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Abstract:
This paper aids our understanding of the link between innovation and exporting behavior by detailing how firms may purposefully decide on the source country for the imported innovation and the market that they ultimately serve. We argue that firms who invest in the state-of-the-art technologies pursue a more aggressive exporting strategy and test this hypothesis with firm-level data from Argentina. The empirical results, based on the data from 1402 Argentinean firms over the period 1998-2001, suggest the existence of positive and highly significant effect of spending on new technology on the export performance. The magnitude of the effect is large: a one percent increase in spending on technology increases exports by 30 percent. The effect is even larger if the technology is sourced from one of the world's leaders: a one percent increase in spending on technology imported from leaders increases exports by 176 percent, whereas a one percent increase in spending on technology imported from non-leaders increases exports by about 28 percent.

Keywords: Technology Choice, Exporting, Productivity, Imports of Technology
JEL classification: O3; F1; L1

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1. Introduction

For the past ten years learning-by-exporting literature has been trying to resolve the debate as to whether there are productivity gains from exporting. What the literature agrees on wholeheartedly is that firms who become exporters experience productivity advantage prior to exporting. There are two possible explanations for this pattern. Either better firms self-select into exporting because of an exogenous draw from productivity distribution (Melitz 2003) that allows them to cover the sunk costs associated with exporting or firms deliberately invest in productivity improvements with the intention of breaking into exporting markets. The newest wave of the learning-by-exporting literature attends to the latter possibility by creating a link between deliberate actions of a firm to improve productivity, such as technology upgrading, and the exporting behavior (Aw et al., 2007; Iacovone and Javorcik, 2007; Aw et al., 2008; Damijan et al., 2008; Bustos, 2009; Lileeva and Trefler, forthcoming, to name a few).

This paper aids our understanding of the link between innovation and exporting behavior by detailing how firms may purposefully decide on the source country for the imported innovation and the market that they ultimately serve. We argue that firms who invest in the state-of-the-art technologies pursue a more aggressive exporting strategy and test this hypothesis with firm-level data from Argentina.

The theoretical framework is based on Schmidt (2010) who develops two extensions of the Melitz model. First, she departs from Melitz's assumption of a single, common to all firms, production technology and allows firms to choose between three alternative technologies. The most basic technology (L) is analogous to the firm's own technological frontier: firms use the existing production technologies and do not invest in technology upgrading. The other two technologies go beyond the firm's own technological frontier and differ in their complexity: some firms invest in technological upgrading, however they source technology from the countries within the world technological frontier (technology M), whereas others strive for the world technological frontier and source the technologies from the world leaders in R&D (technology H). The choice between the three alternative technologies, through its impact on productivity, affects the firm's exporting behavior: the higher the firm's technological status, the more aggressive the market strategy it is likely to undergo.

The use of two different exporting profiles – low-commitment and high-commitment exporters – is the second extension of the Melitz model. Low-commitment exporters make the minimum possible investment required to penetrate export markets, whereas high-commitment exporters make additional investments for the sake of establishing themselves in the export market (which could be expressed either in high export sales or in the type of market, with markets in advanced countries being the most challenging to penetrate).

The main issue raised in the empirical part of the paper is whether the sources of innovation incorporated by a firm matter for the chosen market strategy. Although there may be an important causal effect of the choice of technology on export performance, there could also be substantial bias resulting from unobserved heterogeneity, the joint determination of exports and technology decisions, selection into exporting, and additional investments into technology after exporting. For example, if there are fixed costs associated with the upgrading of technology, as posited by our theoretical model, larger and more productive firms will be more likely to invest in new technologies. Moreover, it is sometimes believed that firms who export follow a very ambitious expansion strategy that may also make them more likely than other firms to become involved in other related activities, such as upgrading of technology. In empirical work, if "ambition" is not observed, some of the variation in export performance that should be attributed to differences in ambition may be mistakenly attributed to the differences in investments in technology upgrading. Even more likely is the situation in which a forward-looking firm makes a decision to enter foreign markets and, to improve the survival chances, decides to invest in appropriate technology.

Credibly dealing with the endogeneity of the choice of technology empirically is not easy. Whereas certain firm-specific characteristics may be able to capture some factors such as ambition or anticipatory decision-making, the large amount of variation in export performance remains unexplained after controlling for available firm characteristics. We need to find instruments that both explain a reasonable portion of variation in investments in technology and are unrelated to the firm's export performance except through their effect on the investment in technology. In practice, it is difficult to find such instruments and we rely heavily on our theoretical model to circumvent this problem and to identify a list of variables to be used as instruments. Specifically, we use proxies for the inputs into the production function – total labor, investment in capital goods and skill intensity of the labor force, as well as the life cycle of the main product of the firm – as determinants of productivity and, consequently, of the investments in technology.

The empirical results, based on the data from 1402 Argentinean firms over the period 1998-2001, suggest the existence of positive and highly significant effect of spending on new technology on the export performance. The magnitude of the effect is large: a one percent increase in spending on technology increases exports by 30 percent. The effect is even larger if the technology is sourced from one of the world's leaders: a one percent increase in spending on technology imported from leaders increases exports by 176 percent, whereas a one percent increase in spending on technology imported from non-leaders increases exports by about 28 percent.

2. Literature Review

Several studies report statistically significant strong positive linkages between technology upgrading and exports. Wakelin (1998) uses UK firm-level data to uncover a significant positive relationship between the number of innovations and exporting. Roper (2001) uses data for Ireland to show that plants with in-house R&D capability are more likely to export. Sterlacchini (2001) finds that R&D intensity, as well as other types of innovation, have a positive correlation with the propensity to export and export intensity for Italian firms. Bleaney and Wakelin (2002) use data for UK to show that firms are more likely to export if they belong to a sector with a high R&D intensity. Love and Barrios et al. (2003) find a positive impact of R&D spillovers on export intensity of Spanish firms.

2.1. What explains positive correlation between spending on technology and export performance?

In this section we consider the channels through which technology upgrading and exporting outcomes may occur.

