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Openness and Technological Innovations in Developing Countries: Evidence from Firm-Level Surveys

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ABSTRACT

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This paper examines international technology transfers using firm-level data across 43 developing countries. Our findings show that exporting and importing activities are important channels for the transfer of technology. Majority foreign-owned firms are less likely to engage in technological innovations than minority foreign-owned firms or domestic firms. We interpret this finding as evidence that the technology transferred from multinational parents to majority-owned subsidiaries is more mature than that transferred to minority-owned subsidiaries. Our findings also suggest that foreign-owned subsidiaries rely mostly on the direct transfer of technology from their parents and that firms that import intermediate inputs are more likely to acquire new technology from their machinery suppliers.

JEL Classification: F1, F2, O3

Keywords: innovation, technology adoption, exports, imports, foreign ownership, firm level data

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1. Introduction

Growth theory has for long established that improvements in technology have an effect on long-run growth (Romer, 1990; Aghion and Howitt, 1998). Moreover, differences in technology have been found to be an important determinant of differences in total factor productivity across countries (Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999) and across firms (Griliches, 1998; Parisi *et al.*, 2006). While some firms are engaged in the creation of new technologies, most firms simply imitate or adapt existing production techniques to local conditions (Evenson and Westphal, 1995; UNCTAD, 1999). In developing countries, the international transmission of knowledge occurring through several channels - foreign partners, foreign suppliers and/or clients or the direct trade in technologies through licensing – can be vital for technological adoption across firms (Hoekman and Javorcik, 2006).[1] In this paper, we use firm-level data for 43 developing countries to study the link between openness and technology adoption. We also provide evidence on the importance of different channels for technology transfer, such as multinational parents or third parties.

Multinational parents are endowed with a more advanced technology that they often transfer to their subsidiaries. However, the quality of the technology transferred from multinational parents has been the object of some debate. In several developing countries (e.g., China), the policies to attract foreign direct investment (FDI) are based on the premise that joint-ventures between foreign and domestic firms induce a greater technology transfer to the host country than fully-owned foreign subsidiaries. Nevertheless, the available evidence generally suggests that multinational firms have an incentive to transfer fewer and older technologies to their subsidiaries in developing countries than to those in developed countries because they face a higher risk of expropriation in the former (Mansfield and Romeo, 1980; Ramachandran, 1993;

Javorcik, 2006). Moreover, there is evidence that technological transfers from multinational parents increase with the quality of intellectual property rights in the host country (Branstetter *et al.*, 2006).

The international transfer of technology can also occur through trade. Importers can improve their technology by incorporating into their production processes state-of-the-art imported capital goods or inputs, which may not be available domestically (Grossman and Helpman, 1991). If new knowledge is embodied in those imports, then importers should be more innovative than firms that source only in the domestic market. Similarly, exporters can learn about new technologies or products through their interaction with more knowledgeable foreign buyers. Moreover, they may be exposed to more competitive markets and hence be forced to improve their technology more frequently. If the exposure to foreign markets promotes technology adoption, then exporters should be more likely to adopt new technologies than firms selling exclusively to the domestic market. The cross-country evidence shows a positive correlation between trade openness and technology adoption (Caselli and Coleman II, 2001; Comin and Hobijn, 2004) or R&D investments (Lederman and Maloney, 2003). Coe and Helpman (1995) and Coe *et al.* (1997) find that foreign knowledge embodied in imported inputs from countries with larger R&D stocks has a positive effect on aggregate total factor productivity (TFP). The impact of openness on technology adoption is shown to be greater the better is the country's absorptive capacity, which relates to the availability of factor endowments such as skilled labour (Caselli and Coleman II, 2001; Keller, 2004), and the better are the country's institutions (Clarke, 2001). Similarly, the case study literature documents that firms acquire new knowledge and improve their technology through their interactions with foreign clients and suppliers (Rhee *et al.*, 1984; Hobday, 1995; Kim, 1997; Pack and Saggi, 1999; Westphal, 2002; Wie, 2005).

Additional evidence suggests the importance of openness for technology adoption. Several studies for developing countries show that TFP is higher for firms integrated into global markets through exports, FDI, and imports of intermediate inputs (e.g., Tybout, 2000; Keller, 2004; Alvarez and Lopez, 2005; Djankov and Hoekman, 2000; Kasahara and Rodrigue, 2005).[2]

Finally, the international transfer of technology may occur directly as firms engage in the trade of knowledge through licensing agreements that typically involve the purchase of production or distribution rights and the respective know-how. The decision of foreign firms between licensing a technology and establishing a subsidiary through FDI depends heavily on the capacity of the host country to demonstrate that if the technology is licensed, it will not be easily copied through industrial espionage or worker turnover. When this is not the case, foreign firms prefer not to engage in licensing at all or if they do they tend to transfer older technology (Saggi, 1996; Maskus, 2000). As in the case of FDI and trade openness, there is evidence that license transfers are greater in countries with better absorptive capacity (Yang and Maskus, 2001).

An extensive case study literature provides rich details about the determinants and consequences of technology transfer and adoption in developing countries (Rhee *et al.*, 1984; Katz, 1987; Lall, 1987; Pack, 1987, 2006; Hobday, 1995; Young and Lan, 1997). However, case studies are based on the observation of a small number of firms hence their findings are difficult to generalize. Econometric evidence on technology adoption using firm-level data is scarce. The typical industrial census in developing countries lacks detailed information on technology adoption. Our paper provides unique evidence on technology adoption by using a richer dataset (*Investment Climate Surveys)* and a more encompassing measure of technological innovation than previous studies. The surveys cover manufacturing firms across 43 developing countries

and constitute to our knowledge one of the most detailed datasets for studying technology adoption. In particular, the surveys collect rich information on firm characteristics, including foreign ownership, export and import activities, and the channels used by firms to acquire new technologies.

Most of the available evidence measures firm-level technology adoption using with R&D expenditures or the number of patented technologies. However, R&D activities are only one of the inputs in the process of generating new technologies and they do not necessarily lead to successful new technologies. Moreover, the propensity to patent is more important for the creation of new knowledge than for the adoption and adaptation of existing knowledge. In this paper, we define technology adoption in a broader sense. Our definition covers not only the creation of new production processes but also the adoption and adaptation of existing technologies to local conditions. Hence, it captures incremental innovations which allow a progressive catch-up to the world technology frontier, as opposed to movements of the frontier itself. This is arguably a better measure of technological innovations for developing countries where most firms operate below the world technology frontier.

Our main findings can be summarized as follows. First, we find significant heterogeneity in the firm's decision to adopt new technology within countries and industries. Second, we find a strong positive correlation between openness and technology adoption. After controlling for firm characteristics and country and industry fixed effects, minority foreign-owned firms, firms that import, and firms that export are, respectively, 4.5, 3.1, and 6.4 percentage points more likely to engage in technological innovations than firms without these characteristics. Majority foreign-owned firms in low-tech industries are significantly less likely to engage in technology adoption than domestic or minority foreign-owned firms. We interpret this finding as evidence that the

technology transferred from foreign multinationals to majority-owned subsidiaries in developing countries is older and thus less prone to innovation than the technology transferred to minority-owned subsidiaries. This finding supports the idea that minority-owned subsidiaries are more beneficial than majority-owned subsidiaries to foster technology adoption in developing countries, which is the premise of many developing countries' FDI policies Third, we find that for the acquisition of technological innovations, foreign-owned subsidiaries rely mostly on the direct transfer of technology from multinational parents, as opposed to interactions with suppliers, clients, or third parties (e.g., universities). Also, firms that import their intermediate inputs are more likely to acquire technology from their machinery suppliers. These findings are important for the current discussion within the WTO about ways to foster international technology transfers to firms in developing countries (Hoekman *et al.,* 2005).

The cross-sectional nature of our data makes it difficult to interpret the estimated positive correlation between openness and technology adoption as causal. For example, exporting firms may innovate more than non-exporting firms because more innovative firms self-select into exporting and not because exporting leads to technology adoption. We only observe firms at one point in time and we do not have valid instruments for openness. Hence, we attempt to mitigate this problem by controlling for firm characteristics such as managerial education, access to finance, or competition that may be simultaneously correlated with firm innovation and with openness. However, we acknowledge that our findings could be partly driven by unobservable firm characteristics.

Our paper contributes to the micro literature that examines the determinants of innovation and technology adoption. This literature, which originated with Schumpeter (1942), relates the firm's incentives to innovate with product market competition, access to finance, or workforce

quality (Cohen and Levin, 1989; Aghion *et al.*, 2005). More closely related to our work are Vishwasrao and Bosshardt (2001), Alvarez and Robertson (2004), Criscuolo *et al.* (2005), Damijan *et al.* (2005), and Girma *et al.* (2006) which use firm-level data to study the effect of openness on innovation or technology adoption.[3] In contrast to our study, the aforementioned studies focus only on one country (in Girma *et al.* (2006) only on state-owned firms), use more restrictive measures of innovation, do not examine the role of different degrees of foreign ownership nor present evidence on the importance of different channels for technology acquisition.

The paper proceeds as follows. Section 2 describes the data and provides summary statistics. Section 3 documents the link between openness and technology adoption. Section 4 documents the importance of different channels for technology acquisition. Section 5 concludes.

2. Data

We use firm-level data (*Investment Climate Surveys*) collected by the World Bank in 43 developing countries between 2002 and 2005.[4] In each country the sample was designed to be representative of the population of firms according to their industry and location. The survey has several advantages for analyzing technological adoption. First, it is based on a common questionnaire across a large set of countries, yielding comparable information on several firm-level variables. Among others, the survey collects information on whether the firm recently adopted new technology, its R&D activities, whether the firm licenses technology, the main channels used to acquire technological innovations, the ownership structure, age, size, human capital composition, and whether it participates in international trade. Tables 1 and 2 define all the variables used in the analysis and show the corresponding summary statistics. Our final sample includes 17,667 firms distributed across a wide range of manufacturing industries - auto

and auto components, beverages, chemicals, electronics, food, garments, leather, metals and machinery, non-metallic and plastic materials, paper, textiles, wood and furniture - in 43 countries in Africa (11.5%), East Asia (42.1%), Eastern Europe and Central Asia (20.1%), and Latin America (26.3%).[5]

Second, the survey allows us to use a broad definition of technological innovations. Specifically, we measure technological innovations with a dummy variable equal to one if a firm reports having introduced new technology that substantially changed the production of its main product in the three years prior to the survey. This definition captures the creation of new knowledge but also the adoption and adaptation of production processes. This knowledge may be new to the firm but not to the industry, the country, nor the world. Defining technological innovations in this way is particularly important in the context of developing countries to understand how firms catch-up to the world technological frontier.[6] One shortcoming of our data is that it captures the intensive but not the extensive margin of technological innovation. This contrasts with the information available in the Community Innovation Surveys (CIS) recently conducted in European countries by the OECD (Evangelista *et al.* (1997); Criscuolo *et al.*, 2005; Damijan *et al.*, 2005; Mohnen *et al.*, 2006). Relative to the CIS, our data has the advantage of including information on characteristics for all firms in the sample. With the exception of the UK, the CIS collect this information only for firms that innovate.

Third, the survey collects detailed information on the main channel used by firms to acquire technological innovations. On average, 81 percent of firms that engage in technological innovation in the sample report that their new technology was either embodied in new machinery, developed or adapted within the firm, transferred from the parent company, or developed by hiring key personnel or consultants. A much smaller share of firms (15%) reports

that technology was acquired or developed in coordination with suppliers or clients (i.e., licensing from domestic or foreign sources, developed in cooperation with client firms, or developed with equipment and machinery suppliers) and only 4 percent of firms report that technology was developed in coordination with other institutions (i.e., universities and public institutions, business or industry associations, trade fairs, or study groups).

