + \beta_3 \ln(K/L)_{it-1} + \beta_4 \ln EMP_{it-1} + \beta_5 SCHOOL_{it-1} + \beta_6 \ln TFP_{it-1} + u_i + v_t + u_{it} \quad (12)$$

where δ_1 and δ_2 are the coefficients on $\ln IM$ in the low and high regimes, defined according to the cut-off value, λ_1, of $Tecper$. The impact of importing intermediates is given by δ_1 for observations where $Tecper$ is below λ_1, which we call the low regime, while δ_2 describes the impact for observations in the high regime, where $Tecper$ is above λ_1. We follow Hansen (1999) and estimate λ_1 by least squares, estimating equation (12) for values of $\hat{\lambda}_1$ above zero and below its 90th percentile of $Tecper$, and choosing the one that minimizes the sum of squared errors. This method allows firms to appear in different regimes at different points in time, since the thresholds are determined at the level of observations.

Once we obtain $\hat{\lambda}_1$, we must determine if it is statistically significant. If $\delta_1 = \delta_2$, the threshold does not exist, while the rejection of the null hypothesis indicates the presence of a non-linearity. An obstacle is that the threshold is not identified under the null hypothesis, making the distribution of classical tests non-standard. We follow Hansen (1999) and use a bootstrap procedure to obtain a p-value for the test. We adopt the significance level of 5% to reject the null hypothesis of no threshold.

Once we obtain a first threshold, we start the search for a second threshold with the model taking the following form:

$$\ln EX_{it} = \alpha + \delta_1 \ln IM_{it-1} I(Tecper_{it-1} \leq \lambda_1) + \delta_2 \ln IM_{it-1} I(\lambda_1 < Tecper_{it-1} \leq \lambda_2) + \delta_3 \ln IM_{it-1} I(Tecper_{it-1} > \lambda_2) + \beta_2 Tecper_{it-1} + \beta_3 \ln(K/L)_{it-1} + \beta_4 \ln EMP_{it-1} + \beta_5 SCHOOL_{it-1} + \beta_6 \ln TFP_{it-1} + u_i + v_t + u_{it} \quad (13)$$

where δ_1, δ_2 and δ_3 are the coefficients on $\ln IM$ in the three different regimes, defined according to the cut-off values, λ_1 and λ_2, of $Tecper$. The impact of importing intermediates is now given by δ_2 for observations in a medium regime (i.e. between λ_1 and λ_2) and by δ_3 for observations in the high regime (i.e. above the λ_2 level of $Tecper$). A similar bootstrap procedure is followed to test if $\delta_3 = \delta_2$. We further re-estimate λ_1 since the initial estimate $\hat{\lambda}_1$ is not efficient in the presence of a second threshold.

The differences in the estimates $\hat{\delta}_1$, $\hat{\delta}_2$ and $\hat{\delta}_3$ potentially capture the presence of complementarities between imported inputs and technological capabilities. This effect is not constrained to be the same or significant along the entire distribution of technological capabilities, however. We limit our search to two thresholds for the remainder of this work, which is enough to test our hypotheses. In the few cases in which we search for a third threshold, we never find the estimate to be significant.

We also test for thresholds for two variables: imported intermediates originating from OECD[8] and from non-OECD countries. The different origins of inputs serve as a proxy for the

[8] We exclude countries that entered the OECD during the 1990s and after, therefore classifying as OECD only the older – and mostly wealthier – members of the organization. These are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, Japan, Australia and New Zealand.

quality/technology embodied in these goods, which is not directly observable in the data. Developed countries produce higher quality goods used by firms for technological upgrading, while imports from developing countries tend to be connected to cost-saving effects (Bas & Strauss-kahn, 2015; Bas & Strauss-Kahn, 2014; Feng et al., 2016b; Lo Turco & Maggioni, 2013). Overall, this model is similar to (3), with the necessary additions in terms of coefficients and thresholds variables. However, comparing the non-linear effects of $Tecper$ for low and high-quality imports – as captured by origin of imports – provides an additional and more convincing test for the presence of complementarities between capabilities and input quality.

We follow analogous stepwise procedures, which are also explained in Appendix II, estimating one threshold a time. The model with the highest number of thresholds takes the following form:

$$\ln EX_{it} = \alpha + \delta_1 \ln IM\_OECD_{it-1}\, I(Tecper_{it-1} \leq \lambda_1) + \delta_2 \ln IM\_OECD_{it-1}\, I(\lambda_1 < Tecper_{it-1} \leq \lambda_2) + \delta_3 \ln IM\_OECD_{it-1}\, I(Tecper_{it-1} > \lambda_2) + \delta_4 \ln IM\_NOECD_{it-1}\, I(Tecper_{it-1} \leq \lambda_3) + \delta_5 \ln IM\_NOECD_{it-1}\, I(\lambda_3 < Tecper_{it-1} \leq \lambda_4) + \delta_6 \ln IM\_NOECD_{it-1}\, I(Tecper_{it-1} > \lambda_4) + \beta_2 Tecper_{it-1} + \beta_3 \ln(K/L)_{it-1} + \beta_4 \ln EMP_{it-1} + \beta_5 SCHOOL_{it-1} + \beta_6 \ln TFP_{it-1} + u_i + v_t + u_{it} \qquad (14)$$

where $\ln IM\_OECD$ and $\ln IM\_NOECD$ are now the log of imported intermediates from OECD and non-OECD countries, respectively.

Additionally, we estimate models (12), (13) and (14) by considering as the dependent variable both the revenue from the exports of customized exports and of non-customized products. Following previous studies (Bas & Strauss-Kahn, 2015; Fan et al., 2015; Flach, 2016), we use Rauch (1999)'s classification of products to differentiate exports between these two categories of goods. The former should present a wide scope for quality differentiation, while the competition in the latter would be mostly governed by cost factors, allowing lower opportunities for product innovation. Since almost all non-customized products are intermediates, we also limit exports of customized products to intermediate products to concentrate only on suppliers in global value chains, increasing comparability. This provides us with a test for prediction (iii).

4. Data

This work is based on data from three different sources: (i) the Brazilian Annual Industrial Survey (PIA); (ii) the Annual Registry of Social Information (RAIS); and (iii) the registry of foreign trade of the Secretary of Foreign Trade (Secex). PIA is the most representative database of Brazilian firms. It annually collects detailed business information (revenues, expenses, personnel, wages, investments, etc.) of Brazilian firms in manufacturing and extractive industries. All firms with more than 30 employees or revenues above R$ 13.6 million in the previous year are surveyed, while firms below these thresholds are sampled. We exclude sampled firms and those from extractive sectors and concentrate only on firms from within manufacturing. This sample is merged with information about firm age, number of employees, average years of study and employee function taken from RAIS, which collects labour information from all active Brazilian firms.

Finally, the resulting sample is merged with the registry of foreign trade (Secex), containing administrative information for all exporting and importing firms (value, product, quantity and destination) from 1997-2007. We restrict our analysis to the 2001-2007 period which is the most recent period for which trade data is available. Most of the empirical analysis involves lagging the dependent variable, which results in a loss of some observations. Nevertheless, the resulting unbalanced panel contains 146,862 entries for 39,307 firms in total and approximately 60% of Brazilian accumulated exports during the period. All data was accessed at the Brazilian Institute of Geography and Statistics (IBGE) safe room and confidentiality procedures were followed.

The value of exports and imports were converted to Brazilian currency using average annual exchange rates and all nominal variables were deflated using 3-digit sector level price indexes (IPA-OG) supplied by the Getulio Vargas Foundation (FGV). Capital stock is estimated using the perpetual inventory method. Total factor productivity (TFP) is one of the controls in the regression and is estimated according to Levinsohn & Petrin (2003). This method, as well as other semiparametric approaches routinely used in the literature (Ackerberg et al., 2006; Olley & Pakes, 1996) correct the bias caused by the endogeneity between variable inputs and unobserved firm productivity. Our TFP estimations are the same as used in Araújo (2016) and Messa (2014).