2.1.1. Causal Channels

It is conceivable that at least some of the correlation between technology upgrading and export outcomes may be causal. Indeed, there are several mechanisms through which technology upgrading could improve export performance. It is well established that more productive firms become exporters.[1] If this

[1] According to Wagner (2007), who summarizes the results from a comprehensive survey of the empirical literature that covers 45 studies with data from 33 countries published between 1995 and 2006, details aside, the big picture that emerges after a decade of firm-level empirical research is that exporters are more productive than non-exporters, and that the more productive firms self-select into export markets, while exporting does not necessarily improve productivity.

productivity premium is induced by upgrading of technology, investments in technology upgrading will result in better export performance.[2]

Another causal channel can be attributed to the product-cycle models (Vernon, 1966; Krugman, 1979). The basic prediction of these models is that developed countries export high tech goods, which are later imitated by developing countries. Eventually, developing countries will export these goods to the developed countries. For developed countries to keep up their exports (and incomes), they must continually innovate. The more they innovate, the larger are their exports.

For some firms, upgrading of technology may change their network. For example, a firm that decides to import technology may establish networks that would allow it to meet prospects for its products abroad and thus expand its foreign sales.[3] In addition to affecting the type of prospects firms come into contact with, investments in technology upgrading may make these firms more attractive to the foreign clients via signaling channels.[4]

Technology upgrading may also have an impact on the survival rates in foreign markets.[5] It may be that investors in technology upgrading have more precise information regarding the market they intend to target, thus reducing the incidence of failure due to later shocks about the realized "market match." This might be particularly true if the firm imports technology from a market that it later targets.[6] Additionally, investors in technology upgrading may engage in other activities that reduce the incidence of failure.

These channels plausibly explain why higher spending on technology upgrading should have a causal effect on export performance. Unfortunately, recovering this causal effect is not straightforward.

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[2] According to Aw et al. (2009), R&D investment increases future productivity of a Taiwanese plant by 4.79 percent.
[3] For an overview of how networks impact trade see Rauch (2001).
[4] This supposition is an extension of the idea of the signaling properties of R&D expenses by Cazavan-Jeny and Jeanjean (2003).
[5] Baldwin and Gu (2004) studies the differences in the impact of process vs. product innovation on plants' survival. They report that process innovation improves survival rates for Canadian manufacturing plants, whereas introduction of a new product weakens them. It is conceivable that similar forces are at play for the plants operating in foreign markets.
[6] Whereas the literature on the link between productivity gains from exporting and the destination of the exports is emerging (Barrios et al. (2003), Ruane and Sutherland (2005), Trofimenko (2008)), the evidence on the link between the sources of technology and the level of commitment in export markets is limited. Schmidt (2010) proposes a theoretical model that links these two outcomes.

Next we discuss several problems that arise in uncovering the causal effect of technology upgrading on export outcomes.

2.1.2. Unobserved Heterogeneity and the Joint Determination of Technology Upgrading and Exporting Outcomes

Spending on technology is endogenous to export market expectations and realizations. Additionally, factors affecting the cost of technology upgrading may have an independent effect on export outcomes. Because of this, firms who find it optimal to invest heavily in technology upgrading are likely to have systematically different export outcomes from those who invest little. To the extent that we do not observe all factors affecting the choices to upgrade technology and to export, the estimated impact of spending on technology is likely to reflect omitted variables bias. In Schmidt (2010) total firm productivity is determined by two components: "idiosyncratic factors" and the quality of technology. Because high absorptive capacity (modeled as high idiosyncratic productivity) lowers a firm's cost of technology upgrading while simultaneously independently improving its prospects in the foreign markets, there is a positive correlation between the two outcomes. One could use "sales" as a control variable to proxy for the "idiosyncratic productivity"[7]. However, to the extent that the model necessarily entails a simplification of reality and there could be other factors that influence the absorptive capacity and remain unaccounted for, the estimated impact of spending on technology on export performance may still be biased upward.

The bias due to unobserved heterogeneity does not have to be positive. This is most clear when considering how firms may alter spending on technology in response to the expectations in foreign markets. For example, a well-connected firm with good prospects in a foreign market (networks effect) may find it optimal to make relatively small investments in technology upgrading. In this example, the existence of networks is positively correlated to the foreign market expectations and negatively correlated to the spending on technology. If one does not control adequately for the existence of networks the estimated impact of the technology upgrading is likely to be biased downward.

Firms likely respond not only to the expectations in foreign markets but also to the foreign market realizations. To the extent that technology upgrading has a positive foreign market return, once a firm enters a foreign market it may no longer find additional technology investments optimal.

[7] See Bernard et. al. (2001) on the use of sales as a proxy for productivity.

In general, unobserved heterogeneity and the joint determination of technology upgrading and export outcomes will bias OLS estimates on the impact of the spending on technology in an indeterminate direction. Instrumenting for technology upgrading can circumvent this problem as long as the instrument affects the decision to upgrading technology but has no independent impact on the decision to export.

2.1.3. Selection Bias

Another obstacle to identifying the effect of technology upgrading on export performance is selection bias. Sales in foreign markets are observed only for those firms who choose to export. It seems plausible that the latent benefits from exporting for those who choose not to enter foreign markets are worse than for exporters. If technology upgrading has a positive impact on the latent benefits from exporting, as spending on technology increases, firms with marginal prospects in foreign markets may choose to export. This will pull down the average export sales for firms with large investments in technology and generate a downward bias of the estimates. In general, one would need an additional variable that affects the probability of exporting but no export sales to properly address this issue.

2.2. Sorting out causality empirically

The work by Lachenmaier and Wössmann (2006) is the only paper that recognizes the endogenous nature of innovation without incorporating the reverse effect of exports on innovation. These authors use instrumental-variables method to yield the estimates of the causal effect of innovation on exports. Specifically, they use information on innovation impulses – such as suggestions from the firms' production and resource management – and on innovation obstacles – such as the lack of equity capital – and find that innovation leads to an increase of roughly seven percentage points in the export share of German manufacturing firms.