Table 3 shows the share of firms engaged in technological innovations across regions and industries. A large share of firms report being engaged in technological innovations (56%) but there is substantial heterogeneity across industries. Traditional industries (e.g., food) have fewer innovative firms while high-tech industries have more (e.g., electronics). The percentage of firms that report being engaged in technological innovations (56%) or having conducted R&D activities (48%) seems high for developing countries. Evangelista *et al.* (1997) find that the average propensity of European firms to introduce process (technological) or product innovations is 53 percent. The comparable average in our sample is 78 percent. Since different industries have different propensities to adopt new technology, the difference in averages could be explained by the industrial composition across the two samples. Nevertheless, the differences remain within industries. For example, in European countries, the average propensity to innovate in the electronics (textiles) industry is 67% (33%), which compares with an average of 82% (77%) in our sample. However, the ranking of industries by innovation propensity is very similar across the two samples, which suggests that it could be simply a matter of scale. The difference in the propensity to innovate across the two samples can also be explained by managers in developing countries being more likely to report small improvements in technology as an innovation than managers in developed countries. Finally, the fact that more than one quarter of the firms in our sample adopt new technology without having conducted R&D activities

reinforces the importance of using our measure, instead of R&D, to capture technological innovation in developing countries.

We should note, however, that our measure of technological innovation is somewhat subjective and this could introduce measurement error in the variable of interest. The average propensity to innovate differs significantly across countries in our sample: Egypt and Uzbekistan exhibit the lowest propensity while Thailand and Brazil exhibit the highest propensity. In between, the ranking of countries in terms of innovation propensity is broadly correlated with the level of development, as shown in the Appendix (available online). However, we believe that potential differences in the manager's definition of what is considered a technological innovation are a more severe problem when comparing firms in different countries than when comparing firms within countries and industries. Note that the latter is the approach followed in Sections 3 and 4 where our preferred empirical specifications include dummy variables to account for time-invariant differences in technological innovation across countries and industries. Unfortunately, if the measurement error is systematically related to firm characteristics, it is not possible to know the sign of the biases in the corresponding effects on technological innovation. For example, small firms may report that they adopt new technology more or less often than other firms. Thus, the direction of the bias in the estimated correlation between innovation and firm size is unclear.

Our measure of technological innovation is strongly and positively correlated with labour productivity, both within and across countries. We interpret this evidence as suggesting that our measure of technological innovation captures an economically important activity.

Table 3 also reports the frequency of technological innovations for different types of firms. While only 54 percent of domestic firms report having adopted new technology, foreign-

owned firms are substantially more innovative, particularly those with minority foreign ownership whose propensity to adopt new technology is 74.1 percent. The share of firms reporting technological innovations is also much higher for exporters (64.8%) and for importers (62.7%) than for the full sample. The same patterns hold within industries and countries. These statistics suggest that openness, measured by trade and FDI, is associated with more frequent firm-level technological innovations. More open firms also exhibit higher innovation inputs, measured by the propensity to engage in R&D activities. Hence, it is possible that their higher probability of technological innovation is simply explained by their higher probability of conducting R&D activities. Alternatively, there may be other important factors influencing simultaneously technological innovations and openness. For example, in our sample, large firms are substantially more prone to adopt new technologies than smaller firms. This issue will be investigated in the next section.

3. Openness and Technology Adoption

3.1 Main Findings

Our empirical framework considers profit-maximizing firms deciding whether or not to engage in technological innovation. A firm decides to innovate if this decision is expected to increase its profits, i.e., if the benefits from this decision are larger than the costs. Let π^*_{ijc} be the profits of a firm *i* in industry *j* in country *c*. Then, we assume that:

$$Innov_{ijc} = \begin{cases} 1 \; if \pi^*_{ijc} > 0 \\ 0 \; otherwise. \end{cases} \qquad (1)$$

where *Innov* is a dummy variable that equals one if firm *i* reports engaging in technological innovation. Since π^*_{ijc} is unobserved, Equation (1) cannot be estimated directly. Therefore, we

assume that π^*_{ijc} is a function of firm, industry, and country characteristics. In particular, we assume a linear form so that $\pi^*_{ijc} = \beta X_{ijc} + I_j + \gamma I_c + \varepsilon_{ijc}$, where X_{ijc} is a vector of firm characteristics, I_j are industry fixed effects, I_c are country fixed effects, and ε_{ijc} captures unobserved firm, industry, and country characteristics. For this functional form, the probability that firm *i* innovates is given by:

$$\Pr(Innov_{ijc} = 1) = \Pr(\varepsilon_{ijc} > -\beta X_{ijc} - I_j - \gamma I_c). \quad (2)$$

Assuming that the residuals ε_{ijc} are normally distributed, we can estimate Equation (2) by maximum likelihood (probit). Standard errors are clustered to allow for possible correlations in technological innovations across firms within the same country and industry. Table 4 reports the marginal effects at mean values of the variables of interest for different specifications of Equation (2). All the specifications control for 2-digit ISIC industry fixed effects to account for differences across industries in production technology, product demand, or competition. These are likely to affect the incentives of firms to adopt new technology (Cohen and Levin, 1989). As discussed in Section 2, there could also be differences across industries in what managers consider to be a technological innovation. For example, in an industry where there is continuous change a small technological change may not be considered an innovation.

In column (1), we find that minority foreign ownership is associated with more innovation. In contrast, majority foreign-owned firms are as likely as domestic firms to adopt new technology. There is also evidence that within industries, exporters and importers are significantly more likely to adopt new technology than firms that do not trade. Firms that directly engage in the trade of knowledge or technology through licenses are also more likely to report technological innovations. Although for most countries in our sample the data does not specify whether these licensing agreements are domestic or foreign, for 16 countries we do have

information on the use of technology licensed from a foreign-owned firm. The findings for this smaller sample, shown in the Appendix (available online), support the positive correlation between licensing and innovation, and the results for the trade and FDI variables remain robust.

Globally-integrated firms may be larger or older and these characteristics could be associated with a higher propensity to adopt new technology. Column (2) includes firm age, age squared, firm size, and a dummy variable for public ownership. Controlling for the quality of the firm's human capital is particularly important to capture the firm's absorptive capacity to new technology and knowledge (Cohen and Levintahl, 1989; Pack, 2006). The specification in column (3) includes the incidence of on-the-job training in the firm and the percentage of the workforce with more than secondary education. The previous findings on openness are robust to the inclusion of these variables. Now majority foreign-owned firms are significantly less likely to adopt new technology than minority foreign-owned or domestic firms. This result is robust to alternative definitions of foreign ownership. For example, in the Appendix (available online) we show that when we include a separate dummy variable for fully foreign-owned firms, there is still evidence that majority and fully foreign-owned firms are less likely to innovate than minority foreign-owned firms or than domestic firms.

Countries with a more favorable environment for innovation may also offer better export and import opportunities, receive more FDI, and have a more educated workforce. Since several policy and institutional dimensions are shown in the literature to be relevant for international activities and could also affect technology adoption, we control in columns (4) and (5) for country GDP per capita (in 1995) and for country fixed effects, respectively. We use past GDP per capita since it is less likely than current GDP per capita to be correlated with potentially relevant omitted variables. The relationship between firm-level openness and technological

innovation remains robust. The magnitude of the effects in our preferred specification with country fixed effects (column (5)) is economically significant. Firms that export are 3.1 percentage points more likely to innovate than firms selling only to the domestic market while importers are 6.4 percentage points more likely to innovate than firms using only domestic intermediate inputs' suppliers. Minority foreign-owned firms are 4.5 percentage points more likely, while majority foreign-owned firms are 5.9 percentage points less likely, to adopt new technology than domestic firms.

The findings in Table 4 also show other interesting patterns. First, there is a negative and convex relation between the propensity to engage in technological innovations and firm age. This finding could be the result of "creative destruction", as younger firms could be more innovative and dynamic than older firms with weaker learning possibilities (Schumpeter, 1942).[7] Second, larger firms are more likely to engage in technological innovations than smaller firms. This size advantage can be the result of economies of scale in the adaptation or development of new technology (Cohen and Klepper, 1996) or it can reflect the greater capacity of large firms to finance innovation projects in the presence of imperfect financial markets. Third, public-owned firms are less likely than private firms to adopt new technology. This finding reflects the fact that public-owned firms tend to operate in more protected markets and thus have smaller incentives to innovate. Finally, the firm's human capital is positively related with the propensity to adopt new technology.[8] This result is in line with the idea that a more qualified workforce improves the firm's absorptive capability and reduces the costs of adopting or creating new technologies (Cohen and Levinthal, 1989).

In sum, our findings suggest an important role of trade, FDI, and licensing. They are in line with evidence that global integration facilitates the diffusion of knowledge (Hoekman and

Javorcik, 2006). The technological advantage of exporters could result from knowledge absorbed in the interactions with foreign buyers or it could simply reflect a higher pressure to innovate driven by the strong competitive pressures felt in foreign markets. Our findings complement the evidence in case studies (Rhee *et al.*, 1984; Westphal, 2002) of direct technological transfers (e.g., blueprints, periodic visits and technical assistance by foreign clients, training of technical staff) and indirect technological transfers (e.g., challenges from foreign buyers may trigger technological updates by the exporting firm). Moreoever, exporters may benefit from scale economies in innovation due to their access to larger foreign markets (Hobday, 1995). The technological innovation advantage of importers could reflect a process of reverse engineering of higher quality foreign inputs. This mechanism would allow firms to learn about the embodied technological knowledge which may not be available domestically (Grossman and Helpman, 1991; Keller, 2004).

Our findings shed some doubts on the extent of technology transfers of multinational parents to their majority-owned subsidiaries in developing countries.[9] In particular, they are suggestive that multinational parents are more likely to transfer more mature technologies to their majority-owned subsidiaries than to their minority-owned subsidiaries. Such technologies are already established in the industry and, thus are less prone to adaptations and improvements. Hence, the collaboration with foreigners in the form of equity joint-ventures, rather than fully-owned subsidiaries is apparently a more efficient mechanism for promoting technology adoption in the host country. While this idea is at the heart of policies to attract FDI in many developing countries, most of the available evidence to date has not been supportive of this mechanism (Mansfield and Romeo, 1980; Ramachandran, 1993; Javorcik, 2006).[10] However, some case

studies have indeed been supportive of this mechanism (e.g., Young and Lan, 1997, and Wie, 2005) [11]

Although our results document a strong positive correlation between openness and technology adoption, it is very difficult to disentangle correlation from causality. For example, assume that multinational parents tend to acquire the more innovative (and possibly productive) domestic firms. Then, the positive correlation between minority foreign ownership and innovation could be driven by foreign multinationals selecting the more innovative domestic-owned firms ('cherry-picking'). Similarly, technological innovations may improve the firm's ability to enter and remain in foreign markets as a buyer or a supplier. This type of bias is not problematic for the link between innovation and majority foreign ownership. In this case, the reverse causality bias would imply that the negative coefficient is actually a lower bound on the true effect of majority foreign ownership on technology adoption. However, this bias could be relevant when interpreting the findings for minority foreign ownership, imports, or exports. In the next section we explore the richness of the survey to test the sensitivity of our main findings. Nevertheless, in the absence of panel data or of valid instruments for our variables of interest, it is impossible to rule out a role for unobservable factors in driving the observed correlations in the data.

3.2 Sensitivity Analysis

In this section we investigate the robustness of our main findings to the inclusion of several firm characteristics which are likely to be simultaneously correlated with innovation and openness such as R&D activities, managerial quality, access to finance, competition in the output market, technological sophistication of the industry, and the firm's geographical location. When omitted from the analysis, these could be possible explanations for the observed correlations

between openness and technology adoption. We also examine the sensitivity of our results to estimating separate effects according to the country's income group and quality of property rights protection. Finally, we check the extent to which our main findings are driven by the importance of the Asian firms in our sample. Tables 5 and 6 report most of the results from our sensitivity analysis (using as the starting point our preferred specification - column (5) of Table 4).[12] The other results discussed below but not reported in those tables are shown in the Appendix (available online).