In Appendix I.a, we depict the number, average exported value and average number of country-product pairs exported and imported by Brazilian firms each year. The percentage of traders is high relative to the overall population of Brazilian firms (Kannebley Jr et al., 2009), with around 26% (23%) of firms exporting (importing). This is due to our sample being limited to firms with more than 30 employees or revenues above R$ 13.6 million, therefore excluding very small firms. The number of exporters and importers tends to grow, albeit with quite some variation across years. These movements might be related to exchange rate variations, which are rather sharp in Brazil. Nevertheless, we control for these effects using time fixed-effects in all regressions.

One of the major differences from our work in comparison to previous contributions is to proxy firms' technological capabilities directly. We explore the richness of our dataset to identify specific *occupations* of employees within the firm that are likely related to advanced technical and scientific activities. These include employees classified as researchers, engineers, R&D managers, IT personnel, physicists, chemists and other science-related functions.[9] This variable was developed by Araújo et al (2009), who showed that it is highly correlated with firms' internal R&D expenditures as declared in innovation surveys.[10] We divide the number of technical and scientific personnel by total employment to obtain an intensity variable, i.e. the $Tecper$ variable described above.

This approach is similar in nature to the one used by Harrigan et al (2016) to proxy the adoption of new technologies, although we include a broader range of occupations compared to the ICT-related "techies" they concentrate on. Compared to usual measurements of labour quality, this type of approach has the advantage of separating science and engineering personnel from qualified overall white-collar staff, providing a better proxy for internal functions associated with innovation activities. The use of *occupations* helps to separate the qualification level of employees from the activities effectively performed by them in the firm. Our objective is to proxy the presence of 'intermediate' and 'advanced' capabilities related to the management of technological change, as described for instance in Lall (1992) and Bell & Pavitt (1993). Moreover, since innovation frequently involves investments in the development of new skills and in technical personnel capable of implementing these innovations, we follow Harrigan et al. (2016) and use this variable as an indicator of innovation activities – which despite the richness of our dataset, we cannot observe directly at the firm-level. It is important to highlight that our proxy only partially reflects innovation activities because firms might use their existing personnel for more incremental or routine activities, or to hire outside consultants. More radical changes will tend to involve expansions in technical and scientific personnel more intensively. In order to capture variations more

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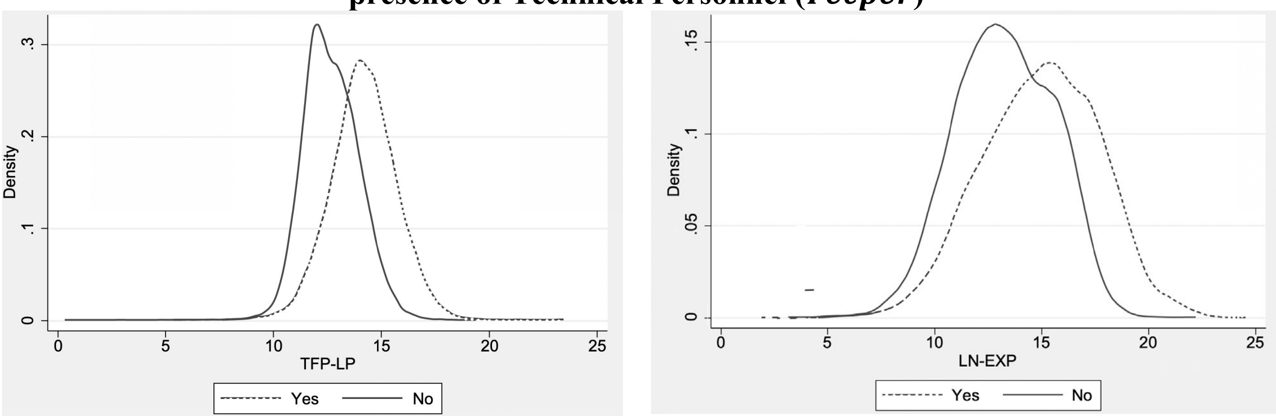
[9] The $Tecper$ variable is constructed based on the Brazilian Classification of Occupations (CBO). It includes the following functions (CBO codes between parenthesis): researchers (203), engineers (202, 214, 222), R&D directors (1,237) and R&D managers (1,426), biotechnologists, geneticists, meteorologists (201), mathematicians, statisticians and similar (211), IT professionals (212), physicists, chemists and similar (213), biologists and similar (221). The most numerous sub-group is engineers.

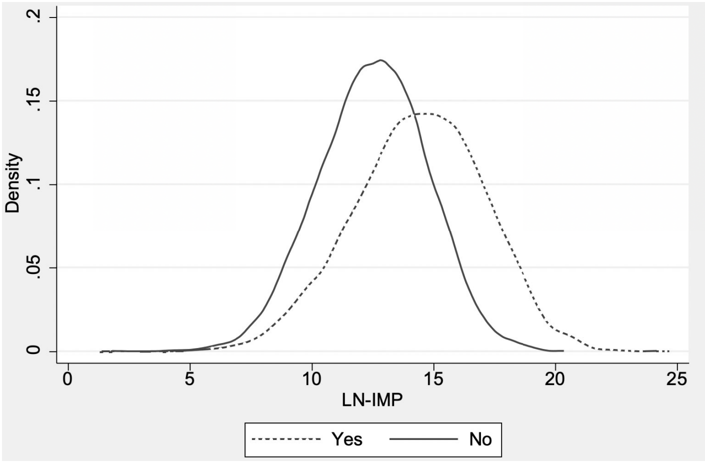
[10] This correlation varied between 0.83 and 0.92, depending on the wave of the innovation survey used.

precisely, we build this variable from monthly data and obtain the average number of technical and scientific employees in the firm during the year.

The average intensity of technical and scientific personnel is 0.7% of total employees for the overall population – only 29% of observations have positive values for technical and scientific personnel, with an average intensity of 2.3% in this group. Appendix I.b presents descriptive statistics for the main variables used in the empirical section, differentiating between firms that have technical and scientific personnel and those that do not. In Figure 1, we compare the density distribution of productivity, exports and imports of intermediates between firms that have positive and zero values for technical personnel. As expected, the density distribution of firms that have technical personnel clearly dominates the remaining firms in the case of all three performance variables, reinforcing previous indications that technological capabilities are associated with higher performance both in local and international markets.

Figure 1: K-density of productivity (left), exports (right) and imports (below) according to the presence of Technical Personnel ($Tecper$)





Notes: Kernel densities for firms that have technical and scientific personnel (dotted line) and firms that do not (unbroken line). The dotted curve dominates the unbroken curve along the entire distribution. Only firms with non-zero export and import values are included in the graphs for the export and import densities.

5. Results

5.1. The Linear Model

In Column (1) of Table 1 we present results for the complete linear model of equation (11). Control variables are all positive and significant. Increasing the number of employees by 1% is associated with a 0.65% increase in exports, whereas the same percentage increase in total factor productivity and capital intensity is associated with a 0.25% and a 0.012% increase in foreign sales, respectively. A one-year increase in average schooling of employees has a sizeable effect, being associated with an increase in foreign sales of 7.1%. Regarding our variables of interest, a 10% increase in imported intermediates is associated with a 0.53% increase in exports, which although not large is a significant effect. The $Tecper$ variable presents a strong and significant direct correlation: a 1 percentage-point increase in $Tecper$ is associated with a 2.86% increase in exports. The interaction term capturing complementarities between imports and innovation is positive but remains non-significant in all estimations, indicating either the absence of complementarities or that these are not being properly estimated by the linear interaction term.