Many more authors focus on the existence of the reverse effect of exports on technology upgrading, while simultaneously considering the possibility of the previously discussed causal effect of technology upgrading on exports. Using data from Taiwanese manufacturing firms, Aw et al. (2007) find that exporters who invest in worker training or R&D have significantly higher future productivity than exporters who do not make such investments. They argue that R&D spending and worker training improve a firm's ability to benefit from exposure to foreign markets, but do not stimulate participation in foreign markets. They arrive at these findings in a bivariate probit framework that allows for the interdependence of exporting and R&D decisions. Their approach has become a convention for other works that investigate the link between exports and technology upgrading.

Girma et al. (2008) use firm level data for Great Britain and Ireland to explore whether R&D activity stimulates exports and whether exporters demonstrate learning effects from their exporting activity through improved R&D activity post exporting. The authors support earlier findings, that both R&D and exporting are persistent activities. More importantly, the authors find that in case of Ireland, lagged exporting status is significantly related to the R&D status. That is, previous exporting experience enhances the innovative capability of the firms in a small open economy. The evidence in favor of the hypothesis that causality runs from R&D to exports is not robust.

Damijan et al. (2008) use firm level data from Slovenia to test whether a firm's inclination to innovate increases its probability of becoming an exporter, as well as whether exporting leads to additional innovations. The unique feature of this study is that the authors are able to compare different types of innovation: product and process. These authors find no evidence to support the hypothesis that either process or product innovation increases the likelihood of becoming an exporter. They do find evidence that exporting stimulates innovative activity, in particular product innovations.

3. Theoretical Background

As shown in the previous section, the multiple factors driving the relationship between technology upgrading and export performance make it difficult to interpret the observed correlation. We attempt to formalize this relationship in a theoretical framework.

The point of departure of our paper is an extension of the Melitz (2003) Monopolistic Competition trade model with heterogeneous firms by Schmidt (2010), who lets us draw conclusions regarding the correlations between the firm's choice of technology and the resulting exporting behavior. She proposes two adjustments to the Melitz model. The first extension consists in the introduction of technology choice between three alternatives: L, M and H. Technology L is assumed to be the same as Melitz's single production technology. Technologies M and H are assumed to be superior production technologies. This superiority stems from two sources: (1) these technologies substitute the more primitive capital goods used in technology L with newer, updated versions which embody technological advances, and (2) technologies M and H are more skill-intensive than L. Technologies M and H are equally skill intensive, but H is superior to M because it incorporates world-technology frontier capital goods, while the capital goods used in M remain inside such frontier. Each technology features a constant marginal cost (c), which reflects the payments to two types of labor, skilled (S) and unskilled (U), and a fixed cost (f), which in turn reflects the cost of the machinery needed for production. The more advanced the technology, the higher the fixed cost and the lower the variable cost.

The second extension consists in the introduction of two different exporting profiles: "low-commitment exporters" and "high-commitment exporters." Low-commitment exporters make the minimum investment required to penetrate export markets, whereas high-commitment exporters make an additional investment for the sake of gaining additional sales in foreign markets. This way, the three aforementioned "technology strategies" (L, M, and H) have a correspondence with the three "market strategies" (non-exporter, low-commitment exporter, and high-commitment exporter) which emerge in the open economy setting, with more productive firms using better technologies and exporting more.

As in Melitz (2003) and Bustos (2005), firms in Schmidt (2010) are heterogeneous in their productivity, in the sense that the marginal labor cost varies across firms using the same technology. This idiosyncratic component of labor productivity will be indexed by $\varphi > 0$.[8] The Total Cost function for technology T is:

$TC(\varphi) = f_T + c_T \frac{q}{\varphi}$, for T= L, M and H,

where $f_L < f_M < f_H$ and $c_L > c_M > c_H$.[9]

The expressions for technology-specific variable costs are:

- $c_L = a_{LU} + \frac{w_S}{w_U} a_{LS}$, where w_U is the salary paid to unskilled workers and w_S is the salary paid to skilled workers;

[8] According to Melitz (2003), higher productivity can be understood either as producing a symmetric variety at lower marginal cost (the so called "efficiency differences interpretation" of the Melitz model) or as producing a higher quality variety at equal cost (the "quality differences interpretation" of the Melitz model). Given the form of product differentiation assumed, the modeling of either type of productivity difference is isomorphic.

[9] The modeling of the cost functions follow Bustos (2005), only departing from her framework in the introduction of the "productivity enhancing effect" α_H , which is incorporated in c_H .

- $c_M = a_{MU} + \frac{w_S}{w_U} a_{MS}$, being $\frac{a_{MS}}{a_{MU}} > \frac{a_{LS}}{a_{LU}}$ as technology M is more skill-intensive than technology L;
- $c_H = a_{HU} + \frac{w_S}{w_U} a_{HS} = \left[a_{MU} + \frac{w_S}{w_U} a_{MS} \right] (1 - \alpha_H)$ because $a_{HU} = a_{MU}$ and $a_{HS} = a_{MS}$.

That is, technologies M and H are equally skill-intensive. The only difference between them lies in the "productivity enhancing effect" α_H, where $0 < \alpha_H < 1$. The "productivity enhancing effect" stems from the superior quality of the technology embodied in H-type machines. It has a homogeneous enhancing effect on the productivity of both skilled and unskilled labor. This results in c_H being lower than c_M.

Because Schmidt's deterministic approach is not the most suitable for the empirical investigation we attempt in this paper, we will depart slightly from such framework by introducing a probabilistic element. We will still assume that upgrading technology entails paying a fixed cost larger than the one needed to produce with the existing technology (L). Moreover, the costs are larger for upgrading to H than to M. However, instead of modeling the gains for the firm from upgrading technology as a deterministic decrease in the parameter reflecting its variable cost like in Schmidt (2010), we will assume that adopting a superior technology is equivalent to participation in a lottery. The expected value from such participation is an increase of a given proportion in the firm's productivity parameter. The expected value of such lottery is assumed larger for firms adopting technology H.[10] As a result, the distribution of productivities after technology choice is more skewed towards the high values. While for firms who use technology L total productivity equals idiosyncratic productivity, firms adopting the superior technologies are likely to experience a boost in their overall productivity because, along with the idiosyncratic factors, they now also have technological factors contributing to it. However, the possibility of ending up with a lower productivity parameter than before upgrading technology is not excluded.[11]

[10] This is also more in line with the intuition that innovation activities entail risks for the firm (because the positive results are not guaranteed).