We begin with a discussion of firm characteristics that may be positively correlated with technological innovations and with openness. In columns (1)-(3) of Table 5 we add an indicator variable for whether the firm conducts R&D activities, a proxy for managerial quality (a dummy variable if the manager has a college or a post-graduate degree) and a measure of the firm's access to finance. The R&D activities of the firm may directly improve the likelihood of technological innovation or its capacity to absorb external knowledge or technology (Cohen and Levinthal, 1989). More entrepreneurial managers are more likely to engage in technological innovations more often, but are also more likely to export or import. Similarly, foreign-owned firms or exporters may have easier access to finance through their multinational parents or through export-promoting policies. If firms are credit constrained, lower costs or increased access to finance can increase their ability to innovate (King and Levine, 1993).[13] We find that the variables added in columns (1) to (3) are positively and significantly correlated with the firm's propensity to innovate.[14] The effects of minority foreign ownership, exports, and imports on innovation are maintained, suggesting that our main findings are not driven by these variables.

Regarding the effect of exports on innovation, we try to disentangle the importance of the firm's presence in external markets versus the importance of the quantity that is being exported. To address further the reverse causality problem, we test the sensitivity of our results to considering only the exporting firms that entered foreign markets more than 10 or more than 20 years prior to the survey. The rationale is that current technology adoption is unlikely to influence the firm's past exporting status. Our findings suggest a strong positive correlation between technology adoption and the incidence of exporting, independently of how long the firm has been exporting. We do not find evidence that the quantity exported is important to explain differences in technology adoption. This evidence is in line with Alvarez and Robertson (2004).

The degree of competition faced by firms can also explain the link between openness and technology adoption. Firms operating in more competitive markets may face stronger pressures to innovate and may also be more engaged in international activities. Column (4) of Table 5 includes four dummy variables, based on the total number of competitors faced by the firm in its main product in the domestic market. They indicate whether the firm faces no competition, weak competition (1 to 3 competitors), medium competition (4 to 20 competitors), or strong competition (more than 20 competitors). We find a positive effect of competition on technological innovation that is stronger when the number of competitors ranges from 4 to 20 firms. A non-monotonic relation between innovation and competition is also found by Aghion *et al.* (2005) for UK firms. Statistical tests reject the hypothesis that the effects are similar across competition categories. Given the difficulties in measuring competition, we verify that our findings are robust to the use of alternative measures of competition.[15]

The industry's degree of technological sophistication may affect the role of technology diffusion through trade and FDI for firm-level innovation. Industries with a higher degree of

technological sophistication (high-tech) face and take advantage of more innovation opportunities than traditional industries (low-tech). In columns (5) and (6), we report regression results separately for firms in high and low tech industries, respectively. We find that importers have a higher propensity to innovate in both industries but that exporters are more likely to innovate only in high-tech industries. Foreign-owned firms are not more innovative than domestic firms in high-tech industries. In low-tech industries there is evidence that majority foreign-owned firms are less likely to innovate, while minority foreign-owned firms are more likely to innovate than domestic firms. These findings suggest that in low-tech industries multinational parents invest in majority-owned subsidiaries to use them as export platforms. They are likely to operate with a better technology than that available in domestic firms, but do not innovate more than domestic firms. This contrasts with the technological transfers from multinational parents to minority-owned subsidiaries.

A firm's geographical location may enhance its propensity to innovate (Audretsch, 1998), while also facilitating its access to global markets through exports and imports and increasing its attractiveness for FDI. This could happen either through the proximity to other firms (e.g., suppliers, clients) or to other institutions present, for example, in the capital city. The association between openness and innovation that we obtain could thus be spuriously due to location. Moreover, industries and regions with a large presence of firms integrated into global markets may provide a particularly dynamic environment for innovation to flourish. Thus, it is possible that the engagement of other firms in the same industry and region in international activities matters for the firm’s propensity to innovate. In column (7) of Table 5 we include in the regression the share of firms that export and the share of firms that import in the same industry and region. It is reassuring to see that the effects of minority foreign ownership, exports, and

imports on innovation are robust to this control. The effects of these 'spillover' variables are positive and significant for importers, but negative, though weak, for exporters, suggesting possible market-stealing effects. Our finding contrasts with the positive export spillover effects on firm TFP obtained by Alvarez and Lopez (2006) for Chile. Column (8) shows that our main findings are robust when we restrict the sample to firms located outside the country's capital city, although the effect of minority foreign ownership is weaker.[16]

A stylized fact in the literature is that the international transfer of technology is larger in countries with a better absorptive capacity and institutions (Caselli and Coleman II, 2001; Keller, 2004). Hoekman *et al.* (2005) argue that the optimal policy to promote the international transfer of technology should vary across countries at different stages of the "technology ladder". Moreover, they emphasise that policies should be tailored to the level of development of the local economies. Table 6 allows the coefficients in column (4) of Table 4 to vary by income group. We divide the sample countries into low income (13.9% of the sample), lower-middle income (67.9% of the sample) and upper-middle income countries (18.2% of the sample) groups, according to the World Bank classification. We find that in low income countries majority foreign-owned firms are less likely to engage in technological innovations than domestic firms or than minority foreign-owned firms. This gap in the propensity to innovate between majority foreign-owned firms and domestic firms or between majority and minority foreign-owned firms is reduced for the upper-middle income countries. In low income countries there is a positive, although weak, correlation between exports and technology adoption. This effect is stronger for upper-middle income countries. Interestingly, we find that the effect of importing on technology adoption does not vary significantly across income groups and that the positive effect of licenses on technology adoption is stronger for upper-middle income than for lower-middle income

countries. These findings are in line with the argument in Hoekman *et al.* (2005) that, regardless of the level of development, countries with liberalized trade regimes maximize the international transfer of technology and knowledge and that licensing is more important for countries higher up in the technology ladder. However, we also find that the effect of licensing on technology adoption is higher in low income countries than in lower-middle income countries, which is not fully in line with this argument.

We also examine the extent to which the effect of openness on technology adoption varies with the degree of protection of property rights in the country. Difficulties in enforcing contracts or in the ability to effectively use justice if local partners illegally appropriate technology may limit the transfer of technology. Measuring the protection of property rights by the patent protection index of Ginarte and Park (1995) or by an index of investor protection from Doing Business (World Bank, 2005), our findings reinforce the existing evidence that technology transfers tend to be higher in countries with better protection of property rights. This evidence confirms that in countries with weak property rights multinationals' fear of leakage of proprietary knowledge and of the threat of imitation by domestic firms influences their technology transfers (Saggi, 2002).[17]

Finally, given that East Asian countries account for 42.1 percent of our sample and their integration into global markets is stronger than that of countries in other regions, we examine whether our main findings are driven by Asian firms. The results confirm that the patterns found in Table 4 are common to Asian and non-Asian countries. The point estimates suggest that the transfer of technology through FDI and exports is stronger in Asian countries relative to the other regions.

In sum, our evidence contributes to the understanding of how host developing countries may promote the international transmission of technology. We find a robust positive association between trade - either exports or imports - and technological innovations. We also find robust evidence that majority foreign-owned firms are significantly less likely to adopt new technology than firms with minority foreign ownership or than domestic firms. These findings are stronger for low-tech industries, in upper-middle income countries, and in countries with better property rights' protection.

4. Channels for Technology Adoption

Firms may acquire technological innovations and knowledge through a variety of channels. New technology can be obtained by purchasing new or used equipment (foreign or domestic), by engaging in technology licensing agreements (from foreign or domestic sources), or by hiring consultants. Firms may also improve their knowledge about state-of-the-art technology through their interactions with clients or suppliers or through the interaction with business associations or universities. Of particular interest are the channels for the acquisition of technological innovations explored by firms engaged in trade or with some foreign ownership. Some case studies document the importance of the technology transferred from parent companies to their subsidiaries in developing countries or of the importance of the imported machinery and inputs for innovation (Pack, 1987; Young and Lan, 1997; UNCTAD, 2004). However, we are not aware of micro-econometric evidence documenting the importance of different channels for different types of firms. This section provides this evidence for developing countries.

The *Investment Climate Surveys* report information on the most important source of technological innovations used by each firm. Based on this information, we construct a categorical variable, *innovation channels*. This variable ranges from 1 to 6 depending on which

sources are most important. If the firm reports that the most important source for acquiring technological innovations is through hiring personnel (including consultants) or by developing technology within the firm the variable assumes the value 1; if the firm reports that it is through buying new equipment or development jointly with suppliers it assumes the value 2; if the firm reports that it is through domestic or foreign licensing agreements it assumes the value 3; if the firm reports that it is through transfers from the parent company it assumes the value 4; if the firm reports that it is through development of technology with client firms it assumes the value 5; and if the firm reports that it is through interactions with third parties (universities or public institutes, business or industry associations, trade fairs, study groups) it assumes the value 6. This variable is categorical but the its multiple outcomes are not ordered (i.e., the fact that 1<…<6 does not imply that outcome 1 is less than outcome 6). The appropriate estimation procedure to examine the firm characteristics associated with different innovation channels is a multinomial logistic regression. Let *Channels* denote the innovation channels variable, k denote the 6 outcome categories, and Ω_k denote the coefficient vector corresponding to outcome k. Then, the probability of firm *i* in industry *j* and country *c* choosing outcome k is given by:

$$\Pr(Channels_{ijc} = 1) = \frac{1}{1 + \sum_{k=2}^{6} e^{Z_{ijc}\Omega_k}}$$
$$\Pr(Channels_{ijc} = m) = \frac{e^{Z_{ijc}\Omega_m}}{1 + \sum_{k=2}^{6} e^{Z_{ijc}\Omega_k}} \quad m = 2,...,6 \qquad (3)$$

where Z_{ijc} is a vector that includes firm characteristics, industry fixed effects, and country GDP per capita. In Z_{ijc} we include dummy variables for minority and majority foreign ownership, and for exporting and importing firms, firm age age squared, size, share of the workforce with at least secondary education, a dummy variable if the firm provides training and a dummy variable

for public ownership. We allow the errors to be correlated across firms in the same country and industry. For identification purposes, in the estimation we set Ω_1 to zero so the estimated coefficients $\Omega_2,...,\Omega_6$ are measured relative to Ω_1. Table 7 reports the marginal effects of each regressor at the mean values of the independent variables for all outcomes (including outcome 1 used for normalization). These measure the effect of each variable on the likelihood of the firm choosing a given innovation channel. The number of observations in Table 7 is smaller than those in earlier tables because the multinomial logistic regression is estimated only for firms that engage in technological innovations. Moreover, information on innovation channels is not available for firms in China.

The findings in Table 7 illustrate some interesting patterns. First, we reject the hypothesis that foreign-owned firms make equal use of the different innovation channels. We find that technology transfers from parent companies are significantly more used than any other channel by minority and majority foreign-owned firms. These findings confirm the evidence mentioned earlier in Pack (1987) and UNCTAD (2004) of the importance of technology transfers from multinational parents to affiliates in developing countries. Moreover, we find that, relative to all other innovation channels, foreign-owned firms, especially majority foreign-owned firms, are less likely to rely on collaborations with third parties than domestic firms. Minority foreign-owned firms are more likely than domestic firms to acquire technology from client firms (that may operate in the domestic or the foreign market) while the reverse happens to majority foreign-owned firms.

Second, the results in Table 7 suggest that, relative to other innovation channels, exporting firms seem more likely to explore the collaboration with third parties, to develop

technology with client firms, to use licensing agreements, or to develop technology internally. However, the coefficients on the various channels do not differ significantly from one another.

Third, firms importing intermediate inputs are more likely to acquire new technology embodied in machinery or developed with machinery suppliers relative to other innovation channels. This finding supports the idea that in some international production networks (e.g., garments, electronics) suppliers tend to offer bundles of inputs and technology (Dahlman and Westphal, 1982; Bhattacharya, 1985). Importing firms are less likely to obtain technological innovations through hiring of personnel and through interactions with clients. The main findings in this table are robust to the inclusion of country dummy variables instead of controlling for the country's GDP per capita.

Our findings in Table 7 provide interesting evidence for the debate amongst policy-makers and international organizations of the need for a systemic approach to innovation at the national level (OECD, 1997). The *innovation systems approach* is based on the premise that firms do not innovate in isolation. Rather they are engaged in complex interactions with their technology suppliers, other firms, clients, technology service providers, universities, and government research institutes. Our findings show that for foreign-owned subsidiaries in developing countries, the knowledge obtained from third parties (universities, research institutes, or business associations) is much less important relative to the knowledge transferred from the parent company. Moreover, we also find that interactions with third parties are a relatively important channel for technological acquisition for exporting firms (although the effect is weak). This finding is consistent with the evidence (mostly in case studies) that some government institutions in developing countries provide technology and skill training services for exporters (Beyene, 2002).