In Column (2) we exclude the TFP variable and the coefficients on most variables increases, especially employment (size). This signals the influence of efficiency and cost selection in the model, as expected due to self-selection of more productive firms in export markets. The coefficient on the interaction term increases in size by a factor of three, but remains insignificant. In Column (3) we also include the intensity of personnel with college degree in the firm to test to what extent $Tecper$ indeed represents firms' technological capabilities or just proxies for white-collar workers in the firm. As expected, the two variables most correlated with college personnel – $Tecper$ and $SCHOOL$ – see their coefficients reduced when compared to Column (1), although they remain highly significant. Moreover, the effect of $Tecper$ is almost two times higher than that of college degree personnel, which increases our confidence in $Tecper$ as a good proxy for capability.

Table 1: Linear Model (FE-OLS Regressions)

VARIABLES	(1) Ln Exports	(2) Ln Exports	(3) Ln Exports	(4) Ln Exports
ln IM (-1)	0.053	0.056	0.053	0.044
	(0.003)***	(0.003)***	(0.003)***	(0.003)***
Tecper (-1)	2.861	2.766	2.170	
	(1.028)***	(1.022)***	(1.040)**	
ln IM X Tecper (-1)	0.016	0.047	0.020	
	(0.082)	(0.081)	(0.082)	
ln EMP (-1)	0.654	0.709	0.665	0.629
	(0.030)***	(0.029)***	(0.030)***	(0.029)***
ln K/L (-1)	0.012	0.005	0.012	0.012
	(0.005)**	(0.005)	(0.005)**	(0.0049)**
SCHOOL (-1)	0.071	0.076	0.047	0.073
	(0.014)***	(0.015)***	(0.015)***	(0.014)***
ln TFP (-1)	0.256		0.256	0.256
	(0.019)***		(0.019)***	(0.018)***
College Personnel (-1)			1.3681	
			(0.322)***	
Tecper Dummy (-1)				0.060
				(0.040)
Tecper Dm X ln IM (-1)				0.019
				(0.004)***
Observations	146,862	146,862	146,862	146,862
Firm fixed-effects	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES
Number of groups	39,307	39,307	39,307	39,307
F-statistic	131.4	126.0	122.7	133.0
R-squared	0.39	0.36	0.39	0.39

Standard errors in parentheses. All models estimated with time and firm-specific fixed effects. *** p<0.01, ** p<0.05, * p<0.1

As we saw in Section 2, we have good reasons to assume that complementarities between technological capabilities and input quality have a more complex relationship, likely dependent on the level of technological capabilities itself. In this case, the linear interaction term is not well equipped to test this hypothesis. A first hint in that direction is given in Column (4), where we replace $Tecper$ by a binary version that takes the value one for any positive value of technical and scientific personnel in the firm. Results suggest that the correlation between imported intermediates and exports is indeed higher for firms that employ technical and scientific personnel, although the dummy variable itself is non-significant. This serves as a further motivation to look deeper into these non-linearities using less strict assumptions about their functional form.

5.2. Threshold Effects for Imported Intermediates

Column (1) in Table 2 depicts results from a linear FE-OLS model without thresholds for comparison, while in Column (2) results for the one threshold case of equation (12) are shown. This threshold is found very close to the zero cut-off, at 0.06% of $Tecper$. The bootstrapping procedure indicates a p-value of 0.00, which allows us to reject the hypothesis of linearity. This implies that very low levels of technical personnel already change the effect of imported intermediates from 0.044 to 0.064 on average – a 45% percent difference between the low regime and the high regime. Since this threshold is very close to zero, it is almost equivalent to the dummy interaction model that we estimated in Column (6) of Table 1. Indeed, the marginal effect of imported Intermediates is almost the same in the two models.

This result confirms the presence of complementarities, but we would like to know if they continue to increase as the level of technological capabilities grow or if any positive level of $Tecper$ allows firms to reap more benefits from importing. As such, we estimate equation (13), with the results reported in Column (3) of Table 2. The second threshold found at a value of $Tecper$ of 1.17% is significant with a p-value of 0.001. An increase of 10% in imported intermediates is correlated with a future increase of exports of 0.72% in the high regime of $Tecper$, 0.58% in the medium regime and 0.44% in the low regime. The remaining co-variables remain largely unaffected in the regressions, with the exception of $Tecper$, whose impact is significantly reduced from 3% to around 2%, indicating that some of the effect of firms' technological capabilities on exports is indeed related to variations in imported intermediates.

Table 2: Threshold Regressions for Imported Intermediates

VARIABLES	(1) Ln Exports	(2) Ln Exports	(3) Ln Exports	(4) Ln Exports
ln EMP (-1)	0.654	0.641	0.642	0.642
	(0.029)***	(0.029)***	(0.029)***	(0.029)***
ln K/L (-1)	0.012	0.012	0.012	0.012
	(0.0043)**	(0.0046)**	(0.0046)**	(0.0046)**
SCHOOL (-1)	0.071	0.070	0.070	0.070
	(0.014)***	(0.014)***	(0.014)***	(0.014)***
ln TFP (-1)	0.256	0.256	0.255	0.255
	(0.018)***	(0.018)***	(0.018)***	(0.018)***
Tecper (-1)	3.015	2.414	1.986	1.814
	(0.686)***	(0.695)***	(0.706)***	(0.7149)**
ln IM (-1)				
No Threshold	0.053			
	(0.003)***			
(Tecper ≤ 0.06%)		0.044	0.043	0.043
		(0.003)***	(0.003)***	(0.003)***
(Tecper > 0.06%)		0.064		
		(0.003)***		
(0.06% < Tecper ≤ 1.17%)			0.058	0.058
			(0.004)***	(0.004)***
(Tecper > 1.17%)			0.072	
			(0.004)***	
(1.17% < Tecper ≤ 1.70%)				0.068
				(0.005)***
(Tecper > 1.70%)				0.075
				(0.005)***
p-value (threshold)	-	0.00	0.00	0.11
Observations	146,862	146,862	146,862	146,862
Firm fixed-effects	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES
Number of groups	39,307	39,307	39,307	39,307
F-statistic	143.3	133.9	124.5	115.8
R-squared	0.38	0.38	0.39	0.39

Standard errors in parentheses. Constant omitted. All models estimated with time and firm-specific fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

These results suggest that complementarities continue to exist as firms accumulate more technological capabilities. We check if this process continues at even higher levels of $Tecper$ by searching for additional thresholds, but no significant evidence of a further threshold was found. Column (4) shows the results for the estimation of a third threshold with four regimes of imports of intermediates. This extra threshold is found at 1.70% of $Tecper$, but the bootstrap procedure indicates a p-value of 0.11, allowing us to reject the hypothesis of a third non-linearity in the model. Therefore, model (3) remains our preferred formulation.

5.3.Threshold Effects and the Quality of Imports

Results in Table 2 confirm both the existence of significant impacts of technological capabilities on firms' export performance and the presence of complementarities between imported intermediates and technological capabilities. These complementarities create non-linearities that are not well described by linear interaction terms. An increase in technological capabilities from a low initial base increases the correlation between imported intermediates and export performance as firms become more capable of managing technology; but at higher capability levels the additional impact ceases to be relevant, indicating decreasing returns in the complementarities between capabilities and imported intermediates.

Furthermore, if exporters with higher technological capabilities benefit more from importing because of the superior quality and embodied technology of these inputs – which allows them to innovate and improve their products – imports of higher quality/technological content will present stronger complementarities with technological capabilities. Therefore, as an additional test for this hypothesis, we proceed to separate imported inputs coming from OECD and non-OECD countries.