[11] While most firms will experience productivity gains as a consequence of upgrading technology, some will fail to adequately absorb the new technologies and will consequently experience a negative impact on their overall productivity. Thus, some firms may end up with lower productivity than prior to the introduction of new technologies.

Regarding the "market strategy" choice, the departing point is Melitz's assumption that exporters face two types of trade related costs: a variable "iceberg" cost (capturing mainly fleet and tariffs) and a fixed cost (which is independent from export volume). The fixed costs represent the investment needed to penetrate export markets. It is assumed that firms can choose between three alternative states regarding the participation in export markets: they can serve the domestic market only, or they can self-select into the export markets in two different ways, one "more accessible" and the other "more demanding". The "accessible" route involves incurring the minimum fixed cost required to enter the foreign market. Firms who follow this strategy are called "low-commitment exporters". The "demanding" route involves making an additional investment, beyond the minimum fixed cost required to begin exporting, in order to gain a greater market share in the foreign market. Firms who follow this strategy are called "high-commitment exporters". The per unit trade iceberg cost captures mainly fleet and tariffs and is the same for both types of exporting firms.

In the model sales only increase if the price decreases or, for a given price, as the quality of the product increases (which is equivalent to saying that the firm's overall productivity increases). Hence, the specific purpose of the additional trade-related fixed investments made by high-commitment exporters is to make potential buyers in the foreign market perceive a qualitative difference in the product they sell, which will make it stand as better than competing varieties, no matter if such perceived qualitative difference is real or imaginary.[12] This way, the firm engaging in the most aggressive export profile is able to expand its sales in the foreign market beyond what its overall productivity would predict. Therefore, given its overall productivity level, a firm will achieve greater export sales (and thus, higher total sales) if it follows the "demanding" strategy than if it follows the "accessible" strategy. This will be reflected in higher export sales by high-commitment exporters. It is in exchange for greater sales that the high-commitment exporter is willing to pay a higher fixed export cost.

Among other things, Schmidt (2010) posits a correlation between the three technology strategies (L, M, and H) and the three market strategies (non-exporter, low-commitment exporter, and high-commitment exporter). As stated before, her deterministic approach excludes the possibility of any overlaps. With the aforementioned modification of the theoretical model, we relax this requirement and

[12] This additional trade-related investment can be understood in terms of the creation of better distribution channels, better post-sale service structures, extra advertising expenditure, etc.

only anticipate that the *majority* of firms will follow the pattern outlined in the model. That is, we anticipate that the higher the firm's idiosyncratic productivity, the higher its expected technological status will be, and the higher its technological status, the higher the market status it is likely to achieve. Consequently the following pattern should be observed in the data: the majority of Technology L users are non-exporters; the majority of Technology M users are low-commitment exporters; and the majority of technology H users are high-commitment exporters.

We also expect the emergence of performance differences between Technology L users (firms who have not updated technology at all and are less skill-intensive) and the rest of the firms (Technology M and H users, those who have updated technology and are more skill-intensive). Moreover, we claim that such differences should be larger between the groups L and M than between the groups M and H. In line with some recent literature relating the quality of inputs with the quality of output[13], we also expect the nature of the differences in performance between users of technologies L and M, and H and M to differ. In particular, we speculate that the differences in performance found between Technology L users and Technology M users are mainly attributable to "efficiency differences." That is, Technology M users would be able to produce a quality similar to that produced by Technology L users but at a lower cost. In contrast, the differences in performance between Technology M users and Technology H users would be mainly due to the "quality differences." That is, Technology H users would be producing a higher quality product than Technology M and Technology L users. Even though our data do not allow thorough investigation of this last "quality-differences" hypothesis, they nevertheless allow at least some insight into the matter.[14]

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[13] Verhoogen (2008) posits the hypothesis that more productive manufacturing plants produce better quality products and pay higher salaries –to more skilled workers-, for which he finds support in firm-level Mexican data. Kugler and Verhoogen (2008) extend the Melitz (2003) framework to include heterogeneity of inputs and a complementarity between plant productivity and input quality in producing output quality. Using data on Colombian manufacturing plants they find that both input and output prices are positively correlated with plant size –a common proxy for plant productivity- and that both correlations are more positive in industries with more scope for quality differentiation.

[14] While a thorough investigation of such "quality differences" hypothesis would require informatioon about product prices or, at least, export destinations – which is not available in the current dataset – we are able to have some insight into the question by considering the information about the location of the firm's main market.

4. Data and Stylized Facts

We use information from the Second National Survey on Innovation and Technological Conduct of Argentine Enterprises 1998-2001 (*Segunda Encuesta Nacional de Innovación y Conducta Tecnológica de las Empresas Argentinas 1998-2001*).

The unique feature of this data set is the amount of information it provides on the firm-level R&D and non-R&D innovative activities. Among the reported categories are: in-house and external I&D, purchase of capital goods containing technological innovations for the firm, purchase of hardware and software entailing innovations for the firm, technology transfers, in-house engineering and industrial design, in-house innovations in management, training of employees in subjects or activities that are innovative for the firm, and consulting services. The data include expenses on each of these activities, percentage of them that has been imported, as well as the main supplier, i.e. the country source of the imported innovation.

The data set also contains information on the firm's exporting activities: total volume of exports and the main market for the firm's products: whether it is located in the same province/state where the firm has its headquarters, in the firm's home country (Argentina), in MERCOSUR, in the USA, in the EU or in other countries. Unfortunately, there is no direct information on the destination markets and the exact amounts of exports going to those markets. Another caveat of the data is the absence of information on the industry to which a firm belongs. We use information on the product cycle of the main products to proxy for this essential variable in our analysis.

Additional information includes: whether the firm is independent or belongs to a firms' group; percentage of foreign capital in firm's total capital and which country it comes from; total sales; imports of inputs, parts and pieces, final products and capital goods; gross investment in capital goods and other investments; and number of employees (by level of education).