In the Appendix (available online), we report the results from allowing the effects of openness on the innovation channels to vary by income groups. Some patterns are worth emphasising. First, the importance of technological transfers from parent companies for majority foreign-owned firms in host countries is robust across income groups. Second, for upper-middle income countries - in contrast to what happens in low and lower-middle income countries - third parties are not more important for the technology acquisition of exporting firms than for non-exporting firms. However, we do find that foreign-owned firms are less likely to use this channel in low income and lower-middle income countries. Third, the correlation between imports of intermediate inputs and the development of technology with suppliers is positive in lower-middle and upper-middle income countries.

Finally, we also check the sensitivity of our results across Asian and non-Asian firms. The main findings, shown in the Appendix (available online), hold broadly for both samples suggesting that the effects are not driven by the importance of Asian firms in our sample. The innovation channels used by firms integrated into global markets are quite similar across regions.

5. Conclusion

This paper provides evidence on the importance of technology transfers through trade, FDI, and licenses for technological innovations using firm-level data for 43 developing countries. We measure technological innovations looking at the creation of new production processes but also the adoption and adaptation of existing technologies to local conditions. This broad concept of innovation is particularly important for firms in developing countries.

Our findings show a strong positive correlation between trade and technological innovations within industries and countries. Moreover, our findings are robust to the control for several firm characteristics, such as R&D activities, managerial education, access to finance, and

competition. We also find strong evidence that majority foreign-owned firms are significantly less likely to engage in technological innovations than domestic firms in the same industry and country. This result is particularly strong in low-tech industries. We interpret this finding as evidence that the technology transferred from multinational parents to majority-owned subsidiaries is more mature and less prone to innovation than that transferred to minority-owned subsidiaries. Around the world, policies to attract FDI have been based on this presumption although the little empirical evidence available so far supported the contrary.

Despite the limitations in our approach, we believe that our findings feed well into some important policy discussions. Our evidence provides support to the argument that liberalized trade regimes maximize the international transfer of technology for countries at all levels of development (Hoekman *et al.*, 2005). Also, policies that promote joint-ventures with foreign partners can generate higher technological transfers to the host economy. Our findings also suggest that the firm's absorptive capacity is important to incorporate and transform foreign knowledge into technological innovations. Finally, our findings confirm the importance of technology transfers from multinational parents as an important channel for technology adoption in developing countries.

[1] The transmission of knowledge may also occur through the mobility of individuals across countries. Our paper does not analyze this mechanism for the transmission of knowledge (e.g., Hobday, 1995; Kim, 1997). Moreover, our paper does not examine the technological spillovers that firms integrated into global markets may generate to domestic firms (e.g., Javorcik, 2004; Ivarsson and Alvstam, 2005).

[2] The literature analyzing the link between exports and TFP finds strong evidence of self-selection of the most productive firms into export markets, but weaker evidence that presence in exporting markets improves firm performance. Alvarez and Lopez (2005), Van Biesebroeck (2005), and Fernandes and Isgut (2007) are some of the studies that find learning-by-exporting effects. Other studies such as Hallward-Driemeier *et al.* (2002) and Lopez (2005) argue that the access to export markets provides firms with incentives to upgrade their technology.

[3] Criscuolo et al. (2005) show that UK firms that are more integrated into global markets are more likely to innovate, but most of the difference is explained by their innovation inputs (number of scientists and researchers). Alvarez and Robertson (2004) find an insignificant effect of foreign ownership on innovation in Chile but a strong positive effect in Mexico. Vishwasrao and Bosshardt (2001), Damijan et al. (2005), and Girma et al. (2006) find that foreign-owned firms are more likely to innovate than domestic firms in India, Slovenia, and China respectively. However,

Vishwasrao and Bosshardt (2001) measure innovation using the number of foreign technical collaborations, Criscuolo et al. (2005) and Damijan et al. (2005) do not distinguish between product and process (technological) innovation, and Girma et al. (2006) study only product innovation.

[4] The *Investment Climate Surveys* were conducted in 68 developing countries. We use data for only 43 countries due to the lack of information on the main variables of interest for the remaining countries. We focus the analysis on manufacturing firms. The information collected in the surveys is based on a 1.5-2 hours interview with the firm manager. Detailed information on the surveys can be obtained at http://www.enterprisesurveys.org/Default.aspx. In what follows, we will refer to firms as being the unit of analysis but the unit of data collection was the plant.

[5] The countries included in our dataset are Albania, Armenia, Belarus, Bosnia and Herzegovina, Brazil, Bulgaria, Chile, China, Croatia, Czech Republic, Ecuador, Egypt, El Salvador, Estonia, Georgia, Guatemala, Honduras, Hungary, Indonesia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Madagascar, Malaysia, Moldova, Nicaragua, Philippines, Poland, Romania, Russia, Serbia and Montenegro, Slovakia, Slovenia, South Africa, Tajikistan, Thailand, Turkey, Ukraine, Uzbekistan, Vietnam, and Zambia.

[6] While the survey also collects information on product innovations, in this paper we focus on technological innovations. Nevertheless, our main findings are robust to an alternative definition of innovation that encompasses technological innovations and product innovations. Further discussion on product innovations can be found in the Appendix (available online).

[7] A negative relation between age and the propensity to innovate is predicted by the model of Klepper (1996). If technological innovations improve the probability of survival, then the negative point estimate in Table 4 would be an upper bound on the true effect of age on innovation (Audrestch, 1995).

[8] The effect of workforce education is weak in column (3) but strengthens in columns (4) and (5) when country heterogeneity is accounted for. A possible rationale for this finding is the positive correlation between innovation or technology adoption and human capital at the aggregate level documented by Lederman and Maloney (2003), Comin and Hobijn (2004), and Keller (2004).

[9] Note that our empirical findings differ from those (i) in Criscuolo *et al.* (2005) for the UK where firms with more than 10% of foreign capital are more likely to innovate than domestic firms, and (ii) in Vishwasrao and Bosshardt (2001) for India where firms with any positive share of foreign capital are more likely to adopt foreign technology than domestic firms.

[10] Mansfield and Romeo (1980) show that U.S. multinational parents transfer more advanced technologies to fully-owned subsidiaries than to minority-owned subsidiaries in developing countries. Ramachandran (1993) finds higher technology transfers from multinational parents to fully-owned subsidiaries than to minority-owned subsidiaries in India. Javorcik (2006) shows that multinationals with the most advanced technologies tend to enter into Eastern European countries through majority rather than minority foreign ownership.

[11] Young and Lan (1997) show that in China most technology transfers from multinational parents occur to joint-ventures rather than to fully-owned subsidiaries. Wie (2005) finds that foreign managers in Indonesia in charge of production management or of quality control typically transfer little knowledge into their majority foreign-owned subsidiaries.

[12] The Appendix (available online) shows also the point estimates for the firm characteristics included in the specifications in Table 5 but not shown (which are very similar to those reported in column (5) of Table 4).

[13] King and Levine (1993) argue that the development of financial intermediaries reduces the costs of identifying entrepreneurs more capable of generating innovations. Increased access to finance for firms can affect innovation through an improved screening of the quality and probability of success of the projects that are financed as well as through their effects on innovation inputs.

[14] Qualitatively similar findings on access to finance are obtained by Ayyagari *et al.* (2006) using a smaller sample of countries from the *Investment Climate Surveys*.

[15] The results are shown in the Appendix (available online). The alternative competition measures considered are: (i) a Herfindahl index of industrial concentration, (ii) the average number of competitors in the firm's industry and in the firm's industry-region, (iii) a dummy variable that equals one if the manager reports anti-competitive or informal practices being a major or very severe obstacle to firm growth, (iv) the share of firms in the industry-region whose managers report anti-competitive or informal practices being a major or very severe obstacle to firm growth, and (v) a dummy variable that equals one if managers report that domestic or foreign competitors are the main influence for the firm to develop new products, services and markets.

[16] In the Appendix (available online) we show that similar results are obtained restricting the sample to firms located outside the country's capital and second major cities, and to the inclusion of industry-region fixed effects. The latter

account more generally for unobservable industrial or regional policies, or geographical factors that could be simultaneously correlated with innovation and openness.

[17] The results are shown in the Appendix (available online) and show positive and significant coefficients on the proxies for the quality of property rights protection (the patent protection index and the investor protection index) and on an interaction between these proxies and openness (i.e., a dummy variable that equals one if the firm has a foreign participation or engages in trade).

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Table 1. Variable Definitions

Variable Name	Definition
Technological Innovation	Dummy variable equal to 1 if the firm introduced a new technology that substantially changed the way the main product was produced in the three years prior to the survey.
Majority Foreign-Owned	Dummy variable equal to 1 if 50% or more of the firm's capital is owned by foreigners.
Minority Foreign-Owned	Dummy variable equal to 1 if more than 0% but less than 50% of the firm's capital is owned by foreigners.
Domestic	Dummy variable equal to 1 if 100% of the firm's capital is owned by domestic entities.
Exporter	Dummy variable equal to 1 if the firm exports some of its output directly or indirectly.
Importer	Dummy variable equal to 1 if the firm imports some of its intermediate inputs and supplies directly or indirectly.
Technology Licensing	Dummy variable equal to 1 if the firm obtained a new technology licensing agreement in the three years prior to the survey.
Age	Year of the survey minus the year when the firm started operations.
Size	Logarithm of the total number of employees working at the firm.
Public Ownership	Dummy variable equal to 1 if the share of the firm's capital owned by the government or state is positive.
Training	Dummy variable equal to 1 if the firm provides internal or external training to its workers.
Workforce with More than Secondary Education	Percentage of the firm's workforce which has finished secondary, college, or post-graduate education.
R&D	Dummy variable equal to 1 if the firm has design and R&D expenditures (e.g., labor costs with R&D personnel, materials or subcontracting costs).
Manager with College Education or More	Dummy variable equal to 1 if the firm's manager has some university training, college, or post-graduate education.
Access to External Finance	Dummy variable equal to 1 if a firm finances its investments through commercial banks or leasing arrangements.
Share of Exporters (importers) in Region-Industry	Percentage of exporters (importers) in the total number of firms in the firm's industry-region, excluding the own firm.
No, Weak, Medium, and Strong Competition	Dummy variables equal to 1 if the firm faces 0, between 1and 3, between 4 and 20, and more than 20 competitors, respectively in its main product line in the domestic market.
High-Tech Industries	Auto and auto-components, chemicals and pharmaceuticals, electronics, and metals and machinery (following Parisi et al. , 2006).
Low-Tech Industries	Beverages, food, garments, leather, non-metallic and plastic materials, paper, other manufacturing, textiles, and wood and furniture (following Parisi *et al.* , 2006).
Innovation Channels	Variable ranging from 1 to 6 depending on whether the most important way in which the firm acquires technological innovations is (1) related to the hiring of key personnel, consultants or developed and adapted within the firm, (2) embodied in new machinery or equipment or developed with equipment and machinery suppliers, (3) through licensing or turnkey operations from international or domestic sources, (4) transferred from the parent company, (5) developed in cooperation with client firms, (6) from universities and public institutions, business or industry associations, or trade fairs and study groups.
GDP per Capita (log)	Values in constant 2000 USD for the year 1995 (Source: World Development Indicators)

Note: The source is the Investment Climate Surveys unless otherwise stated.