Table 3: Threshold Regressions for Imported Intermediates from OECD and non-OECD countries

VARIABLES	(1) Ln Exports	(2) Ln Exports	(3) Ln Exports	(4) Ln Exports
ln EMP (-1)	0.642	0.638	0.639	0.640
	(0.029)***	(0.029)***	(0.029)***	(0.029)***
ln K/L (-1)	0.012	0.012	0.012	0.012
	(0.004)***	(0.004)***	(0.004)***	(0.004)***
SCHOOL (-1)	0.076	0.070	0.070	0.070
	(0.014)***	(0.014)***	(0.014)***	(0.014)***
ln TFP (-1)	0.257	0.256	0.256	0.256
	(0.018)***	(0.018)***	(0.018)***	(0.018)***
Tecper (-1)		2.437	2.053	2.135
		(0.694)***	(0.704)***	(0.705)***
ln IM_OECD (-1)				
No Threshold	0.039			
	(0.003)***			
(Tecper ≤ 0.05%)		0.028	0.028	0.026
		(0.004)***	(0.004)***	(0.004)***
(Tecper > 0.05%)		0.050		
		(0.004)***		
(0.05% < Tecper ≤ 1.18%)			0.044	0.046
			(0.004)***	(0.005)***
(Tecper > 1.18%)			0.058	0.061
			(0.004)***	(0.005)***
ln IM_NOECD (-1)				
No Threshold	0.029	0.029	0.029	
	(0.003)***	(0.003)***	(0.003)***	
(Tecper ≤ 0.24%)				0.033
				(0.004)***
(Tecper > 0.24%)				0.024
				(0.004)***
p-value (threshold)	-	0	0	.065
Observations	146,862	146,862	146,862	146,862
Firm fixed-effects	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES
Number of groups	39,307	39,307	39,307	39,307
F-statistic	138.7	121	113.2	105.9
R-squared	0.38	0.39	0.39	0.39

Standard errors in parentheses. Constant omitted. All models estimated with time and firm-specific fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

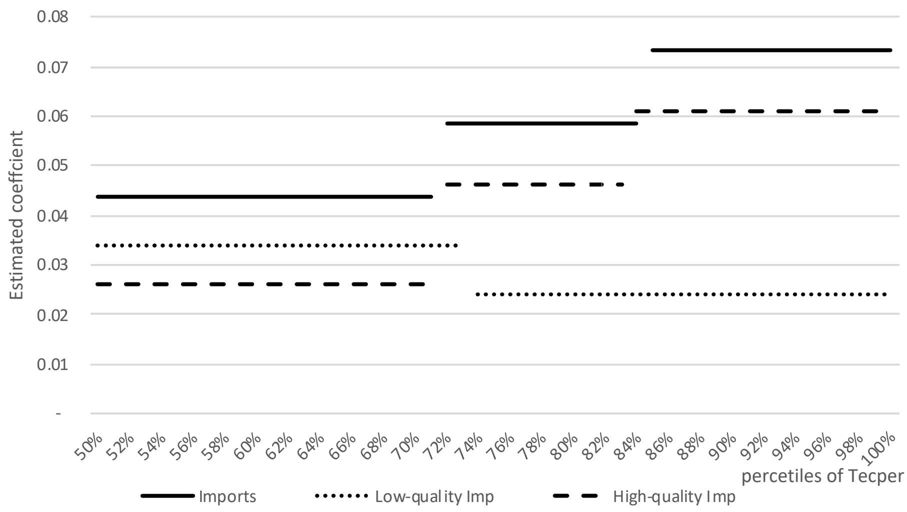
Table 3 depicts the results when separating imports in this way. Column (1) shows results for a linear model[11], while columns (2) and (3) report results for the one and two threshold model for OECD imports, respectively. The thresholds are at similar levels of $Tecper$ as those found for overall imported intermediates and both are significant. The low regime for OECD imports is at the same level as the coefficient for non-OECD imports, while the medium and high regime are significantly above. In Column (4) we report results from estimating

[11] One should observe that both coefficients are below the value we obtain for overall imports in equation (1) due to the log transformation we use: the sum of the logs of OECD and non-OECD imports equals the log of their product and not the log of their sum. Therefore, these two models are not directly comparable.

equation (14), in which a threshold for non-OECD imports is estimated while maintaining the previous thresholds for OECD imports. The estimated threshold on non-OECD imports is found at a value of $Tecper$ of 0.2%, but this is not significant at the 5% level. Furthermore, the high regime has a lower coefficient, suggesting that firms with higher technological capabilities might actually depend less on imported inputs of lower quality/technology to export. As before, the direct effect of $Tecper$ remains positive and significant.

Figure 2 offers a graphical visualization of the previous results. It depicts estimates for imported intermediates from Column (4) of Table 1 together with the estimates for OECD and non-OECD intermediates from Column (4) of Table 2 at the different percentiles of the $Tecper$ distribution. As $Tecper$ increases, non-OECD intermediates have their effect reduced, while overall imports increase their effect accompanying the higher coefficients for OECD imports. Therefore, these results offer additional support for the existence of complementarities between firms' capabilities and the quality of the intermediates they import.

Figure 2: Threshold estimates for overall, OECD and non-OECD imported intermediates along the distribution of technological capabilities



Notes: Estimates of non-linear effects of imported intermediates taken from column (4) of Table 1 together with estimates for OECD (high-quality) and non-OECD (low-quality) intermediates taken from column (4) of Table 2 at the different percentiles of the $Tecper$ distribution (horizontal axis). We start at 50% since 72% of observations have zero value for $Tecper$.

5.4. Different Levels of Customization in Export Products

In Table 4 we turn to the case of different levels of customization of exports. Customized products offer a higher scope for quality differentiation, which according to the model we presented in Section 2 should result in a stronger effect of technological capabilities on firms' performance and a stronger effect of high-quality intermediates for more capable firms. In columns (1) and (2) we estimate the model for customized products with one and two thresholds and observe that complementarities with high-quality intermediates are present for these markets as the effect of imported intermediates decreases from 0.057 to 0.025 once we move to lower capability firms in Column (2). In columns (3) and (4), we observe that there is also an increase in the effect of intermediates for non-customized products, but the coefficients remain largely below those in columns (1) and (2) for similar regimes of technological capability, with the absolute difference increasing as we move to higher regimes of technological capabilities. Regarding the direct effect of technological capabilities, we observe that the coefficient for $Tecper$ is always positive, but only significant (at the 10% level) in Column (1), falling slightly in magnitude in Column (2). However, for exports of non-customized products, estimates for technological capabilities remain negative and non-significant.

The evidence presented above therefore confirms our expectations, although the results are somewhat weaker when considering the direct effect of firm capability. In Table 5 we repeat the procedure of dividing exports of customized and non-customized products as done in Table 3, but now estimate thresholds dividing imports from OECD and non-OECD countries to once again proxy for their quality. The direct effect of technological capabilities presents similar coefficients in all equations. However, the results for imported intermediates add some important insights. Columns (1) and (2) depict results for one and two thresholds of OECD imports already accounting for two thresholds of non-OECD imports, which are confirmed to be significant. However, for the latter complementarities only arise for the high regime and the effect is much smaller compared to the higher quality OECD imports. Indeed, there are strong complementarities for OECD imports, as estimates reduce from 0.059 to 0.018 between the high and low regimes of technological capabilities in Column (2).