Of all firms, 52.3% report to have positive technology spending in 1998 and 55.4% in 2001. Exporters are more likely to be innovating: of the 687 exporters in 1998, 66.08% report positive technology spending; of the 739 exporters in 2001, 67.4% report positive technology spending. As shown in Table 1, most firms, irrespective of the exporting status, innovate by investing in capital goods containing innovation (the next most common innovative activities are in-house R&D, employee training, and purchases of computers and software). It is also by far the largest expense category: the median spending by exporters was 400 thousand pesos in 1998 and over 220 thousand pesos in 2001; non-exporters invested one third of the amounts invested by exporters, but still more than into any other category. Across all spending categories, it is safe to say that exporters are not only more likely to invest in technology upgrading but they also spend several times the amounts spent by non-exporters.

Purchases of software and hardware, as well as technology transfers, are the three categories that are more likely to be entirely imported. However, capital goods containing innovations are also likely to be coming from foreign sources. Curiously, non-exporters are the ones who invest a greater share in the imported capital goods. One would think that exporters, who have to operate in highly competitive foreign markets, would be the ones investing in capital goods of foreign origin and, presumably, of better quality. This logic is not supported by our data.

We now look at some of the data patterns predicted by the theory in section 3. First, we define firms according to the technology strategy that they are pursuing into three groups: those who do not upgrade technology (L), those who invest in technology upgrading from below-the-world-frontier sources (M), and those who import at least part of the innovations incorporated by the firm from the world leaders (H). We begin by verifying the predictions (1) that the firms who upgrade technology are more skill intensive than those who do not and (2) that the firms who upgrade technology have no differences in skill intensity. As shown in Table 2, the firms investing in technology upgrading are twice as skill intensive as those who do not. The p-values for the differences in skill intensity for the Technology M and Technology H users reveal that also Technology H are somewhat more skill intensive, this difference is not statistically significant.

Secondly, in Table 3 we report mean values for the logarithm of total sales per worker for firms of different technology upgrading strategies. These values suggest that the firms who upgrade technology are on average more productive than the firms who do not, and that firms who invest in technology from world leaders are more productive than firms who invest in technology from other sources.

Finally, we also distinguish between two types of exporters, based on the degree of their commitment in foreign markets: exporters with the main market in Argentina and, hence, exporting less than half of their production, and exporters with the main market abroad and, hence, exporting over half of their production. We then link the technology strategy of the firm in 1998 with the exporting status of the firm in 2001. We then check the following predictions from the theory: (1) the majority of Technology L users are non-exporters; (2) the majority of Technology M users are low-commitment exporters; and the majority of Technology H users are high-commitment exporters.

As shown in Table 4, most of the firms who did not invest in technology upgrading in 1998 are non-exporters in 2001. Most of the firms who invested in technology M are low-commitment exporters with the main market remaining in Argentina. The theoretical pattern that does not withstand the data check is the third one: the majority of the technology H users are low-commitment rather than high-commitment exporters. However, we do see that the proportion of high-commitment exporters among firms who have invested in technology H is significantly larger than the proportion of high-commitment exporters among firms who invested in technology M (and among firms who did not invest in technology, thus L users). Furthermore, we find that the percentages of low-commitment exporters among firms who invested in technologies M and H are roughly the same (57.32% and 56.36% respectively) and well above the percentage of low-commitment exporters among L users (30.71%). We also find that the percentage of high-commitment exporters among firms who invested in technology H (10%) is significantly above the percentages of high-commitment exporters among users of M and L, which are almost the same in both technologies (7.96% and 8.01% respectively).

A plausible interpretation of these results could be that while users of technology M are definitely "more efficient" than users of technology L (as evidenced by the percentage of M exporters being nearly the double of the percentage of L exporters), they would not be exploiting any "quality differences", as evidenced by the similar percentages of high-commitment exporters in both technologies (recall that the additional fixed investments aimed at enhancing perceived product quality in the export markets are central to our definition of the high-commitment exporting strategy). On the contrary, the similar percentages of low-commitment exporters in technologies M and H would suggest that there are no major efficiency differences between both technologies; the substantially larger proportion of high-commitment exporters in H points out at the existence of quality differences between M and H.

Given the very small number of the Technology H users who are high-commitment exporters (11 firms), we are able to check their records manually. We find that firms in this group are more likely to trade with exigent markets in the US, EU, or the broad category "other" which contains countries such as Japan, Switzerland, Canada and Australia. We also find that firms in this group targeting mainly high-income countries do not simultaneously have an equally important target market in medium income countries, and vice versa. Since we only have information on the main market and not on the exact destinations, we leave this venue of research for future analysis.

To summarize, cursory look at the data suggest the presence of linkages between the firm's productivity, its choice of technology upgrading strategy and its market strategy. We now test the existence of such linkages formally.

5. Econometric Specification and Estimation Results

In order to estimate the relationship between the choice of technology and the export performance, we examine equation (1):

$$\log(Exports)_{i,2001} = \beta_0 + \beta_1 \log(TechSpending)_{i,1998} + \beta_2 \log(Sales)_{i,1998} + \beta_3 ForeignOwnership_i + \beta_4 Group_i + \varepsilon_i$$

Our primary interest is in β_1 which measures the return to additional spending on technology, while controlling for total sales, foreign ownership of the firm, and belonging to some group (for example, ethnic). Conventional wisdom, as discussed in earlier sections, suggests that β_1 is positive.

This base line analysis is being adjusted, depending on the questions we ask. Thus, when we link spending on technology to the level of commitment with the export markets, we replace the dependent variable "export sales" with a categorical variable equal to 0 for non-exporters, 1 for exporters with the main market in Argentina, and 2 for exporters with the main market abroad. As for the right hand side variable "technology spending", depending on specification we define it as spending on domestic or imported technology, technology imported from the world leaders, and technology imported from other sources. We also look at the various components of technological spending, in which case we define technology spending to be spending on in-house R&D, spending on external R&D, spending on capital goods containing innovation for the firm, and so on for the ten components discussed in detail in the data section.