Table 2. Descriptive Statistics

	Obs.	Mean	Standard Deviation
Technological Innovation	17,667	0.56	-
Majority Foreign-Owned	17622	0.13	-
Minority Foreign-Owned	17,622	0.04	-
Exporter	17,667	0.40	-
Importer	17,429	0.47	-
Technology Licensing	16,050	0.10	-
Age	17,630	18.26	17.02
Total Employment	17,380	224.08	645.85
Public-Owned	17,667	0.08	-
Training	17,667	0.54	-
Workforce with More than Secondary Education	17,054	0.21	0.25
R&D	17,667	0.48	-
Manager with College Education or More	14,045	0.75	-
Access to External Finance	15,363	0.50	-
Share of Exporters in Region-Industry	17,667	0.37	-
Share of Importers in Region-Industry	17,667	0.37	-
No Competition	14,409	0.13	-
Weak Competition	14,409	0.13	-
Medium Competition	14,409	0.37	-
Strong Competition	14,409	0.38	-
For firms engaged in technological innovation the major mode of acquisition is:			
Embodied in New Machinery or Equipment or Developed with Equipment or Machinery Supplier	7,429	0.60	-
Acquired By Hiring Key Personnel, Consultants, or Developed or Adapted Within Establishment	7,429	0.21	-
Acquired from Licensing or Turnkey Operations from International or Domestic Sources	7,429	0.03	-
Transferred from Parent Company	7,429	0.05	-
Developed in Cooperation with Client Firms	7,429	0.07	-
Acquired from Business or Industry Association, from Trade Fairs and Study Groups, from Universities or Public Institutions	7,429	0.04	-

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The column entitled 'Obs.' shows the number of firms with non-missing values for each variable based on the sample of 17,667 firms with non-missing values for technological innovation. All variables are defined in Table 1.

Table 3. Technological Innovation across Regions, Industries, and Firm Characteristics

	Obs.	Percentage of Firms Engaged in Technological Innovation
Region:		
Africa	2,032	37.8%
East Asia	7,486	61.5%
Eastern Europe and Central Asia	3,551	48.7%
Latin America	4,654	60.9%
Industry:		
Auto and Auto Components	977	72.5%
Beverages	834	52.2%
Chemicals and Pharmaceuticals	975	54.7%
Electronics	1,526	73.4%
Food	2,494	50.0%
Garments	2,779	53.9%
Leather	455	60.0%
Metals and Machinery	2,848	55.2%
Non-Metallic and Plastic Materials	1,425	52.2%
Other Manufacturing	402	54.7%
Paper	381	45.5%
Textiles	1,143	51.5%
Wood and Furniture	1,484	55.0%
Majority Foreign-Owned	2,285	63.7%
Minority Foreign-Owned	726	74.1%
Domestic	14,640	54.0%
Exporter	7,168	64.8%
Importer	8,307	62.7%
Technology Licensing	1,556	77.1%
Micro (1-10 Employees)	2,774	41.4%
Small (10-50 Employees)	6,304	49.1%
Medium (50-150 Employees)	3,698	63.0%
Large (More than 150 Employees)	4,657	68.4%
Full Sample	17,667	56.0%

Source: Authors' calculations using data from the Investment Climate Surveys.
Note: All variables are defined in Table 1.

Table 4. Determinants of Technological Innovation

	(1)	(2)	(3)	(4)	(5)
Majority Foreign-Owned	-0.026	-0.076	-0.081	-0.075	-0.059
	[0.021]	[0.022]***	[0.021]***	[0.021]***	[0.018]***
Minority Foreign-Owned	0.117	0.079	0.076	0.072	0.045
	[0.028]***	[0.030]***	[0.029]***	[0.028]***	[0.025]*
Exporter	0.116	0.056	0.043	0.033	0.031
	[0.019]***	[0.019]***	[0.018]**	[0.017]*	[0.013]**
Importer	0.098	0.082	0.067	0.068	0.064
	[0.017]***	[0.016]***	[0.016]***	[0.015]***	[0.011]***
Technology Licensing	0.227	0.215	0.196	0.206	0.215
	[0.023]***	[0.023]***	[0.023]***	[0.023]***	[0.022]***
Age		-0.001	-0.001	-0.002	-0.002
		[0.001]	[0.001]	[0.001]**	[0.001]**
Age Squared		-0.000004	-0.000006	-0.000005	-0.000004
		[0.000005]	[0.000005]	[0.000005]	[0.000004]
Size		0.061	0.045	0.05	0.055
		[0.007]***	[0.006]***	[0.006]***	[0.004]***
Public-Owned		-0.127	-0.127	-0.067	-0.044
		[0.029]***	[0.028]***	[0.026]**	[0.021]**
Training			0.197	0.182	0.125
			[0.017]***	[0.016]***	[0.010]***
Workforce More Second. Educat.			0.056	0.084	0.090
			[0.034]	[0.030]***	[0.019]***
Observations	15,819	15,689	15,222	15,222	15,222
Industry Dummies Included?	Yes	Yes	Yes	Yes	Yes
Log Past per Capita GDP Included?	No	No	No	Yes	No
Country Dummies Included?	No	No	No	No	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. All variables are defined in Table 1.

Table 5. Determinants of Technological Innovation - Sensitivity Analysis

	Full Sample	Full Sample	Full Sample	Full Sample	Sample of High-Tech Industries	Sample of Low-Tech Industries	Full Sample	Sample Excluding Firms in Country's Capital City
	(1)	(2)	(3)	(5)	(7)	(8)	(4)	(6)
Majority Foreign-Owned	-0.057	-0.053	-0.057	-0.067	-0.044	-0.075	-0.058	-0.064
	[0.018]***	[0.022]**	[0.019]***	[0.020]***	[0.031]	[0.022]***	[0.018]***	[0.020]***
Minority Foreign-Owned	0.045	0.064	0.050	0.038	-0.015	0.081	0.046	0.042
	[0.026]*	[0.028]**	[0.026]*	[0.026]	[0.051]	[0.029]***	[0.026]*	[0.028]
Exporter	0.031	0.027	0.032	0.035	0.058	0.019	0.035	0.029
	[0.013]**	[0.015]*	[0.014]**	[0.013]***	[0.023]**	[0.017]	[0.013]***	[0.016]*
Importer	0.061	0.057	0.062	0.066	0.073	0.057	0.059	0.071
	[0.011]***	[0.013]***	[0.012]***	[0.013]***	[0.020]***	[0.014]***	[0.012]***	[0.013]***
Technology Licensing	0.211	0.197	0.186	0.206	0.153	0.264	0.215	0.193
	[0.023]***	[0.029]***	[0.021]***	[0.021]***	[0.032]***	[0.022]***	[0.023]***	[0.023]***
R&D	0.063							
	[0.012]***							
Manager College Educat. or More		0.037						
		[0.014]***						
Access to External Finance			0.022					
			[0.011]**					
Weak Competition				0.038				
				[0.021]*				
Medium Competition				0.073				
				[0.019]***				
Strong Competition				0.062				
				[0.021]***				
Share of Exporters in Region-Industry							-0.052	
							[0.036]	
Share of Importers in Region-Industry							0.100	
							[0.033]***	
Observations	15,222	11,733	13,143	13,714	4,890	10,332	15,222	10,579
Industry Dummies Included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummies Included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The regressions include also firm age and age squared, the logarithm of firm size, a dummy variable for public ownership, a dummy variable for the provision of training, and the percentage of the workforce with more than secondary education. The omitted competition category in column (5) is no competition. All variables are defined in Table 1.

Table 6. Determinants of Technological Innovation Across Income Groups

	(1)
Majority Foreign-Owned	-0.1
	[0.035]***
Minority Foreign-Owned	0.035
	[0.067]
Exporter	0.017
	[0.030]
Importer	0.071
	[0.028]**
Technology Licensing	0.277
	[0.035]***
Majority Foreign-Owned * Lower-Middle Income Group	0.048
	[0.043]
Minority Foreign-Owned * Lower-Middle Income Group	0.074
	[0.074]
Exporter * Lower-Middle Income Group	0.026
	[0.035]
Importer * Lower-Middle Income Group	0.008
	[0.032]
Technology Licensing * Lower-Middle Income Group	-0.108
	[0.058]*
Majority Foreign-Owned * Upper-Middle Income Group	0.08
	[0.045]*
Minority Foreign-Owned * Upper-Middle Income Group	0.036
	[0.088]
Exporter * Upper-Middle Income Group	0.078
	[0.039]**
Importer * Upper-Middle Income Group	-0.033
	[0.039]
Technology Licensing * Upper-Middle Income Group	-0.027
	[0.061]
Observations	15,222
Industry Dummies Included?	Yes
Log Past per Capita GDP Included?	Yes
Dummies for Lower-Middle and Upper-Middle Income Groups Included?	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The regression includes also firm age and age squared, the logarithm of firm size, a dummy variable for public ownership, a dummy variable for the provision of training, and the percentage of the workforce with more than secondary education. All variables are defined in Table 1.

Table 7. Innovation Channels and Firm Openness

	By Hiring Key Personnel or Consultants or Developed or Adapted Within Establishment	Embodied in New Machinery or Equipment or Developed with Equipment or Machinery Supplier	Licensing or Turnkey Operations from International Sources or Domestic Sources	Transferred from Parent Company	Developed in Cooperation with Client Firms	From Universities or Public Institutions, Business or Industry Associations, and Trade Fairs or Study Groups
Majority Foreign-Owned	-0.059***	-0.055***	0.003	0.140***	-0.019**	-0.010***
	[0.018]	[0.022]	[0.008]	[0.018]	[0.008]	[0.004]
Minority Foreign-Owned	-0.041*	-0.054**	0.009	0.073***	0.019	-0.006
	[0.022]	[0.027]	[0.010]	[0.024]	[0.014]	[0.006]
Exporter	0.003	-0.018	0.004	-0.001	0.009	0.004
	[0.012]	[0.013]	[0.005]	[0.002]	[0.006]	[0.003]
Importer	-0.032***	0.051***	0.005	0.004**	-0.026***	-0.002
	[0.011]	[0.016]	[0.005]	[0.002]	[0.010]	[0.003]
Observations	7,085					
Industry Dummies Included?	Yes					
Log Past per Capita GDP Included?	Yes					

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is innovation channels. The table reports the marginal effects (at mean values) on the firm's propensity to choose one of the innovation channels from a multinomial logistic regression. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The regression includes also firm age and age squared, the logarithm of firm size, a dummy variable for public ownership, a dummy variable for the provision of training, and the percentage of the workforce with more than secondary education. All variables are defined in Table 1.

"Openness and Technological Innovations in Developing Countries: Evidence from Firm-Level Surveys" Appendix

Appendix A: Data

A.1. Sensitivity to an Alternative Definition of Innovation

The *Investment Climate Surveys* collect information on whether the firm developed new major product line(s) or upgraded existing product line(s) in the three years prior to the survey. Firms in our sample are more likely to engage in product innovation (68.8%) than in technological innovation (56%). This finding holds for most industries and countries. The percentage of firms that engage in both types of innovation is 47.5 percent, while the probability of engaging in product innovation for firms that have also introduced technological innovations is 84.7 percent. The latter figure shows that technological innovations are likely to result in changes in product design and quality and thus new or improved products. However, engaging in technological innovations does not result in product innovation with certainty. Table A.1 replicates Table 4 in the paper using an alternative definition of innovation that encompasses technological and product innovations. Our main findings are generally robust to this alternative definition. The issue of product innovation is discussed in Section 2 of the paper.

Table A.1. Determinants of Technological or Product Innovation

	(1)	(2)	(3)	(4)	(5)
Majority Foreign-Owned	-0.044	-0.077	-0.085	-0.081	-0.056
	[0.018]**	[0.019]***	[0.019]***	[0.019]***	[0.015]***
Minority Foreign-Owned	0.016	-0.013	-0.021	-0.022	0.013
	[0.019]	[0.021]	[0.020]	[0.020]	[0.015]
Exporter	0.073	0.03	0.018	0.015	0.028
	[0.013]***	[0.012]**	[0.011]	[0.012]	[0.007]***
Importer	0.127	0.114	0.098	0.098	0.067
	[0.012]***	[0.012]***	[0.011]***	[0.010]***	[0.007]***
Technology Licensing	0.137	0.131	0.116	0.119	0.112
	[0.017]***	[0.017]***	[0.017]***	[0.016]***	[0.013]***
Age		0.00001	0.0002	-0.0002	-0.0002
		[0.0005]	[0.0005]	[0.0005]	[0.0004]
Age Squared		-0.000004	-0.000006	-0.000005	-0.0002
		[0.000005]	[0.000005]	[0.000005]	[0.000004]
Size		0.041	0.03	0.032	0.032
		[0.004]***	[0.004]***	[0.004]***	[0.003]***
Public-Owned		-0.081	-0.085	-0.060	-0.031
		[0.024]***	[0.023]***	[0.023]***	[0.016]*
Training			0.143	0.137	0.089
			[0.013]***	[0.013]***	[0.007]***
Workforce More Second. Educat.			0.107	0.117	0.048
			[0.027]***	[0.025]***	[0.018]***
Observations	15,819	15,689	15,222	15,222	15,222
Industry Dummies Included?	Yes	Yes	Yes	Yes	Yes
Log Past per Capita GDP Included?	No	No	No	Yes	No
Country Dummies Included?	No	No	No	No	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is an innovation definition that encompasses technological or product innovations. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively.