Table 4: Threshold Regressions for Exports of Customized and non-Customized Intermediates

VARIABLES	(1) Ln Cust	(2) Ln Cust	(3) Ln Non Cust	(4) Ln Non Cust
Tecper (-1)	0.983	0.787	0.114	-0.266
	(0.590)*	(0.592)	(0.497)	(0.506)
ln IM (-1)				
(Tecper ≤ 1.28%)	0.030			
	(0.002)***			
(Tecper > 1.28%)	0.054	0.057		
	(0.003)***	(0.003)***		
(0.09% < Tecper ≤ 1.28%)		0.039		
		(0.003)***		
(Tecper ≤ 0.09%)		0.025		
		(0.003)***		
(Tecper ≤ 0.14%)			0.006	0.006
			(0.002)**	(0.002)**
(Tecper > 0.14%)			0.022	
			(0.002)***	
(0.14% < Tecper ≤ 1.35%)				0.017
				(0.003)***
(Tecper > 1.35%)				0.029
				(0.003)***
p-value (threshold)	0.00	0.00	0.00	0.00
Observations	146,862	146,862	146,862	146,862
Firm fixed-effects	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES
Number of groups	39,307	39,307	39,307	39,307
F-statistic	98.12	91.94	57.60	54.40
R-squared	0.27	0.28	0.22	0.23

Standard errors in parentheses. Constant omitted. All models estimated with time and firm-specific fixed-effects. Control variables ommited are the same as in Table 2.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Threshold Regressions for exports of Customized and non-Customized Intermediates, Imported Intermediates from OECD and non-OECD countries

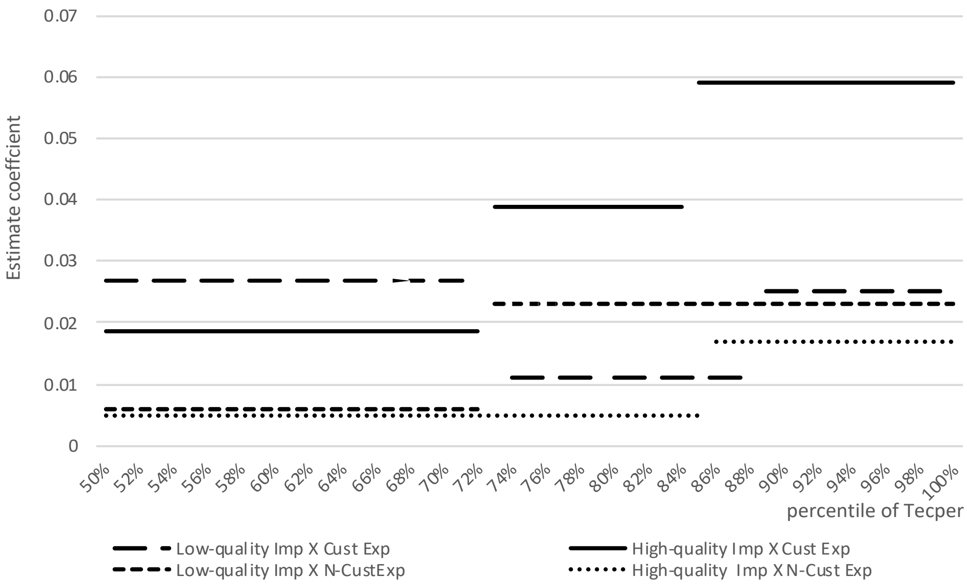
VARIABLES	(1) Ln Cust	(2) Ln Cust	(3) Ln Non Cust	(4) Ln Non Cust
Tecper (-1)	0.099	0.068	-0.220	-0.260
	(0.591)*	(0.591)	(0.505)	(0.505)
ln IM_OECD (-1)				
(Tecper ≤ 1.28%)	0.018			
	(0.003)***			
(Tecper > 1.28%)	0.048	0.058		
	(0.004)***	(0.004)***		
(0.05% < Tecper ≤ 1.28%)		0.04		
		(0.003)***		
(Tecper ≤ 0.05%)		0.018		
		(0.003)***		
(Tecper ≤ 1.35%)			0.005	
			(0.002)**	
(Tecper > 1.35%)			0.017	0.019
			(0.003)***	(0.003)***
(0.15% < Tecper ≤ 1.35%)				0.01
				(0.003)***
(Tecper ≤ 0.15%)				0.002
				(0.003)
ln IM_NOECD (-1)				
(Tecper ≤ 0.26%)	0.027	0.027		
	(0.003)***	(0.003)***		
(0.26% < Tecper ≤ 1.85%)	0.011	0.011		
	(0.003)***	(0.003)***		
(Tecper > 1.85%)	0.025	0.025		
	(0.005)***	(0.005)***		
(Tecper ≤ 0.19%)			0.006	0.008
			(0.002)**	(0.003)**
(Tecper > 0.19%)			0.023	0.022
			(0.002)***	(0.002)***
p-value (threshold)	0	0	0	0.059
Observations	146,862	146,862	146,862	146,862
Firm fixed-effects	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES
Number of groups	39,307	39,307	39,307	39,307
F-statistic	83.88	79.43	52.79	49.55
Within R-squared	0.011	0.012	0.007	0.007
R-squared	0.29	0.29	0.23	0.23

Standard errors in parentheses. Constant omitted. All models estimated with time and firm-specific fixed-effects. Control variables ommited are the same as in Table 2.
*** p<0.01, ** p<0.05, * p<0.1

In columns (3) and (4), we depict results for non-customized exports. In both cases we only show one threshold for non-OECD imports, as we do not find a second significant threshold.

In Column (4), we also estimate a second threshold for OECD imports, but again the threshold is not significant (p-value of 5.9% in the bootstrap procedure). Therefore, Column (3) remains our preferred estimation, with results suggesting a lower presence of complementarities for exports of non-customized products. This is further demonstrated in Figure 3, which depicts results for columns (2) and (3) in graphical form. It is possible to observe that the effect of high-quality imports for more capable firms becomes relatively stronger for firms exporting to more quality-demanding markets. That is true for all other categories of imported intermediates. In the case of the two series describing exports of non-customized products, we observe that higher quality imports have a smaller effect, although the difference is statistically insignificant at the lowest and highest sections of $Tecper$. These results therefore confirm the predictions of the previous sections, although to a lesser extent for the direct effect of technological capabilities.

Figure 3: Threshold estimates for OECD and non-OECD imported intermediates along the distribution of technological capabilities, Cust and non-Cust Exports



Notes: Estimates for non-linear effects of OECD (high-quality) and non-OECD (low-quality) imported intermediates taken from column (2) and (3) of table 5 at the different percentiles of the $Tecper$ distribution (horizontal axis), starting at 50%. The solid and long broken lines depict estimates for exports of customized products; whereas the short broken and dotted lines for non-customized exports.

5.5. Destination Markets and the Customization of Imports

In Table 6 we perform two additional tests for the presence of complementarities between capabilities and the quality of imports. First, in columns (1) and (2), we divide exports into non-OECD and OECD countries. OECD countries produce higher quality goods and have more quality-demanding consumers, favouring both a stronger effect of technological capabilities upon firm's performance and the effect of high-quality intermediates for more capable firms, which have a relative comparative advantage in the use of this kind of inputs. In Column (1), we depict results for the preferred model with no thresholds for non-OECD imports – the hypothesis of non-linearity is rejected for this variable. In Column (2), the preferred model has one threshold for non-OECD imports. While the effect of OECD imports appears to be similar in both cases, Column (2) confirms that lower quality intermediates have a significantly smaller effect for high capability firms in OECD markets, whereas no such trend is verified in Column (1) regarding non-OECD markets. We consider this pattern compatible with a more intensive role for complementarities between quality and capability in higher income markets, although less pronounced when compared to the case of product customization depicted in the previous section. Regarding the direct effect of technological capabilities, the coefficient is higher and only significant for exports to OECD markets, which clearly reinforces our previous results.

Additionally, in columns (3) and (4), we replace the origin of intermediates with their level of customization. Although they are not a proxy for quality, we still expect technological capabilities to be more important for the group of customized goods due to their higher level of complexity. In Table 5 we obtain preferred specifications with two thresholds for each variable, with results in Table 6 being very similar. We can observe for customized exports in Column (4) strong complementarities between capability and intermediates, with an estimate for the effect of customized imports more than twice as high in the high capability regime

(0.056) compared to the low regime (0.024). This is not the case for non-customized imports in Column (4) and is also not observed in Column (3) regarding exports of non-customized products, where the effect of both types of imports is very similar in all capability regimes.

