Journal of International Business Studies (2010) 41, 606–619

www.jibs.net

An international multilevel analysis of product innovation

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Abstract
This paper studies multilevel determinants of product innovation by incumbent firms with data from 68 countries, covering over 25,000 firms in eight manufacturing sectors. The author assesses the predictions of interdisciplinary research on firm behavior in different contexts, which have emphasized that product innovation is affected by three sets of factors: the extent of global engagement, information spillovers, and market structure. The empirical model of the probability of observing a product innovation, a probit model, by a firm considers three levels of analysis: firm characteristics, industry characteristics, and the national context. The econometric evidence supports the global engagement and information spillovers hypotheses, but the evidence on the role of market structure is mixed. Regarding global engagement, the evidence suggests that product innovation by incumbent firms is positively correlated with the act of investing in R&D and licensing of foreign technologies, and country-level average import tariffs reduce the probability of product innovation. Regarding information spillovers, the evidence also shows that a country's patent density is positively correlated with product innovation. In contrast, concerning the market structure hypotheses, country-level indicators of business density and of policy-induced costs of entry are not robustly correlated with product innovation.
Journal of International Business Studies (2010) **41,** 606–619.
doi:10.1057/jibs.2009.30

Keywords: new product development; innovation and R&D; economics of innovation; levels of analysis

INTRODUCTION

It is so widely recognized that innovation is a key driver of economic growth that it is a cliché to say so. Existing literatures from economics and international business (IB) on innovation and firm performance in different contextual environments can be divided into three distinct hypotheses, which we call the global engagement, the information spillovers, and the market structure hypotheses. The *global engagement hypothesis* posits that firms engaged in global business activities, through foreign investment, adoption of foreign technologies, or through imports of capital goods, are more likely to undertake innovations than other firms. The *information spillovers hypothesis* suggests that firms can learn from aggregate accumulated knowledge even if they have not made the research and development investments to produce this knowledge. The implication is that firms that have broader access to commercial knowledge, including by adopting foreign technologies, will tend to have higher propensities to innovate than

Received: 29 June 2007
Revised: 29 December 2008
Accepted: 19 January 2009
Online publication date: 28 May 2009

otherwise similar firms. *Market structure hypotheses* have a long tradition, but with seemingly contradictory predictions about firm innovation. One possibility is that competition and the threat of entry can stimulate innovation by incumbent firms. Some studies predict, however, that firms that are far from the technological frontier will tend to have low propensities to innovate.

This paper pushes forward the research agenda in IB, focused on how contextual factors affect firm performance, which can motivate future theories to help us narrow the existing gap between micro-theories of firm performance and macro-theories of the contextual environment (Bamberger, 2008). In addition, the IB literature has for some time emphasized multilevel analysis, covering national, industry, firm, and even project characteristics, for understanding firm performance (Luo, 2001). While there are numerous examples of multilevel analysis of how contextual environments affect firm performance, including analyses of the role of cultural differences (Tihanyi, Griffith, & Russell, 2005), corruption (Habib & Zurawicki, 2002), economic integration (Benito, Grogaard, & Narula, 2003), and economic reforms in transition economies (Park, Li, & Tse, 2006), none cover the breadth or the scope of multilevel factors on firm performance in general, nor product innovation in particular, that are covered in this paper. While contemporary IB literature stresses multilevel analysis, which is often required to identify the true effect of firm choices such as multinational enterprises' (MNEs) organizational models on subsidiary performance and innovation (Venaik, Midgley, & Devinney, 2005), such examples remain scarce in the IB literature. Moreover, there are no contributions to the IB literature that test multiple hypotheses, covering variables measured at multiple levels of analysis, in a nested empirical model of firm innovation probabilities covering both domestic and foreign-owned firms.

This paper examines the empirical determinants of the probability of product innovation in a large sample of over 25,000 manufacturing firms from around the world, covering 68 developing and high-income economies and eight manufacturing industries. We assess the merits of the three alternative sets of hypotheses related to microeconomic and macroeconomic determinants of the probability of product innovation by incumbent firms. This multilevel analysis, encompassing the firm, industry and country levels of analysis, thus provides a novel nested empirical assessment of competing hypotheses regarding the nature of the probability of product innovation. The econometric evidence supports the global engagement and informational spillover hypotheses at both the firm and national levels of analysis, but provides mixed evidence for the market structure hypotheses.