A.2. Technological Innovation at the Country Level

Figure A.1 shows the propensity to innovate at the country level which is discussed in Section 2 of the paper.

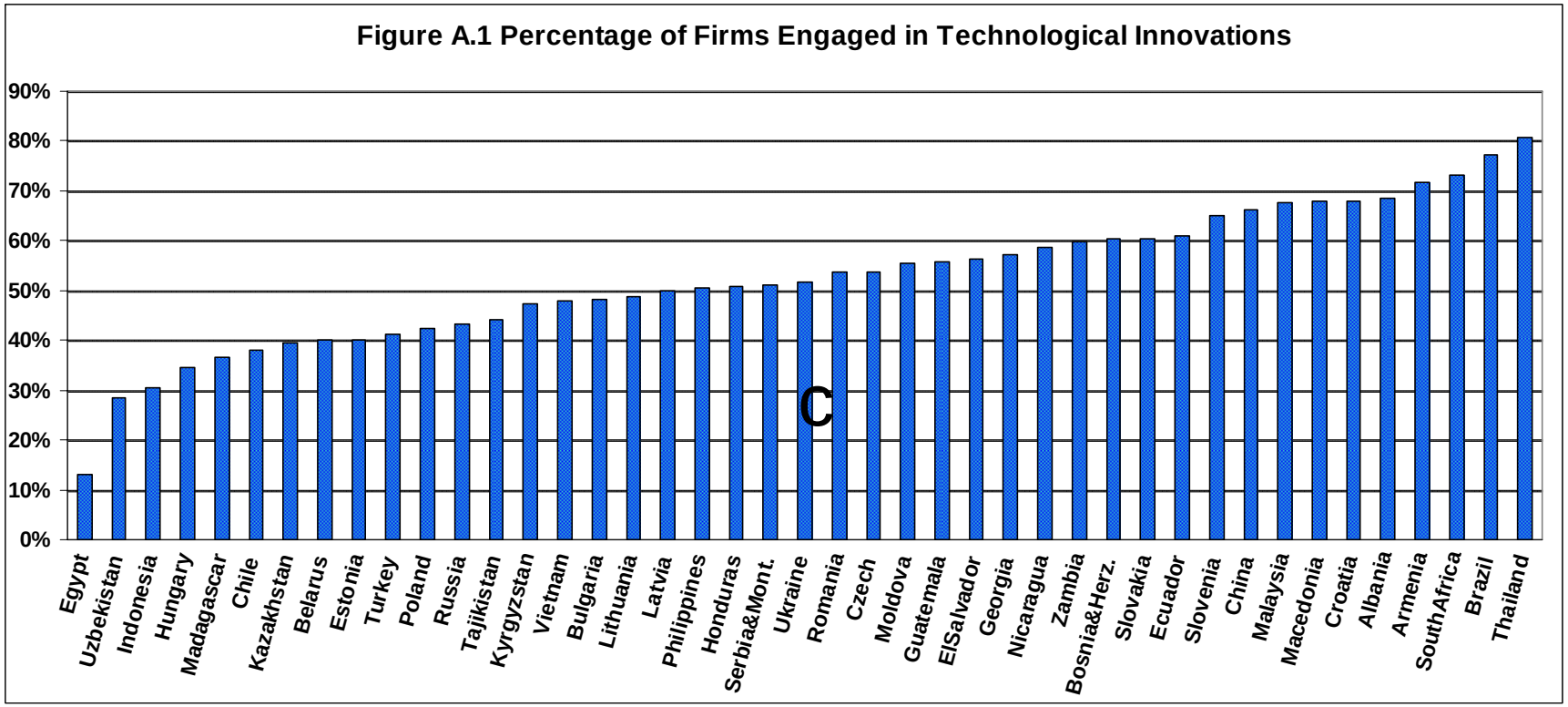
Figure A.1 Percentage of Firms Engaged in Technological Innovations
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Egypt
Uzbekistan
Indonesia
Hungary
Madagascar
Chile
Kazakhstan
Belarus
Estonia
Turkey
Poland
Russia
Tajikistan
Kyrgyzstan
Vietnam
Bulgaria
Lithuania
Latvia
Philippines
Honduras
Serbia&Mont.
Ukraine
Romania
Czech
Moldova
Guatemala
ElSalvador
Georgia
Nicaragua
Zambia
Bosnia&Herz.
Slovakia
Ecuador
Slovenia
China
Malaysia
Macedonia
Croatia
Albania
Armenia
SouthAfrica
Brazil
Thailand

In our sample, Egypt and Uzbekistan have the lowest frequency of firms engaged in technological innovations while Thailand and Brazil have the highest frequency. In between these countries, the ranking of countries according to the innovation propensity is as expected – i.e., positively correlated with the level of development - with some exceptions. For example, Chilean firms innovate less often (38.1%) than firms in some Eastern European countries (67.9% in Macedonia and 68.4% in Albania). These differences are very likely explained by discrepancies in what managers consider to be an innovation that substantially changes the way the main product is produced. Since Eastern Europe is the region where more countries have an unexpected position in the ranking, we have also tested whether our main findings were robust to the exclusion of these firms from the sample. It is reassuring to see that they are.

Appendix B: Sensitivity Analysis - Determinants of Technological Innovations

B.1. Foreign Technical Licenses and Full Foreign Ownership

The survey includes information on whether the firms use technology licensed from a foreign-owned firm for 16 of the 43 countries in the sample. Column (1) of Table B.1 shows the results from estimating our preferred specification (column (5) of Table 4) using this foreign licensing variable. The results support a positive correlation between licensing and innovation and the effects of the openness variables are robust. Column (2) of Table B.1 shows that both majority foreign-owned as well as fully foreign-owned firms are less likely to innovate to innovate than minority foreign-owned or domestic firms. Both these findings are discussed in Section 3.1 of the paper.

Table B.1. Determinants of Technological Innovation - Foreign Licenses and Full Foreign Ownership

	(1)	(2)
Majority Foreign-Owned	-0.057	-0.053
	[0.021]***	[0.026]**
Minority Foreign-Owned	0.049	0.045
	[0.028]*	[0.025]*
Fully Foreign-Owned		-0.064
		[0.021]***
Exporter	0.026	0.031
	[0.015]*	[0.013]**
Importer	0.052	0.064
	[0.012]***	[0.011]***
Technology Licensing		0.215
		[0.022]***
Foreign Technology Licensing	0.097	
	[0.021]***	
Age	-0.003	-0.002
	[0.001]***	[0.001]**
Age Squared	0.00002	0.000004
	[0.00001]	[0.000007]
Size	0.049	0.055
	[0.006]***	[0.004]***
Public-Owned	-0.039	-0.044
	[0.050]	[0.021]**
Training	0.147	0.125
	[0.012]***	[0.010]***
Workforce More Second. Educat.	0.062	0.090
	[0.021]***	[0.019]***
Observations	10,197	15,222
Industry Dummies Included?	Yes	Yes
Country Dummies Included?	Yes	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is an innovation definition that encompasses technological or product innovations. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively.

B.2. Determinants of Technological Innovations

Table B.2 reports the point estimates for all the variables included in the specifications shown in Table 5 and discussed in Section 3.2 of the paper. The estimates are very close those reported in our preferred specification.

Table B.2. Determinants of Technological Innovation - Robustness

	Full Sample	Full Sample	Full Sample	Full Sample	Sample of High-Tech Industries	Sample of Low-Tech Industries	Full Sample	Sample Excluding Firms in Country's Capital City
	(1)	(2)	(3)	(5)	(7)	(8)	(4)	(6)
Majority Foreign-Owned	-0.057	-0.053	-0.057	-0.067	-0.044	-0.075	-0.058	-0.064
	[0.018]***	[0.022]**	[0.019]***	[0.020]***	[0.031]	[0.022]***	[0.018]***	[0.020]***
Minority Foreign-Owned	0.045	0.064	0.050	0.038	-0.015	0.081	0.046	0.042
	[0.026]*	[0.028]**	[0.026]*	[0.026]	[0.051]	[0.029]***	[0.026]*	[0.028]
Exporter	0.031	0.027	0.032	0.035	0.058	0.019	0.035	0.029
	[0.013]**	[0.015]*	[0.014]**	[0.013]***	[0.023]**	[0.017]	[0.013]***	[0.016]*
Importer	0.061	0.057	0.062	0.066	0.073	0.057	0.059	0.071
	[0.011]***	[0.013]***	[0.012]***	[0.013]***	[0.020]***	[0.014]***	[0.012]***	[0.013]***
Technology Licensing	0.211	0.197	0.186	0.206	0.153	0.264	0.215	0.193
	[0.023]***	[0.029]***	[0.021]***	[0.021]***	[0.032]***	[0.022]***	[0.023]***	[0.023]***
R&D	0.063							
	[0.012]***							
Manager College Educat. or More		0.037						
		[0.014]***						
Access to External Finance			0.022					
			[0.011]**					
Weak Competition				0.038				
				[0.021]*				
Medium Competition				0.073				
				[0.019]***				
Strong Competition				0.062				
				[0.021]***				
Share Exporters in Region-Industry							-0.052	
							[0.036]	
Share Importers in Region-Industry							0.100	
							[0.033]***	
Age	-0.002	-0.002	-0.001	-0.002	-0.003	-0.001	-0.002	-0.001
	[0.001]**	[0.001]**	[0.001]**	[0.001]**	[0.001]**	[0.001]	[0.001]**	[0.001]
Age Squared	0.000004	0.00001	0.000003	0.000004	0.00002	0.0000004	0.000004	-0.000002
	[0.000007]	[0.00001]	[0.000008]	[0.000008]	[0.00001]	[0.000009]	[0.000007]	[0.00001]
Size (Logarithm)	0.052	-0.028	0.049	0.055	0.045	0.060	0.056	0.055
	[0.004]***	[0.024]	[0.005]***	[0.005]***	[0.006]***	[0.005]***	[0.004]***	[0.006]***
Public-Owned	-0.043	0.133	-0.027	-0.046	-0.012	-0.063	-0.045	-0.045
	[0.021]**	[0.012]***	[0.021]	[0.023]*	[0.029]	[0.026]**	[0.021]**	[0.024]*
Training	0.121	0.071	0.119	0.119	0.135	0.121	0.125	0.126
	[0.010]***	[0.020]***	[0.011]***	[0.011]***	[0.018]***	[0.013]***	[0.010]***	[0.013]***
Workforce More Second. Educat.	0.083	0.037	0.099	0.100	0.084	0.087	0.087	0.114
	[0.019]***	[0.014]***	[0.024]***	[0.020]***	[0.034]**	[0.023]***	[0.019]***	[0.031]***
Observations	15,222	11,733	13,143	13,714	4,890	10,332	15,222	10,579
Industry Dummies Included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummies Included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.
Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The omitted competition category in column (5) is no competition.