Table 6: Threshold Regressions for exports according to destination and imports of Customized and non-Customized Intermediates

	(1)	(2)	(3)	(4)
VARIABLES	Ln NOECD Exp	Ln OECD Exp	Ln Non Cust.	Ln Cust.
Tecper (-1)	0.912	1.706	-0.160	0.820
	(0.700)	(0.665)***	(0.520)	(0.592)
ln IM_OECD (-1)				
(Tecper ≤ π1)	0.022	0.019		
	(0.004)***	(0.004)***		
(π1 < Tecper ≤ π2)	0.039	0.030		
	(0.004)***	(0.005)***		
(Tecper > π2)	0.052	0.049		
	(0.004)***	(0.004)***		
ln IM_Cust. (-1)				
(Tecper ≤ δ1)			0.006	0.024
			(0.003)***	(0.003)***
(δ1 < Tecper ≤ δ2)			-0.002	0.047
			(0.003)	(0.004)***
(Tecper > δ2)			0.025	0.056
			(0.004)***	(0.004)***
ln IM_NOECD (-1)				
No Threshold	0.032			
	(0.003)***			
(Tecper ≤ 1.88%)		0.023		
		(0.003)***		
(Tecper > 1.88%)		0.012		
		(0.004)***		
ln IM_Non Cust. (-1)				
(Tecper ≤ λ1)			0.018	0.011
			(0.003)***	(0.003)***
(λ1 < Tecper ≤ λ2)			0.007	0.037
			(0.004)*	(0.003)***
(Tecper > λ2)			0.026	0.019
			(0.005)***	(0.004)***
p-value (threshold)	0	0.01	0	0.002
Observations	146,862	146,862	146,862	146,862
Firm fixed-effects	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES
Number of groups	39,307	39,307	39,307	39,307
F-statistic	116.2	63.3	50	80
R-squared	0.38	0.30	0.24	0.30

Notes: in column (1): π1=0.07% and π2 = 1.18%

in column (2): π1=0.09% and π2 = 1.30%

in column (3): δ1=0.15%, δ2=1.47%, λ1=0.42% and λ2=1.42%

in column (4): δ1=0.05%, δ2=1.28%, λ1=0.26% and λ2=1.42%

Standard errors in parentheses. All models estimated with time and firm-specific fixed-effects. Control variables ommited are the same as in Table 2.

*** p<0.01, ** p<0.05, * p<0.1

5.6. Extensions: country-product varieties and capital goods

We expand our framework to look more closely at the introduction of product-country varieties by firms. The relative importance of cost-competitiveness versus quality/technology might vary depending on whether the firm is already a known player in a market or if it is an entrant trying to establish a reputation and new commercial relationships (Feng et al., 2016). Entrants might be more dependent on cost advantages to challenge established competitors and persuade buyers to change their suppliers, or alternatively, they might use innovation and quality to get a competitive edge over their competitors.

In Column (1) of Table 7 we replace the value of exports by the number of country-product pairs exported by firms, an indicator that firms are introducing new products or expanding into new markets, which will frequently involve adaptations. Estimation of equation (3) with imported intermediates as a dependent variable suggests very similar results to the previous ones obtained for export values as the dependent variable. However, when we divide imports from OECD and non-OECD countries in Column (2), findings are considerably different. Complementarities with OECD imports once again exist and sharply increase the importance of both OECD and non-OECD imports, but very asymmetrically: non-OECD imports are almost two times higher at the lowest regime compared to OECD imports, while in the high regime non-OECD imports are still above OECD imports, but the difference is very small. These results indicate that at low technological levels, cost-competitiveness allowed for by non-OECD imported intermediates is more relevant for market access than OECD imports, being at least equally relevant at high levels. Overall, Brazilian firms appear to rely relatively more on cost competitiveness for entry, while product upgrading becomes more relevant for more capable firms and for the expansion of sales in markets where they were already present.

In columns (3) and (4), we replace the value by the logarithm of the number of imported product-country varieties of intermediates and look at their effect on the value and on the number of exported product-country pairs. Results demonstrate once again the presence of complementarities in both cases. A 1% increase in the number of imported country-product pairs is associated with an increase of 0.51% in exported value and 0.12% in the number of country-product pairs served by the more technologically capable firms. This is a sizeable effect and qualifies previous results that demonstrated the importance of imported varieties but ignored asymmetries in technological capabilities between firms (Bas & Strauss-Kahn, 2014; Castellani & Fassio, 2019).

Finally, we consider the influence of imported capital goods on the export performance of local firms and possible complementarities with their technological capabilities. Capital goods are connected to investments in tangible assets and in the implementation of new production techniques. Imported capital goods in particular should embody frontier foreign technology and relate more closely with the implementations of process innovations by firms (Dosi et al., 2015; Hall, Ae, & Mairesse, 2009). In "technology gap" theories of development, they are connected to the 'advantage of backwardness' (Gerschenkron, 1962), i.e. the possibility that developing countries could benefit from the backlog of technologies developed previously in advanced nations. However, it is usually recognized that that this knowledge can only be successfully applied by firms in developing countries if they already possess a minimum level of absorptive capacities (Abramovitz, 1989; Cohen & Levinthal, 1989; Verspagen, 1991).

Columns (5) and (6) show estimations for one and two thresholds for imported capital goods, controlling for imports of intermediates. First, we find that the effect of capital goods remains considerably below that of imported intermediates at all levels of $Tecper$. Second, we find that there are also complementarities with technological capabilities, but they appear to be smaller: only one threshold is significant at the 5% level, while the most likely candidate for a second threshold is found to be not significant at this level. Firms with high technological capabilities indeed benefit more from imported capital goods than firms at lower levels as predicted by theory. However, complementarities appear much stronger for the case of intermediate products. Castellani & Fassio (2019) found a stronger effect for intermediates compared to capital goods and attributed the result to the possibility that intermediate goods embody technology *and* cost advantages to firms related to more input varieties, whereas capital goods *only* embody new technologies. Our results suggest that these effects are intensified for more capable firms, as complementarities are also a factor increasing the effect of intermediates, a pattern that is less present in the case of capital goods.

Table 7: Extension Regressions, Threshold Regressions for exports of Customized and non-Customized Intermediates, Imported Intermediates from OECD and non-OECD countries

DEP VARIABLES	(1) Ln Prod-Country Exp.	(2) Ln Prod-Country Exp	(3) Ln Exports	(4) Ln Prod-Country	(5) Ln Exports	(6) Ln Exports
IMPORT VARIABLE	Ln Imports	Ln Imports	Ln Prod-Country Imports	Ln Prod-Country Imports	Ln Imports	Ln Imports
Tecper (-1)	0.356	0.356	2.144	0.351	2.565	2.521
	(0.109)***	(0.109)***	(0.0704)***	(0.109)***	(0.695)***	(0.695)***
ln IM (-1)						
(Tecper ≤ 0.07)	0.006		0.379	0.078		
	(0.000)***		(0.027)***	(0.004)***		
(0.07 < Tecper ≤ 1.18)	0.009		0.431	0.096		
	(0.000)***		(0.027)***	(0.004)***		
(Tecper > 1.18)	0.014		0.515	0.124		
	(0.000)***		(0.028)***	(0.004)***		
Interm. No Thresh.					0.050	0.050
					(0.003)***	(0.003)***
ln IM_OECD (-1)						
(Tecper ≤ 0.07%)		0.003				
		(0.000)***				
(0.07% < Tecper ≤ 1.30%)		0.007				
		(0.000)***				
(Tecper > 1.30%)		0.009				
		(0.000)***				
ln IM_NOECD (-1)						
(Tecper ≤ 0.55%)		0.007				
		(0.000)***				
(0.55% < Tecper ≤ 1.18%)		0.004				
		(0.000)***				
(Tecper > 1.18%)		0.010				
		(0.000)***				
ln K goods (-1)						
(Tecper ≤ 0.94%)					0.012	
					(0.003)***	
(Tecper > 0.94%)					0.029	0.030
					(0.004)***	(0.004)***
(0.07% < Tecper ≤ 0.94%)						0.017
						(0.004)***
(Tecper ≤ 0.07%)						0.008
						(0.003)**
p-value (threshold)	0.00	.004	0	0	0.00	.059
Observations	146,862	146,862	146,862	146,862	146,862	146,862
Firm fixed-effects	YES	YES	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES	YES	YES
Number of cnpj	39,307	39,307	39,307	39,307	39,307	39,307
F-stat	348.5	289.7	130	380	125.2	116.5
R-squared	0.40	0.41	0.40	0.44	0.40	0.40