Endogeneity bias will be present if there exist unobservable determinants of export performance (i.e. elements of ε_i) that also influence spending on technology and, potentially, total sales. If these unobservable determinants were firm-specific, permanent attributes that drive certain firms to invest more in technology and to export, we could estimate β_1 consistently with a fixed effects estimator. We cannot resort to this approach for two reasons. First, we do not have sufficient multiple observations per firm to conduct such analysis. Secondly, our theoretical model states that, because of the fixed costs associated with upgrading of technology, the decision to invest in new technology is determined by the ability to cover those costs, i.e. by the firm's productivity.[15] In addition, since there is a feedback from investment in technology to productivity, we treat both spending on technology and sales, a measure of overall performance of the firm, as endogenous. To support our logic, we conduct a formal endogeneity test in which we fail to reject the null hypothesis that the technology spending or sales can be treated as exogenous in our empirical specification. Hence, these variables are instrumented in the following first stage equations:

(2)

$$\log(TechSpending)_{i,1998} = \gamma_0 + \gamma_1 ForeignOwnership_i + \gamma_2 OtherInvestment_{i,1998} + \gamma_3 InvestmentCapital_{i,1998} + \\ + \gamma_4 TotalLabor_{i,1998} + \gamma_5 SkillIntensity_{i,1998} + \gamma_6 Group_i + \gamma_7 LifeCycle_i + \eta_i$$

and

(3)

$$\log(Sales)_{i,1998} = \delta_0 + \delta_1 ForeignOwnership_i + \delta_2 OtherInvestment_{i,1998} + \delta_3 InvestmentCapital_{i,1998} + \\ + \delta_4 TotalLabor_{i,1998} + \delta_5 SkillIntensity_{i,1998} + \delta_6 Group_i + \delta_7 LifeCycle + \mu_i$$

Excluded instruments in these regressions are total labor, skill intensity, investment in capital goods, as well as the life cycle of a product.[16] You will notice that we do not treat foreign ownership as an excluded instrument. Although foreign ownership is often believed to be a channel for the transfer of know-how and should as such be included as the determinant of spending on technology, domestic firms are often bought out by foreigners with the purpose of serving regional, not local market. As such, foreign ownership is likely to have a direct impact on export performance. The same is true for "other investments", which by their definition also includes trade-related investments.

[15] Productivity is also a determinant of the ability of the firm to assimilate new technology, which is assumed to be complementary with skilled labor (Bartel and Source (1987), Acemoglu (1998, 2003), Krusell et. al. (2000) and Bustos (2005), among others have found empirical support for this hypothesis).

[16] An important caveat is the use of imported capital goods spending instead of investment in capital goods as an instrument in the first stage for the regressions where "technology spending" is broken down into imported vs. domestic and where spending is defined according to the source of technology. This is done because, according to the specification tests, the spending on imported capital goods proves to be a better instrument in these regressions than the overall investment in capital goods.

In order to use total labor, skill intensity, investment in capital goods and the life cycle of a product as instruments, the following conditions must be satisfied. First, these variables must influence spending on technology and sales. Second, these variables must not have a direct impact on export performance. That is, the only influence that total labor, skill intensity, investment in capital goods and life cycle of a product have on export performance must come through their effect on sales and spending on technology.

When considering the validity of the fist assumption, it is important to keep in mind that if the excluded instruments are only weakly correlated with spending on technology and sales, then even a weak correlation between these instruments and the residual ε_i can induce a large inconsistency in the IV estimate of β_1 (and that of β_2). Secondly, the finite sample bias of the IV estimate approaches that of OLS as the correlation between the excluded instruments and spending on technology and sales approaches zero. Fortunately, total sales can be explained very well by the inputs into production function or their proxies. Since spending on technology is also determined by the ability to cover fixed costs, inputs into production function and their quality will also explain a large part of variation in this variable. We formally check the relevance of the proposed instruments by making sure that the resulting F statistics are all greater than 10 (in our setting, by a large margin). The validity of the second assumption may be a suspect. We test overidentifying restrictions with Sargan test and arrive at very high p-values.

To summarize, we find that total labor, skill intensity, investment in capital goods, and the life cycle of a product are empirically compelling instruments and proceed under the assumption that they are valid.

6. Results

6.1. Impact of Spending on Technology on Export Performance – Breakdown by the Source

Turning to the estimation output, findings reported in Table 5 suggest a strong positive relationship between spending on technology, firm's efficiency and exports. A one percent increase in total spending on technology increases exports by approximately 30 percent. The impact of efficiency is even stronger – a one percent increase in efficiency increases exports by more than 150 percent.

As expected from previous research, we also find a positive and highly significant coefficient for the dummy indicating foreign ownership of the firm, indicating that foreign owned enterprises are much more likely to be exporters than domestically owned enterprises. In our case, foreign owned enterprises export three times as much as domestically owned enterprises. Note that our approach does not say anything about the direction of causality in this case.

The interpretation of the results for the other regressions (columns 2-5) is in similar veins. We find that irrespective of the source of the technology transfer, spending on technology results in higher export levels: coefficients associated with spending on domestic and imported technology are positive and highly significant, with the coefficient on the imported technology higher in magnitude than that on the domestic technology. A one percent increase in spending on imported technology results in a 44 percent increase in exports, whereas a one percent increase in spending on domestic technology results in a 35 percent increase in exports. When we break the imported technology according to its source (imported from leaders vs. imported from other sources), we find that spending on technology imported from leaders has a larger impact on the volume of exports. Whereas a one percent increase in spending on technology imported from non-leaders increases exports by about 28 percent, a one percent increase in spending on technology imported from leaders nearly doubles exports (an increase of 176 percent).

The difference in the size of the effects supports our impression that the technology imported from the world technological leaders and hence corresponding to the state-of-the-art is associated with the best export performance. Technology coming from other sources is no different in its impact from the technology acquired in Argentina.

6.2. Impact of Spending on Technology on Export Performance – Components of Spending

Table 6 reports the impact of the various components of technology spending on export performance. Spending on technology, irrespective of the type of technological upgrading, has a positive impact on export performance, as indicated by positive and highly significant coefficients on the components of the spending. The smallest impact, against our expectations, is found for spending on capital goods containing innovative features for the firm: a one percent increase in this type of spending increases exports by slightly over 20 percent. A one percent increase in spending on in-house improvements in management, hardware and software, in-house R&D and worker training increases exports from 50 to 80 percent. The highest impact is found for external R&D, in-house engineering and industrial design and consultancies: increasing spending on these categories by one percent more than doubles exports, as reflected by greater than one coefficients on these variables.