B.3. Technological Innovations and Exports

We now discuss further the link between exports and technology adoption. First, we try to disentangle whether what matters for technology adoption is the firm's presence in external markets or whether the firm's export share also plays a role. We add to our

preferred specification the share of exports in total production and a dummy variable that equals one if the firm exports 100 % of its output. Column (1) of Table B.3 shows a positive correlation between technology adoption and the incidence of exporting but no correlation with how much is exported. Most interesting is the fact that firms that export all their output are less likely to innovate than firms that export smaller shares of output or non-exporting firms. The latter is consistent with the '100%-exporters' taking advantage of their location to explore benefits such as tax incentives or low labour costs but not engaging in significant technological innovations. Consistent with this argument is the fact that 47 percent of '100%-exporters'are majority foreign-owned and 48 percent operate in consumer products industries: garments, leather, or textiles. Second, we also test the sensitivity of our main findings to restricting the exporting firms in the sample to those that entered foreign markets more than 10 years or more than 20 years prior to the survey. Columns (2) and (3) of Table B.3 show that the results for these samples are again very close to those in column (5) of Table 4 of the paper.

Table B.3. Determinants of Technological Innovation - Sensivity to Export Variables

	Full Sample	Sample of Non-Exporters and Exporters More than 10 Years	Sample of Non-Exporters and Exporters More than 20 Years
	(1)	(2)	(3)
Majority Foreign-Owned	-0.047	-0.055	-0.053
	[0.019]**	[0.020]***	[0.022]**
Minority Foreign-Owned	0.055	0.032	0.035
	[0.025]**	[0.027]	[0.027]
Exporter	0.047	0.032	0.034
	[0.015]***	[0.015]**	[0.016]**
Importer	0.061	0.071	0.076
	[0.012]***	[0.012]***	[0.012]***
Technology Licensing	0.216	0.222	0.209
	[0.023]***	[0.025]***	[0.026]***
Exporter 100% of Output	-0.066		
	[0.026]***		
Export Share (Less than 100%)	-0.009		
	[0.025]		
Age	-0.002	-0.002	-0.002
	[0.001]***	[0.001]***	[0.001]***
Age Squared	0.000005	0.00001	0.00001
	[0.000008]	[0.000008]	[0.000008]
Size (Logarithm)	0.057	0.059	0.062
	[0.004]***	[0.005]***	[0.005]***
Public-Owned	-0.043	-0.044	-0.05
	[0.021]**	[0.022]**	[0.024]**
Training	0.122	0.132	0.132
	[0.010]***	[0.011]***	[0.012]***
Workforce More Second. Educat.	0.082	0.083	0.086
	[0.019]***	[0.020]***	[0.021]***
Observations	14,898	13,289	12,339
Industry Dummies Included?	Yes	Yes	Yes
Country Dummies Included?	Yes	Yes	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively.

B.4. Technological Innovations and Competition

Given the difficulties in measuring competition, we check the sensitivity of the findings in column (5) of Table 5 to the use of alternative measures of competition. In columns (1)-(6) of Table B.4, we show the results from using the following competition measures: the Herfindahl index of industrial concentration (i.e., the sum of squared firm market shares in the industry), the average number of competitors in the firm's industry and in the firm's industry-region, a dummy variable that equals one if the manager reports anti-competitive or informal practices as being a major or very severe obstacle to firm growth, the share of firms in the industry-region whose managers report anti-competitive or informal practices as being a major or very severe obstacle to firm growth

and a dummy variable that equals one if managers report that domestic or foreign competitors are the main influence for the firm to develop new products, services and markets. The results support a positive link between competition and innovation and the effects of openness are similar to those estimated in our preferred specification.

Table B.4. Determinants of Technological Innovation - Sensivity to Different Measures of Competition

	(1)	(2)	(3)	(4)	(5)	(6)
Majority Foreign-Owned	-0.059	-0.061	-0.061	-0.059	-0.059	-0.067
	[0.018]***	[0.019]***	[0.019]***	[0.019]***	[0.018]***	[0.020]***
Minority Foreign-Owned	0.045	0.047	0.048	0.029	0.033	0.039
	[0.025]*	[0.026]*	[0.025]*	[0.026]	[0.025]	[0.035]
Exporter	0.031	0.031	0.030	0.027	0.028	0.028
	[0.013]**	[0.013]**	[0.013]**	[0.013]**	[0.013]**	[0.014]**
Importer	0.064	0.064	0.064	0.057	0.061	0.067
	[0.011]***	[0.012]***	[0.012]***	[0.012]***	[0.012]***	[0.012]***
Technology Licensing	0.215	0.214	0.214	0.203	0.205	0.222
	[0.023]***	[0.023]***	[0.023]***	[0.022]***	[0.021]***	[0.026]***
Herfindahl Index of Industrial Concentration	-0.041					
	[0.030]					
Weak Competition in Industry		0.027				
		[0.082]				
Medium Competition in Industry		0.037				
		[0.079]				
Strong Competition in Industry		0.027				
		[0.081]				
Weak Competition in Industry-Region			0.020			
			[0.040]			
Medium Competition in Industry-Region			0.092			
			[0.035]***			
Strong Competition in Industry-Region			0.089			
			[0.038]**			
Anti-Competitive or Informal Practices are Major Obstacle				0.024		
				[0.011]**		
Share of Firms in Industry-Region Reporting Anti-Competitive or Informal Practices as Major Obstacle					0.227	
					[0.071]***	
Domestic/Foreign Competitors are Main Influence for Firm to Develop New Products, Services and Markets						0.042
						[0.014]***
Age	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001
	[0.001]**	[0.001]**	[0.001]**	[0.001]***	[0.001]**	[0.001]*
Age Squared	0.000004	0.000004	0.000004	0.000006	0.000005	0.000001
	[0.000007]	[0.000007]	[0.000007]	[0.000007]	[0.000007]	[0.000008]
Size (Logarithm)	0.055	0.055	0.055	0.055	0.055	0.052
	[0.004]***	[0.004]***	[0.004]***	[0.005]***	[0.004]***	[0.004]***
Public-Owned	-0.044	-0.041	-0.042	-0.040	-0.040	-0.034
	[0.021]**	[0.021]**	[0.021]**	[0.022]*	[0.021]*	[0.020]*
Training	0.125	0.126	0.125	0.118	0.118	0.113
	[0.010]***	[0.010]***	[0.010]***	[0.010]***	[0.010]***	[0.011]***
Workforce More Second. Educat.	0.090	0.087	0.086	0.092	0.087	0.092
	[0.019]***	[0.019]***	[0.019]***	[0.020]***	[0.019]***	[0.021]***
Observations	15,222	15,019	15,007	13,783	14,250	12,979
Industry Dummies Included?	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummies Included?	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.
Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The omitted competition category in columns (2) and (3) is no competition.

B.5. Technological Innovations and Location Effects

Column (1) of Table B.5 shows that the results are robust to restricting the sample to firms located outside the country's capital and second major cities. Similarly, column (2) of Table B.5 shows that our findings are robust to the inclusion of industry-region fixed effects to control for unobservable industrial and regional policies or geographical factors that could be simultaneously correlated with firm innovation and openness.

Table B.5. Determinants of Technological Innovation - Sensivity to Location

	Sample Excluding Firms in Country's Capital and Second Major City	Full Sample
	(1)	(2)
Majority Foreign-Owned	-0.073	-0.056
	[0.022]***	[0.021]***
Minority Foreign-Owned	0.037	0.053
	[0.028]	[0.030]*
Exporter	0.041	0.042
	[0.018]**	[0.014]***
Importer	0.061	0.054
	[0.014]***	[0.013]***
Technology Licensing	0.239	0.223
	[0.018]***	[0.025]***
Age	-0.001	-0.002
	[0.001]	[0.001]***
Age Squared	0.000001	0.000008
	[0.000009]	[0.000008]
Size (Logarithm)	0.057	0.055
	[0.006]***	[0.005]***
Public-Owned	-0.067	-0.041
	[0.026]***	[0.022]*
Training	0.131	0.132
	[0.014]***	[0.012]***
Workforce More Second. Educat.	0.102	0.088
	[0.034]***	[0.020]***
Observations	8,957	14,361
Industry Dummies Included?	Yes	
Country Dummies Included?	Yes	
Log Past per Capita GDP Included?		Yes
Industry-Region Dummies Included?		Yes

Source: Authors' calculations using data from the Investment Climate Surveys.
Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively.

B.6. Technological Innovations and Property Rights Protection

Column (1) of Table B.6 shows how the effects of openness on technology adoption vary with the degree of protection of property rights in the country. The latter

are measured by the patent protection index of Ginarte and Park (1995) or by an index of investor protection from Doing Business (World Bank, 2005). The findings show that technology transfers are higher in countries with better protection of property rights.

Table B.6. Determinants of Technological Innovation - Sensivity to Protection of Property Rights

	(1)	(2)
Majority Foreign-Owned	-0.049	-0.087
	[0.021]**	[0.021]***
Minority Foreign-Owned	0.070	0.041
	[0.029]**	[0.029]
Exporter	-0.002	-0.008
	[0.017]	[0.019]
Importer	0.006	0.023
	[0.021]	[0.020]
Technology Licensing	0.199	0.209
	[0.025]***	[0.023]***
Patent Protection Index	0.035	
	[0.020]*	
Patent Protection Index * Openness	0.028	
	[0.009]***	
Investor Protection Index		0.021
		[0.010]**
Investor Protection Index * Openness		0.016
		[0.005]***
Age	-0.001	-0.002
	[0.001]	[0.001]***
Age Squared	0.000005	0.000004
	[0.000007]	[0.000007]
Size	0.054	0.052
	[0.007]***	[0.006]***
Public-Owned	-0.058	-0.035
	[0.028]**	[0.024]
Training	0.194	0.185
	[0.016]***	[0.015]***
Workforce More Second. Educat.	0.124	0.109
	[0.026]***	[0.032]***
Observations	12,928	14,937
Industry Dummies Included?	Yes	Yes
Log Past per Capita GDP Included?	Yes	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. * significant at 10%, ** significant at 5%, *** significant at 1%. Openness is a dummy variable that equals 1 if the firm has a foreign participation or engages in trade.

B.7. Technological Innovations and Openness: Asian Firms versus Non-Asian Firms

Table B.7 shows the results from estimating our preferred specification allowing the effects of openness on technological innovation to vary across Asian firms and non-Asian firms. The results show that the main patterns are similar in Asia and outside Asia.

Table B.7. Determinants of Technological Innovation - Sensitivity to Presence of Asian Firms

	(1)
Majority Foreign-Owned	-0.095
	[0.026]***
Minority Foreign-Owned	-0.058
	[0.051]
Exporter	0.011
	[0.020]
Importer	0.082
	[0.020]***
Technology Licensing	0.225
	[0.024]***
Majority Foreign-Owned * Asia	0.041
	[0.038]
Minority Foreign-Owned * Asia	0.163
	[0.052]***
Exporter * Asia	0.047
	[0.028]*
Importer * Asia	-0.017
	[0.031]
Technology Licensing * Asia	-0.040
	[0.051]
Age	-0.002
	[0.001]**
Age Squared	0.000002
	[0.000007]
Size (Logarithm)	0.047
	[0.006]***
Public-Owned	-0.070
	[0.027]***
Training	0.186
	[0.016]***
Workforce More Second. Educat.	0.083
	[0.030]***
Observations	15,222
Industry Dummies Included?	Yes
Log Past per Capita GDP Included?	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is technological innovation. The table reports the marginal effects (at mean values) on the firm's propensity to innovate from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The regression includes also the dummy variable Asia.

Appendix C: Sensitivity Analysis - Channels for Technology Adoption

C.1. Determinants of Channels for Technology Adoption

Table C.1 reports the point estimates (marginal effects) for all the variables included in the specifications shown in Table 7 and discussed in Section 4 of the paper. Note that we obtain similar point estimates for the openness variables when we exclude

from the multinomial logistic the other firm characteristics and when we use country fixed effects instead of GDP per capita.