THREE SETS OF HYPOTHESES ON THE PROBABILITY OF PRODUCT INNOVATION IN ECONOMICS AND IB

Even in the context of high-income countries, the determinants of the probability of product innovation across firms might be different from those of patentable innovation. In the IB literature, there has been some analysis of how patents can help solve informational problems that affect firm valuations (Heeley, Matusik, & Jain, 2007). When innovation, including product innovation, cannot be patented, then the incentives facing firms to introduce new products are somewhat different. In the economics literature, Criscuolo, Haskel, and Slaughter (2005) find in a panel of firms from the United Kingdom that the correlates of patents and product innovation are different, particularly with respect to the role played by linkages between firms and universities, the latter being more important for patentable innovations. Another example is the study by Aghion, Blundell, Griffith, Howitt, and Prantl (2006) that found that the response of UK firms (measured by productivity changes and patenting) to increased competition due to the regulatory reforms of the Thatcher government was different across firms, depending on their distance to the technological frontier (the productivity gap with respect to the most productive firms in each industry). Yet we still have much to learn about the empirical correlates of product innovation around the world.

The Global Engagement Literature

A distinct literature concerns the relationship between global engagement and innovation by firms. One strand of this literature, surveyed by Keller (2004), focuses on the role of international technology diffusion. That is, firms might be able to innovate and improve their productivities if they have access to imports of foreign technology or capital goods used for production. Eaton and Kortum (1996), however, found that imports are not necessarily correlated with technology flows proxied by patent applications, after controlling for bilateral distance among trading partners in the

context of the gravity model of trade. More recent evidence provided by MacGarvie (2006), with French firm data combined with data on patent citations, suggests that innovative firms (in terms of patent applications) that import inputs from abroad tend to have significantly higher propensities to cite foreign technologies in their patent applications. French exporters, in contrast, do not seem to cite foreign patents in their patent applications more than other firms. These aforementioned studies focus on a particular type of innovation related to patents, which might not be common across countries. Criscuolo et al. (2005) explore the determinants of firm innovation indicators, including product and process innovation, with firm data from the United Kingdom. They found that exporters and multinational enterprises do tend to have higher propensities for product and process innovation than other firms. We call this the global engagement hypothesis, and the firms' license payments for foreign technologies, foreign investment, and international trade policies are relevant variables for assessing its validity. This type of effect needs to be examined jointly with the effects of foreign competition on the innovation decisions of incumbent firms, as per the market structure hypotheses discussed below.

In the IB literature, Benito et al (2003) study how MNE subsidiaries performed across three Nordic countries that had different levels of formal integration with the European Union (EU), thus offering a unique test of how international engagement brought about by policy changes affects the behavior and performance of subsidiaries. The authors found evidence from survey data that subsidiaries in Norway, the "outsider" country that is less integrated with the EU, report both fewer activities and lower levels of competence than subsidiaries in Denmark and Finland, after controlling for other determinants of performance. Thus this study supports the central tenet of the global engagement literature.

The Information Spillovers Literature

A second literature can be labeled the information spillovers hypothesis, whereby an innovation by one firm can benefit imitators. This is due to the fact that new ideas can benefit all firms, not just the innovative firm. In the economics and IB literatures this is called the *appropriability problem* (Heeley et al., 2007). An influential contribution to this literature is Klette and Kortum (2004), which was motivated by empirical patterns observed in rich-country firm data. One such pattern is that investments in R&D as a share of sales do not seem to be strictly correlated with the size of firms, thus contradicting some of the earlier market structure literature reviewed by Cohen and Levin (1989). Rather, the decision to invest in R&D depends on the expected future profits generated by the new product, which in turns depends on the ability of potential competitors to imitate such innovations. Hence in the information spillovers literature the threat of entry matters, but so do the positive spillovers from previously generated knowledge. Another influential piece comes from the development economics literature, namely Hausmann and Rodrik (2003), which is concerned about product innovation for exports in developing countries, where most product innovations are presumably not patentable as they entail the production of existing products that are nevertheless not yet produced in a country. To assess this hypothesis we use data on the accumulated number of patents granted by the US Patent Agency to inventors residing in different countries.