6.3. Impact of Spending on Technology on Export Performance – Level of Commitment

The assumption of symmetric countries in the theoretical model rules out the possibility that the more efficient firms, who produce with better quality inputs, sell their products to more exigent consumers in higher income countries. For this reason, the three market strategies are basically defined in quantitative terms: no exports, some exports, and a lot of exports. Since we do not have information on export destinations, in the empirical part, we are also pushed toward a quantitative approach, even though the fact that we do observe the location of the firm's main market allows us to have some insight on the quality of target markets.[17]

We use ordered probit setting to estimate the impact of the spending on technology on the level of commitment. Recall that in the data section the level of commitment is defined according to the location of the main market of the firm, i.e. low-commitment exporters are

[17] Eaton et. al. (2004) use data from 1986 French firms to find that exporters (only 17.4% of all firms) export mainly to a single destination abroad (34.5% of exporting firms) while keeping their main market at home (in average exports account for 21.6% of total sales). Only a small fraction of exporting firms target several export markets (19.7% target ten or more markets, and only 1.5% target fifty or more markets). They observe little differences in this pattern across industries, even though firms in light industries tend to serve fewer markets. Regarding the export destinations themselves, they find that the larger an export market is, the larger the amount of exports individual French firms will target there. This paper, thus, suggests that the main market reported by the firm is likely to be the only market abroad that the firm serves.

exporters with the main market in Argentina, whereas high-commitment exporters are exporters with the main market abroad (i.e. exporting more than half of their production). Because of a very small number of firms who export over half of their production, we redefine the level of commitment as follows: low-commitment exporters are those who export less than or equal to 20 percent of total sales (a median value of export share in the sample), whereas firms who export more than this are high-commitment exporters. The dependent variable of interest is thus an ordinal categorical variable with three levels: 0 for non-exporters, 1 for low-commitment exporters, and 2 for high-commitment exporters. The main independent variables of interest are spending on technology and total sales. Spending on technology and total sales, in line with the work discussed in previous sessions, are assumed to be endogenous: in the ordered logit regression we use predicted values of these variables, which we obtain from regressions equivalent to equations 2 and 3 in Section 5. The standard errors in the ordered logit equation are bootstrapped to account for the fact that two of the predictor variables are estimated. The marginal effects and their standard errors, are reported in Table 7. The results indicate that a one percent increase in spending on technology would decrease the probability of being a non-exporter by approximately 2 percent and increase the probability of being a low-commitment exporter by 0.9 percent and a high-commitment exporter by 1.2 percent. A one percent increase in spending on imported technology would increase the probability of being a low-commitment exporter by 1.3 percent and a high-commitment exporter by 1.6 percent. These patterns remain unchanged when we define level of commitment based on the location of the main market, however, the statistical significance of the findings is lower. Our evidence, thus, suggests a link between the spending on technology and the chosen market strategy and this link increases in intensity with the "better sourcing" of technology.

7. Conclusions

Using an IV estimation, this article provides evidence of a strong positive relationship between the spending on technology and export performance. The increase in exports brought about by technological upgrading and, especially, by importing technology from the world's leaders, has many external effects. Together, our finding suggest that the export effects of technological upgrading should be taken into consideration when analyzing the consequences of tariffs, R&D subsidies or other policies that would affect technology prices, especially in the case of imported technology.

We have identified the source of technology as one of the important factors that determines the interaction between exporting and spending on technology. Ideally, the next step would be to shed the light on the dynamic interaction of the exporting and technology upgrading processes and establish by how far technology upgrading precedes entry into a foreign market.

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Table 1: Number of Firms Engaged in Innovative Activities, Median Amount Spent on Each Type of Activity, and Share of Imports

	1998				2001			
	Exporter		Non-Exporter		Exporter		Non-Exporter	
	Total	Imported	Total	Imported	Total	Imported	Total	Imported
In-house R&D	255	26	116	11	276	24	112	7
	45 000	32%	17 500	60%	45 901	43.50%	13 066	100%
External R&D	80	21	30	1	98	25	33	7
	25 220	67%	12 857	100%	25 589	100%	11 100	100%
Capital Goods Containing Innovation	290	172	159	70	298	162	119	60
	400 000	79.50%	122 062	85%	221 075	69.50%	69 800	86.50%
Purchases of Hardware	247	71	115	29	256	69	112	33
	24 051	100%	10 000	100%	18 364	100%	5 745	100%
Purchases of Software	226	62	110	19	254	71	112	26
	17 135	100%	5 801	100%	16 136	100%	7 100	100%
Technology Transfers	58	26	19	5	71	42	21	3
	65 128	100%	20 000	50%	43 462	100%	17 235	93%
In-house Engineering and Industrial Design	183	21	70	5	214	25	74	6
	36 000	50%	15 000	50%	28 015	50%	13 312	98%
In-house Improvements in Management	132	12	59	1	166	10	70	2
	17 585	50%	7 000	4%	14 395	75%	9 100	64%
Employee Training	226	25	99	5	278	28	113	6
	17 891	50%	8 250	50%	15 000	50%	5 000	100%
Consulting Services	137	14	48	3	162	14	62	4
	24 000	50%	12 910	50%	20 000	95%	12 300	100%

Table 2: Relationship Between Skill Intensity and Technology Upgrading Strategy

Technology Strategy	1998	2001
No Upgrading (L)	0.05	0.06
Upgrading from Domestic Sources (M)	0.10	0.11
Upgrading with Some Technology from Leaders (H)	0.12	0.13
P-value for the Difference between M and H	0.29	0.51

Table 3: Relationship Between Productivity – Log(Sales per Worker) – and Technology

Upgrading Strategy

Technology Strategy	1998	2001
No Upgrading (L)	14.98	14.83
Upgrading from Domestic Sources (M)	16.07	16.12
Upgrading with Some Technology from Leaders (H)	16.52	16.55