Standard errors in parentheses. All models estimated with time and firm-specific fixed-effects. Control variables ommited are the same as in Table 2.
*** p<0.01, ** p<0.05, * p<0.1

5.7. Robustness: Other Threshold Variables, Value-Added, Wages and Outliers

In Table 8 we perform a number of tests regarding our main choices of variables. First, we test the sensitivity of our results to a different proxy for firms' technological capabilities. In columns (1) and (2), we use the participation of personnel with a college degree in total labour force. This indicator is constructed from the same labour market data we used to obtain the $Tecper$ variable. We consider it to be a less precise indicator because it does not provide information about existing activities and functions within firms, but is nevertheless reasonably correlated to $Tecper$. Both columns (1) and (2) provide estimates compatible with the previous results and confirm the presence of the complementarities observed using the $Tecper$ variable. The only relevant difference is in Column (2), where we obtain a p-value of 14% for a second non-linearity in OECD imports, therefore indicating the best model has only one threshold for this variable. Rather than at odds, this fact further confirms our initial impression that $Tecper$ is indeed the better choice to capture firms' technological capabilities.

In columns (3) and (4), we replace $Tecper$ with total factor productivity as the capability indicator. In the theoretical literature, productivity and capability are usually treated as the same variable, and that is also the case in the Kugler & Verhoogen (2012) model we explored in Section 2. In reality, firm-level productivity is the outcome from the interaction of several internal capabilities and external factors that influence firms' overall efficiency.[12] Therefore, there is less reason to believe productivity will be complementary to the quality of inputs, except to the extent that it correlates with technological capabilities. This is exactly what we observe in columns (3) and (4). There are non-linearities in the effect of imported intermediates along the distribution of productivity, but these do not depict a discernible pattern that could be related to complementarities of any sort. Once we control for several correlated factors, including technological capabilities, it is not clear if the effect of imported intermediates is growing or not for more productive firms.

Finally, in columns (5) and (6) we follow Dosi et al. (2015) and replace TFP and schooling with value added per employee and average wages payed. This framework is intended to

[12] Ones needs to go no further than Lall's (1992) rich characterization of firm-level and national technological capabilities to have an example of this argument.

control for cost competitiveness and production efficiency, although the wage variable usually captures the quality of labour together with its cost, whereas value added indicates not only efficiency but also quality and other factors that might influence prices. Indeed, as usual in the literature we obtain a positive estimate for salary, but our overall results are not affected significantly by the change. In Column (6) we find that in the medium regime the effect of OECD imports is the highest, but the high regime remains significantly above the low one. An important question is related to the trend, i.e. since the coefficient for the medium regime is higher, is the effect of imports increasing or decreasing along the high regime? In order to verify that, we estimate a third threshold for OECD imports and find it at the 89th percentile (not depicted), with a point estimate of 0.051, therefore higher than the 0.047 estimate for the high regime. This confirms there is an increasing trend and the existence of complementarities, although this threshold is found not significant, with a p-value of 24%. This is compatible with diminishing returns for capability complementarities found previously.

Table 8: Robustness Regressions: Different Threshold Variables and Covariates

	(1)	(2)	(3)	(4)	(5)	(6)
DEP VARIABLE	Ln Exports	Ln Exports	Ln Exports	Ln Exports	Ln Exports	Ln Exports
THRESHOLD VARIABLE	College Per.	College Per.	TFP	TFP	Tecper	Tecper
Tecper (-1)	2.84	2.829	2.997	2.981	2.507	2.867
	(0.687)***	(0.687)***	(0.687)***	(0.686)***	(0.749)***	(0.747)***
ln IM (-1)						
(Thresh ≤ π1)	0.043		0.075		0.047	
	(0.003)***		(0.008)***		(0.004)***	
(π1 < Thresh ≤ π2)	0.056		0.044		0.059	
	(0.004)***		(0.003)***		(0.004)***	
(Thresh > π2)	0.076		0.065		0.074	
	(0.005)***		(0.004)***		(0.004)***	
ln IM_OECD (-1)						0.028
(Thresh ≤ δ1)		0.033		0.54		(0.004)***
		(0.003)***		(0.007)***		
(δ1 < Thresh ≤ δ2)		0.055		0.029		0.068
		(0.006)***		(0.004)***		(0.006)***
(Thresh > δ2)		0.064		0.048		0.047
		(0.006)***		(0.005)***		(0.005)***
ln IM_NOECD. Int. (-1)						
(Thresh ≤ λ1)		0.027		0.005		0.036
		(0.004)***		(0.017)		(0.004)***
(λ1 < Thresh ≤ λ2)		0.044		0.068		0.014
		(0.005)***		(0.011)***		(0.005)***
(Thresh > λ2)		0.025		0.028		0.039
		(0.004)***		(0.003)***		(0.005)***
ln VAE					0.088	0.088
					(0.013)***	(0.013)***
ln Salary					0.094	0.095
					(0.047)**	(0.047)**
p-value (threshold)	0	0.14	0	0	0	0
Observations	146,862	146,862	146,862	146,862	141,248	141,248
Firm fixed-effects	YES	YES	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES	YES	YES
Number of groups	39,307	39,307	39,307	39,307	38,747	38,747
F-statistic	124	105	124	100	110	89
R-squared	0.39	0.39	0.40	0.39	0.39	0.38

Notes: in column (1): π1=0.07% and π2 = 1.18%
in column (2): π1=0.09% and π2 = 1.30%
in column (3): δ1=0.15%, δ2=1.47%, λ1=0.42% and λ2=1.42%
in column (4): δ1=0.05%, δ2=1.28%, λ1=0.26% and λ2=1.42%
Standard errors in parentheses. All models estimated with time and firm-specific fixed-effects. Control variables ommited are the same as in Table 2. We add 1 to the number of country product varities to avoid losing observations for non-exporters and importers. *** p<0.01, ** p<0.05, * p<0.1

6. Conclusion

The economic literature has indicated that imported intermediates help firms to obtain cheaper and more varied inputs, frequently of higher quality and with superior embodied technology. In doing so, they allow them to produce more efficiently and increase the variety and quality of their products. Lower prices and better products, in turn, make traders more competitive in foreign markets, boosting exports in existing destinations and frequently helping them to open new ones. Evidence has confirmed that productivity and exports are positively affected by firms' increased use of imported inputs.

Our objective in this paper has been to investigate how innovation and firms' technological capabilities affect the relationship between imported intermediates and firms' export performance. We are motivated by the observation that the process by which firms transform new and better inputs into improved or new products is a process of technological change, and as such, is expected to depend on their skills to manage and implement innovations. Our analysis benefited greatly from datasets containing information about the functions performed by workers, which allowed us to create a proxy indicator of firms' technological capabilities. Using threshold regression techniques, we observed that the effect of imported intermediates on firms' export performance is positively affected by technological capabilities. This complementarity was found to be non-linear however, slowing at higher levels of capabilities, explaining why they could not be captured by simple models with linear interactions.

We found that these complementarities are exclusively found in the case of higher quality imports, indicating more capable firms benefit more from superior inputs to improve their exports. Lower quality imports were frequently found to be less important for firms with greater technological capabilities. A notable exception to this was found for the case of country-product varieties, indicating that cost-competitiveness is highly relevant for Brazilian firms that open new markets for their products, whereas quality-competitiveness increases in importance for the expansion of market shares.