Table C.1. Innovation Channels, Openness, and Firm Characteristics - Results from a Multinomial Logit Regression

	By Hiring Key Personnel or Consultants or Developed or Adapted Within Establishment	Embodied in New Machinery or Equipment or Developed with Equipment or Machinery Supplier	Licensing or Turnkey Operations from International Sources or Domestic Sources	Transferred from Parent Company	Developed in Cooperation with Client Firms	From Universities or Public Institutions, Business or Industry Associations, and Trade Fairs or Study Groups
Majority Foreign-Owned	-0.059***	-0.055***	0.003	0.140***	-0.019**	-0.010***
	[0.018]	[0.022]	[0.008]	[0.018]	[0.008]	[0.004]
Minority Foreign-Owned	-0.041*	-0.054**	0.009	0.073***	0.019	-0.006
	[0.022]	[0.027]	[0.010]	[0.024]	[0.014]	[0.006]
Exporter	0.003	-0.018	0.004	-0.001	0.009	0.004
	[0.012]	[0.013]	[0.005]	[0.002]	[0.006]	[0.003]
Importer	-0.032***	0.051***	0.005	0.004**	-0.026***	-0.002
	[0.011]	[0.016]	[0.005]	[0.002]	[0.010]	[0.003]
Age	0.0007	-0.0008	0.00001	-0.0001	-0.0005	0.0006
	[0.0007]	[0.0008]	[0.0003]	[0.0001]	[0.0005]	[0.0002]
Age Squared	-0.000004	0.00002	-0.000001	0.0000001	-0.000003	-0.00001
	[0.00001]	[0.00001]	[0.00000]	[0.00000]	[0.00001]	[0.00000]
Size	-0.004	-0.009	0.004***	0.003***	0.010***	-0.003***
	[0.004]	[0.006]	[0.002]	[0.0007]	[0.003]	[0.001]
Public-Owned	-0.040	0.104***	0.003	-0.008***	-0.041***	-0.018***
	[0.026]	[0.031]	[0.010]	[0.004]	[0.014]	[0.004]
Training	0.005	-0.015	0.004	0.007***	-0.008	0.006*
	[0.012]	[0.015]	[0.005]	[0.002]	[0.007]	[0.003]
Workforce More Second. Educat.	0.083***	-0.093***	-0.010	0.006	0.008	0.006
	[0.025]	[0.037]	[0.010]	[0.004]	[0.019]	[0.004]
Observations	7085					
Industry Dummies Included?	Yes					
Log Past per Capita GDP Included?	Yes					

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is innovation channels. The table reports the marginal effects (at mean values) on the firm's propensity to choose one of the innovation channels from a multinomial logistic regression. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively.

C.2. Robustness to an Alternative Estimation Method

To check the sensitivity of the main findings of Table 7 of the paper to the estimation method we show in Table C.2 the results from using a probit model for each innovation channel, instead of using a single multinomial logit. For each channel, we define a dummy variable equal to one if the firm reports that such channel was the most important for acquiring technological innovations. The findings for each of the probit regressions are quite similar to those reported in the corresponding column of the multinomial logistic regression in Table 7 of the paper.

Table C.2. Innovation Channels, Openness, and Firm Characteristics - Results from Probit Regressions

	By Hiring Key Personnel or Consultants or Developed or Adapted Within Establishment	Embodied in New Machinery or Equipment or Developed with Equipment or Machinery Supplier	Licensing or Turnkey Operations from International Sources or Domestic Sources	Transferred from Parent Company	Developed in Cooperation with Client Firms	From Universities or Public Institutions, Business or Industry Associations, and Trade Fairs or Study Groups
Majority Foreign-Owned	-0.087	-0.072	0.0004	0.156	-0.025	-0.02
	[0.019]***	[0.019]***	[0.007]	[0.018]***	[0.009]***	[0.007]***
Minority Foreign-Owned	-0.053	-0.041	0.008	0.074	0.020	-0.010
	[0.025]**	[0.022]*	[0.010]	[0.024]***	[0.014]	[0.009]
Exporter	-0.017	0.003	0.004	-0.003	0.009	0.007
	[0.014]	[0.011]	[0.005]	[0.003]	[0.006]	[0.006]
Importer	0.049	-0.029	0.005	0.005	-0.024	-0.004
	[0.016]***	[0.010]***	[0.005]	[0.003]*	[0.010]**	[0.005]
Age	-0.001	0.001	-0.000002	-0.000002	-0.0004	0.001
	[0.001]	[0.001]	[0.0003]	[0.0001]	[0.0005]	[0.0004]***
Age Squared	0.00001	-0.000005	-0.0000006	-0.0000007	-0.000003	-0.00001***
	[0.000009]	[0.000007]	[0.000002]	[0.000001]	[0.000005]	[0.000005]
Size (Logarithm)	-0.011	-0.005	0.004	0.004	0.009	-0.006
	[0.006]*	[0.004]	[0.002]**	[0.001]***	[0.003]***	[0.002]***
Public-Owned	0.111	-0.035	0.004	-0.009	-0.039	-0.030
	[0.033]***	[0.024]	[0.009]	[0.004]**	[0.013]***	[0.006]***
Training	-0.022	0.002	0.003	0.008	-0.009	0.010
	[0.015]	[0.012]	[0.005]	[0.002]***	[0.007]	[0.005]**
Workforce More Second. Educat.	-0.102	0.072	-0.010	0.007	0.003	0.011
	[0.036]***	[0.024]***	[0.009]	[0.005]	[0.018]	[0.008]
Observations	7,085	7,085	7,085	7,085	7,085	6,943
Industry Dummies Included?	Yes	Yes	Yes	Yes	Yes	Yes
Log Past per Capita GDP Included?	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is a different innovation channel in each column. The table reports the marginal effects (at mean values) on the firm's propensity to choose a particular innovation channel from probit regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The number of observations is smaller in the last column since firms in the paper industry are dropped from the probit regression as none chooses that innovation channel.

C.3. Channels for Technology Adoption and Openness across Income Levels

Table C.3 reports the point estimates of the multinomial logit when we allow the effects of openness on each innovation channel to vary across income groups. The results are described in Section 4 of the paper.

Table C.3. Innovation Channels and Openness Across Income Groups

	By Hiring Key Personnel or Consultants or Developed or Adapted Within Establishment	Embodied in New Machinery or Equipment or Developed with Equipment or Machinery Supplier	Licensing or Turnkey Operations from International Sources or Domestic Sources	Transferred from Parent Company	Developed in Cooperation with Client Firms	From Universities or Public Institutions, Business or Industry Associations, and Trade Fairs or Study Groups
Majority Foreign-Owned	0.089	-0.107**	-0.017	0.076***	-0.037	-0.004
	[0.058]	[0.052]	[0.011]	[0.032]	[0.032]	[0.011]
Minority Foreign-Owned	0.143*	-0.028	-0.017	-0.027***	-0.026	-0.045***
	[0.085]	[0.098]	[0.015]	[0.005]	[0.017]	[0.004]
Exporter	-0.018	0.013	0.015	0.002	-0.015	0.003
	[0.034]	[0.040]	[0.011]	[0.006]	[0.021]	[0.008]
Importer	-0.032	-0.012	0.014	0.019***	0.002	0.008
	[0.033]	[0.042]	[0.011]	[0.007]	[0.038]	[0.006]
Majority Foreign-Owned * Lower-Middle Income Group	-0.134***	0.033	0.053	0.013	0.043	-0.007
	[0.034]	[0.080]	[0.045]	[0.012]	[0.075]	[0.009]
Minority Foreign-Owned * Lower-Middle Income Group	-0.227***	-0.661***	-0.031***	0.700***	-0.066***	0.285*
	[0.010]	[0.013]	[0.003]	[0.170]	[0.007]	[0.170]
Exporter * Lower-Middle Income Group	0.046	-0.077*	-0.010	-0.003	0.039	0.004
	[0.038]	[0.044]	[0.011]	[0.006]	[0.027]	[0.009]
Importer * Lower-Middle Income Group	0.015	0.045	-0.013	-0.014**	-0.024	-0.009
	[0.033]	[0.041]	[0.010]	[0.006]	[0.036]	[0.006]
Majority Foreign-Owned * Upper-Middle Income Group	-0.082*	0.043	0.021	0.002	0.010	0.006
	[0.042]	[0.074]	[0.038]	[0.007]	[0.059]	[0.025]
Minority Foreign-Owned * Upper-Middle Income Group	-0.221***	-0.658***	-0.031***	0.091***	-0.067***	0.885***
	[0.009]	[0.013]	[0.003]	[0.018]	[0.007]	[0.019]
Exporter * Upper-Middle Income Group	-0.029	0.053	-0.018*	-0.003	0.006	-0.009*
	[0.044]	[0.057]	[0.010]	[0.005]	[0.029]	[0.006]
Importer * Upper-Middle Income Group	-0.055	0.119***	-0.006	-0.010***	-0.034	-0.015***
	[0.037]	[0.041]	[0.015]	[0.003]	[0.026]	[0.003]
Observations	7085					
Industry Dummies Included?	Yes					
Log Past per Capita GDP Included?	Yes					

Source: Authors' calculations using data from the Investment Climate Surveys.
Notes: The dependent variable is innovation channels. The table reports the marginal effects (at mean values) on the firm's propensity to choose one of the innovation channels from a multinomial logistic regression. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The regressions include also firm age and age squared, the logarithm of firm size, a dummy variable for public ownership, a dummy variable for the provision of training, and the percentage of the workforce with more than secondary education.

C.4. Channels for Technology Adoption and Openness: Asian Firms versus Non-Asian Firms

Table C.4 examines how the findings in Table 7 of the paper on the channels for technology adoption differ for Asian firms relative to non-Asian firms. The results are described in Section 4 of the paper.

Table C.4. Innovation Channels and Openness - Asian Firms versus Non-Asian Firms

	By Hiring Key Personnel or Consultants or Developed or Adapted Within Establishment	Embodied in New Machinery or Equipment or Developed with Equipment or Machinery Supplier	Licensing or Turnkey Operations from International Sources or Domestic Sources	Transferred from Parent Company	Developed in Cooperation with Client Firms	From Universities or Public Institutions, Business or Industry Associations, and Trade Fairs or Study Groups
			Asian Firms			
Majority Foreign-Owned	-0.061**	-0.047	0.002	0.110***	-0.005	-0.001
	[0.028]	[0.036]	[0.015]	[0.019]	[0.005]	[0.001]
Minority Foreign-Owned	-0.039	-0.006	-0.006	0.049***	0.002	-0.001
	[0.026]	[0.027]	[0.011]	[0.016]	[0.007]	[0.001]
Exporter	0.012	-0.013	-0.001	0.001	0.002	0.0006*
	[0.019]	[0.022]	[0.008]	[0.002]	[0.004]	[0.0004]
Importer	-0.036*	0.055***	-0.006	0.004***	-0.016***	-0.0007
	[0.020]	[0.021]	[0.008]	[0.002]	[0.005]	[0.0004]
Observations	2961					
Industry Dummies Included?	Yes					
Log Past per Capita GDP Included?	Yes					
			Non-Asian Firms			
Majority Foreign-Owned	-0.052***	-0.032	0.007	0.111***	-0.022***	-0.013***
	[0.023]	[0.029]	[0.009]	[0.024]	[0.009]	[0.004]
Minority Foreign-Owned	-0.054	-0.028	0.045	0.040	-0.002	-0.001
	[0.051]	[0.052]	[0.030]	[0.030]	[0.017]	[0.012]
Exporter	-0.003	-0.006	0.006	-0.005*	0.005	0.002
	[0.016]	[0.017]	[0.007]	[0.003]	[0.007]	[0.004]
Importer	-0.028**	0.012	0.009	0.004	0.004	-0.001
	[0.014]	[0.014]	[0.006]	[0.003]	[0.008]	[0.003]
Observations	4124					
Industry Dummies Included?	Yes					
Log Past per Capita GDP Included?	Yes					

Source: Authors' calculations using data from the Investment Climate Surveys.

Notes: The dependent variable is innovation channels. The table reports the marginal effects (at mean values) on the firm's propensity to choose one of the innovation channels from multinomial logistic regressions. Clustered standard errors by industry and country are in brackets. *, **, and *** indicate significance at 10%, 5%, and 1% confidence levels, respectively. The regressions include also firm age and age squared, the logarithm of firm size, a dummy variable for public ownership, a dummy variable for the provision of training, and the percentage of the workforce with more than secondary education.