Table 4: Linkages between Technology and Market Strategies

	Technology Strategy 1998			Totals
Market Strategy 2001	No Upgrading (L)	Upgrading from Domestic Sources (M)	Upgrading with Some Technology from Leaders (H)	
Non-Exporters	413	218	37	668
Exporters with Main Market in Argentina	207	360	62	629
Exporters with Main Market Abroad	54	50	11	115
	674	628	110	1402

Table 5: 2SLS Estimation of the Impact of the Spending on Technology (by Source) on Exports

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Log (Total Exports) 2001					
Log (Total Spending on Technology) 1998	0.303**				
	(0.122)				
Log (Spending on Imports of Technology) 1998		0.441**			
		(0.183)			
Log (Spending on Domestic Technology) 1998			0.347**		
			(0.143)		
Log (Spending on Imports of Technology from Leaders) 1998				1.760**	
				(0.865)	
Log (Spending on Imports of Technology from Non-Leaders) 1998					0.280***
					(0.085)
Log (Total Sales)	1.583***	1.611***	1.532***	1.797***	1.815***
	(0.249)	(0.247)	(0.270)	(0.224)	(0.165)
A firm is part of a group	0.233	0.207	0.220	0.548	0.226
	(0.408)	(0.420)	(0.414)	(0.485)	(0.408)
Foreign Ownership	2.830***	2.556***	2.866***	3.000***	2.735***
	(0.469)	(0.518)	(0.473)	(0.534)	(0.468)
Log (Other Investments)	-0.004	-0.011	-0.001	-0.014	0.005
	(0.031)	(0.033)	(0.031)	(0.039)	(0.030)
Constant	-20.600***	-20.286***	-19.885***	-22.933***	-23.126***
	(3.447)	(3.640)	(3.716)	(3.398)	(2.574)
Sargan Test (p-value)	0.510	0.528	0.495	0.128	0.488

note: *** p<0.01, ** p<0.05, * p<0.1

Table 6: 2SLS Estimation of the Impact of the Spending on Technology (by Category) on Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable: Log (Total Exports) 2001										
Log (In-House R&D)	0.686** (0.328)									
Log (External R&D)		1.118* (0.597)								
Log (Capital Containing Innovations)			0.215** (0.086)							
Log (Hardware)				0.535*** (0.194)						
Log (Software)					0.696** (0.286)					
Log (Transfer of Technology)						0.943** (0.437)				
Log (Industrial Engineering and Design)							1.290* (0.728)			
Log (Improvements in Management)								0.832* (0.501)		
Log (Worker Training)									0.611* (0.325)	
Log (Consulting)										1.294** (0.562)
Log(Total Sales)	1.441*** (0.347)	1.747*** (0.240)	1.840*** (0.172)	1.666*** (0.215)	1.498*** (0.293)	1.895*** (0.179)	1.282*** (0.491)	1.732*** (0.264)	1.588*** (0.306)	1.468*** (0.318)

A firm is part of a group	-0.056	0.480	0.203	0.298	0.272	0.211	-0.033	-0.078	0.325	0.116
	(0.468)	(0.451)	(0.407)	(0.415)	(0.432)	(0.439)	(0.540)	(0.495)	(0.417)	(0.486)
Foreign Ownership	3.098***	3.426***	2.935***	2.682***	2.864***	2.314***	2.296***	2.896***	3.025***	2.751***
	(0.485)	(0.532)	(0.458)	(0.487)	(0.492)	(0.602)	(0.717)	(0.498)	(0.471)	(0.556)
Log (Other Investments)	-0.002	-0.012	0.011	-0.014	-0.014	-0.014	-0.060	-0.022	-0.019	-0.039
	(0.033)	(0.038)	(0.029)	(0.033)	(0.035)	(0.036)	(0.060)	(0.042)	(0.038)	(0.044)
Constant	-18.199***	-22.446***	-23.680***	-21.330***	-18.913***	-24.029***	-15.747**	-21.840***	-20.145***	-18.315***
	(4.874)	(3.483)	(2.611)	(3.158)	(4.208)	(2.851)	(6.976)	(3.962)	(4.358)	(4.637)
Sargan Test (p-value)	0.318	0.246	0.493	0.156	0.113	0.072	0.407	0.142	0.167	0.928

note: *** p<0.01, ** p<0.05, * p<0.1

Table 7: Marginal Effects of Technology Spending on Level of Commitment in Export Markets

	Non-Exporter	Low-Commitment Exporter	High-Commitment Exporter
Predicted Log (Total Spending on Technology)	-0.021	0.009	0.012
	(0.011)	(0.005)	(0.006)
Predicted Log (Total Sales)	-0.077	0.033	0.043
	(0.019)	(0.009)	(0.011)
Firm is part of a group	-0.010	0.004	0.006
	(0.029)	(0.013)	(0.016)
Foreign Ownership	-0.154	0.054	0.100
	(0.034)	(0.010)	(0.026)
Log (Other Investments)	0.001	0.000	-0.001
	(0.002)	(0.001)	(0.001)
Predicted Log (Total Imports of Technology)	-0.029	0.013	0.016
	(0.014)	(0.006)	(0.008)
Predicted Log (Total Sales)	-0.081	0.035	0.045

	(0.019)	(0.009)	(0.011)
Firm is part of a group	-0.009	0.004	0.005
	(0.032)	(0.014)	(0.018)
Foreign Ownership	-0.138	0.050	0.088
	(0.042)	(0.012)	(0.031)
Log (Other Investments)	0.001	-0.001	-0.001
	(0.003)	(0.001)	(0.001)
Predicted Log (Total Imports of Technology from World Leaders)	-0.227	0.099	0.128
	(0.178)	(0.078)	(0.100)
Predicted Log (Total Sales)	-0.074	0.032	0.042
	(0.031)	(0.014)	(0.018)
Firm is part of a group	-0.046	0.021	0.025
	(0.046)	(0.022)	(0.024)
Foreign Ownership	-0.161	0.055	0.105
	(0.034)	(0.010)	(0.026)
Log (Other Investments)	0.004	-0.002	-0.002
	(0.004)	(0.002)	(0.003)

Standard Errors in parentheses.