The type of exported product also appears to play a role in two ways. Firstly, there is a direct effect of technological capabilities on firms' export performance, but this is not relevant for products with a low scope for quality differentiation and lower income non-OECD markets, while for products with a higher scope for differentiation and OECD markets the effect appears to be stronger. This result qualifies previous findings regarding the relationship between innovation and exports, which tend to emphasize the role of innovation irrespective of the characteristics of products firms are supplying. Dosi et al. (2015) highlights different sectoral patterns, but our results indicate transversal patterns that are only partially captured in sectoral divisions. It appears that for many exported products innovation is not a relevant factor simply because there are low technological opportunities for firms to compete through product differentiation or consumers are less inclined to pay for quality. Secondly, exporting products with a higher scope for quality differentiation intensifies complementarities between firm capability and input quality. This result is related to the previous, as it indicates complementarities become more important when opportunities for product innovation increase. Both of these patterns provide evidence in favour of theories that suggest the existence of complementarities between input quality and firm capability in the production of higher quality goods and with studies that emphasize the importance of technological capabilities for firms to successfully innovate.

This work also goes beyond firm heterogeneity in terms of productivity and points to innovation as an important determinant of firms' performance in external markets. We make explicit the role of internal capabilities connected to the innovation process, demonstrating both their direct and indirect influence on the international competitiveness of firms. We consider that this provides further encouragement for the exploration of empirical and theoretical approaches that, although not incompatible, go beyond the productivity sorting mechanism described in Melitz-type models of international trade, and look at innovation as one of the main determinants of firms' external performance. Among other benefits, such approaches reveal other dimensions by which trade can affect firms in asymmetrical ways, possibly providing valuable inputs for public policy. In that regard, we showed here that the benefits of accessing intermediates – for instance, in episodes of trade liberalization – will be maximized in the subgroup of highly capable firms, whereas low-skilled firms might not have the ability to take full advantage of the enhanced quality and variety provided by imports.

Appendix I: Descriptive Statistics

Table I.a: Number, average value and country-product pairs of exporters and importers

		2001	2002	2003	2004	2005	2006	2007
Exporters	#	6,979	7,000	7,279	7,764	7,724	8,127	8,062
	value in US$ 1000 (mean)	6,174	6,678	7,970	9,786	11,994	13,269	15,610
	varieties country-prod. (mean)	25.01	26.4	29.01	31.29	34.58	36.25	38.1
Importers Interm.	#	6,503	6,306	6,137	6,308	6,529	6,964	7,316
	value in US$ 1000 (mean)	4,894	4,125	5,015	6,691	7,312	8,291	10,121
	varieties country-prod. (mean)	29.01	29.36	30.99	32.32	32.82	32.87	33.74
Total Firms	#	25,237	26,613	27,986	28,788	30,658	32,077	31,517

Note: For each year the number of firms exporting and importing intermediates is depicted, together with the average value and average number of country-product pairs traded by firm. The last row depicts the total number of firms in the sample each year.

Table I.b: Descriptive Statistics of the main variables according to the presence of technical personnel in the firm, means and standard deviations

	Tecper	
	= 0	> 0
ln TFP	12.62	14.13
	(1.28)	(1.51)
ln EMP	3.94	5.07
	(0.69)	(1.21)
ln K/L	6.52	10.25
	(5.68)	(3.92)
Age	12.90	21.41
	(9.16)	(12.66)
ln EX (R$)	13.26	14.96
	(2.29)	(2.75)
ln # count-prod exported	1.84	2.64
	(0.97)	(1.4)
ln IM (R$)	12.52	14.39
	(2.23)	(2.69)
ln # count-prod imported	1.61	2.68
	(0.93)	(1.45)
Schooling	7.930	9.220
	(1.76)	(1.90)
Tecper (%)	0	2.3%
	0	(0.036)
College deg. (%)	2%	9%
	(0.05)	(0.11)
Total	90,598	56,139

Note: The table depicts the average and standard deviation of the main variables used in the regression, dividing observations that present zero and positive values for science and technological personnel in the firm.

Appendix II: Threshold Regression Model

We follow closely the procedures described by Hansen (1999) and employed by Falvey et al (2006). Initially, we estimate the model with a single threshold for imported intermediates as follows:

$$\ln EX_{it} = \alpha + \delta_1 \ln IM_{it-1}\, I(Tecper_{it-1} < \lambda_1) + \delta_2 \ln IM_{it-1}\, I(Tecper_{it-1} \geq \lambda_1) + \beta_2 \ln K_{it-1} + \beta_3 \ln EMP_{it-1} + \beta_4 SCHOOL_{it-1} + \beta_5 \ln TFP_{it-1} + \beta_6 Tecper_{it-1} + u_i + v_t + u_{it} \quad \text{(A1)}$$

where δ_1 and δ_2 are the coefficients on $\ln IM$ in the low and high regime as defined by the threshold value, λ_1, of $Tecper$. We estimate λ_1 by least squares, which involves: (i) estimating equation $(A1)$ for distinct values of λ_1; and (ii) obtaining an estimate of $\hat{\lambda}_1$ by selecting the value of λ_1 that minimizes the sum of squared errors obtained from the regressions in step (i). We limit our search to values of $Tecper$ below the 90th percentile of non-zero values[13], and define a minimum range of 5% for each regime, i.e. each estimated regime must include at least 5% of observations within the estimation interval. Once we obtain $\hat{\lambda}_1$, estimation of $\hat{\lambda}_2$ is obtained by the same procedure, i.e. choosing the values of λ_1 and λ_2 that minimize the sum of squared errors of the following equation:

$$\ln EX_{it} = \alpha + \delta_1 \ln IM_{it-1}\,(Tecper_{it-1} < \lambda_1) + \delta_2 \ln IM_{it-1}\,(\lambda_1 \leq Tecper_{it-1} < \lambda_2) + \delta_3 \ln IM_{it-1}\,(\lambda_2 \geq Tecper_{it-1}) + \beta_2 \ln K_{it-1} + \beta_3 \ln EMP_{it-1} + \beta_4 SCHOOL_{it-1} + \beta_5 \ln TFP_{it-1} + \beta_6 Tecper_{it-1} + u_i + v_t + u_{it} \quad \text{(A2)}$$

Since this is computationally demanding, we follow a sequential procedure, i.e. we fix $\hat{\lambda}_1$ while searching for $\hat{\lambda}_2$ according to steps (i) and (ii) above. Adopting this approach, $\hat{\lambda}_2$ is efficient but $\hat{\lambda}_1$ is not (Hansen, 1999). We therefore follow the suggestion of Hansen (1999)

[13] We tested for values of *Tecper* until the 95th percentile in initial estimations of (A1) but there was no improvement in the quality of adjustment after the 90th percentile, only decreases followed by stabilization. Therefore, we limit our search to the 90th percentile to reduce the computational burden of the model.

and take a third step, namely: (iii) fix $\hat{\lambda}_2$ to search once again for the first threshold, which we call $\hat{\lambda}_1^r$.

At each step we estimate the significance of the threshold we obtain. To do this, it is necessary to follow a bootstrap procedure since under the null hypothesis – $H_o: \delta_1 = \delta_2$ for $(A1)$ or $H_o: \delta_2 = \delta_3$ for $(A2)$ – the threshold is not identified and the test has a non-standard distribution. We follow the approach of Hansen (1999) and bootstrap to simulate the distribution of the likelihood ratio (F_1) test and obtain a p-value for the test. The likelihood ratio test is given by the following equation:

$$F_1 = n(t-1)\frac{S_0 - S_1}{S_1}$$

where S_0 and S_1 are the residual sum of squares under the null and alternative hypotheses, respectively. The bootstrap is created by drawing from the distribution of the residuals of the estimated threshold model and repeating 1,000 times. The p-value is the number of times the simulated F_1 is above the actual one and we adopt a 5% level of significance for rejecting the null.

We adopt an analogous procedure to estimate the models with the two non-linear variables, OECD and non-OECD imports: we follow steps (i) and (ii) for OECD imports and repeat (i) and (ii) for non-OECD imports fixing the thresholds found for OECD imports. We then adapt (iii) for the two-variable case by fixing the number of thresholds found for non-OECD imports and repeating (i) and (ii) for OECD imports.

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