The Market Structure Literature

One strand of the economics literature focused on industrial organization can be traced to the Schumpeterian idea of creative destruction, whereby innovation can be seen as both cause and consequence of competitive pressures characterized by market structure. The empirical literature linking firm innovation and market structure has assessed two issues, namely whether innovation rises with the size of the firm or with market concentration in terms of the market share of firms (Cohen & Levin, 1989). This literature has produced only ambiguous results, with various studies finding contradictory evidence.

An important theoretical contribution to this literature was Reinganum (1985). The main insight concerned an ambiguous relationship between the extent of market competition and innovation by incumbent firms. The threat of firm entry with new or higher-quality products can affect incumbents' incentives to invest in R&D or other investments associated with product innovation. In Reinganum's model every firm has a temporary monopoly over its product, which dissipates when a challenging firm introduces an improved version of that product. The theoretical model proposed by Aghion, Bloom, Blundell, Griffith, and Howitt (2005) builds on the types of models pioneered by Reinganum by allowing incumbent firms to innovate. Market competition through new entrants therefore can have different

effects on incumbents' decisions to innovate, depending on each firm's assessment of the expected difference between profits before and after innovation. Laggard firms that are far from the technological frontier need to spend a lot of resources to move them towards that frontier, and therefore could choose to reduce their expenditures in innovation to reduce costs. In contrast, firms close to the frontier need to spend relatively little to keep them ahead of potential new entrants, and thus could increase their innovation efforts in the face of rising competition. These contradictory effects on firms that differ in terms of their technological capabilities yield the so-called "inverted-U" relationship between competition and innovation. We call these the market structure hypotheses, and we test them by examining the role of firm size and the regulatory environment that affects the costs and timing of firm entry.

The IB literature has also paid attention to how global and domestic competition affects the performance of firms. For instance, we know from surveys of managers of MNE subsidiaries that global competition and organizational structures interact to produce different learning and innovation outcomes (Venaik et al, 2005). That is, MNEs that encourage organizational learning by subsidiaries tend to respond to competitive pressures through greater innovation. Hence the IB literature also provides ambiguous answers to the question of how market structure affects firm performances, even across MNE subsidiaries, because the outcomes depend on MNE organizational structure.

Hypotheses to be Tested in a Nested Empirical Model

As discussed above, the existing literatures related to product innovation make various predictions about the probability of product innovation by incumbent firms, which can be summarized in seven hypotheses. The global engagement hypotheses are:

Hypothesis 1: Importing foreign know-how through licensing, foreign investment and exporting activities is positively correlated with product innovation.

Hypothesis 2: Trade-policy distortions that raise the costs of global engagement deter innovation.

The information spillovers hypotheses are:

Hypothesis 3: Firms' R&D and the education of their personnel increase the probability of product innovation. Although these firm-level variables do not capture inter-firm learning spillovers, they do capture firms' adoptive capacities.

Hypothesis 4: The density of knowledge available to local firms in their local context spurs innovation.

The market structure hypotheses are:

Hypothesis 5: The size of firms is positively correlated with the probability of product innovation.

Hypothesis 6: The regulatory environment can have either positive or negative effects on the probability of product innovation by incumbent firms.

Hypothesis 7: The degree of market competition characterized by business density can raise or reduce the probability of product innovation by existing firms.

DATA

The firm-level data come from the World Bank's numerous Investment Climate Surveys (ICS) and Business Environment and Enterprise Performance Surveys (BEEPS) conducted in various countries in various years, which are listed in the Appendix. There is substantial overlap between the ICS and BEEPS questionnaires, but there are differences in sampling approaches.

The Surveys

The ICS tend to focus on manufacturing firms; the BEEPS are drawn from a broad range of economic activities including services (actually the BEEPS database is slightly skewed towards services). We restricted the coverage of the BEEPS data to firms in the manufacturing sectors.

The coverage of the BEEPs and ICS data in terms of the sampling of firms is also different. The BEEPS used quota sampling, whereby 10% of selected firms are small, with the number of employees in the 2–49 range; another 10% were firms with 250–999 employees; and the rest were randomly selected in between those two extremes. The ICS survey sampling approaches differed across countries. In some cases, quotas by sector and size were used. In others, existing industrial census shares by industries and size were used as benchmark sampling quotas. Thus there might be some

selectivity of the sampled firms, which might raise doubts about the randomness of the sample. If we were attempting to draw conclusions for each country specifically, these cross-survey and cross-country differences in sampling would be important impediments. Our objective is more modest, as we want to draw general conclusions about the probability of product innovation by incumbent firms from around the world. It is possible that selective sampling for each country but for numerous countries can yield representative samples for the world, because the statistical requirements for representativeness are less restrictive than for smaller subsamples. Thus we interpret our statistical results with caution, and discuss results with different samples.

Multilevel Explanatory Variables and Hypotheses

Three levels of analysis are used in our empirical model: firm-, sector- and country-level variables. The first set includes the dependent variable: the introduction of a new product. The surveys asked managers whether the firm had introduced a new product during the past 2 years. Hence our dependent variable is a dichotomous dummy variable.

Regarding explanatory variables motivated by the aforementioned literatures, firm characteristics that may affect a firm's proclivity to innovate include the following. The market structure literature suggests that firm size matters, which we measure by the natural logarithm of the number of permanent and temporary workers and its squared term (to test for a nonlinear relationship). The global engagement hypothesis motivates the inclusion of firms' exporter status, measured by a dummy variable equal to 1 when a firm exports at least 10% of its sales; and foreign ownership of the firm, measured by a dummy variable equal to 1 for foreign ownership when more than 10% of assets of the firm are owned by foreigners. The surveys also provide information on variables motivated by the information spillovers literature, such as whether firms invested in R&D, a dummy variable. Because the literature on information spillovers, as well as the global engagement hypothesis, has paid much attention to the adoption of foreign technologies, we also use data derived from a question in the surveys that asked managers whether the firm had paid licensing fees during the past 2 years. This variable is also dichotomous, and the estimates of the effect of R&D and licensing status are thus comparable.

The global engagement literature is also related to trade policies, which are observed at the sector level. We use a composite index of the average applied tariffs and its standard deviation. The index was estimated as the first principal component derived from factor analysis, because the levels of the average applied tariff within industries and across countries were highly correlated. Countries with high tariffs in a given sector also tend to have high tariff dispersion. Factor analysis allows for the construction of a single index comprising the information from highly correlated variables. The other trade policy indicator measured at the industry level is the share of tariff lines within each industry that faces one of the so-called "core" non-tariff barriers – see the Appendix. These data were taken from Nicita and Olarreaga (2006).

Country-level variables capture various aspects of the local environment and context. They include an index of infrastructure coverage (from the *World Development Indicators* (WDI) database), institutional quality (from Kaufmann, Kraay, & Mastruzzi, 2005), and real manufacturing GDP growth (also from WDI). In some models, we also include the level of development (GDP per capita from the *Penn World Tables*). An important explanatory variable for our analysis, which is related to the market structure literature, is a regulatory index capturing the ease of entry. It was calculated from data from the World Bank's *Doing Business* database. Because of high correlations among regulatory variables, we again use principal components analysis to calculate a composite index on the quality of governance (including (lack of) corruption, political stability, and rule of law) and the regulatory environment affecting the ease of entry of new firms (including difficulty of firing index, difficulty of hiring index, and days for starting a business). We also use patent-counts data from Lederman and Saenz (2005), namely the sum (stock) of utility patents granted to researchers in each country during 1963–2000 by the United States Patent and Trademark Office (USPTO) per person. The latter provides a measure of the density of innovative ideas available to firms operating in each country.

The literature on market structure studies how market concentration affects firms' investments in innovation. We use data on "business density" from Djankov, Ganser, McLiesh, Ramalho, and Shleifer (2007), which were recently added to the World Bank's *Doing Business* database. This variable is

Table 1 Summary statistics by product innovation status

Variable	*Product innovation status*							*Yes/both (%)*
	Yes			*No*			*Both*	
	Obs	*Mean*	*s.d.*	*Obs*	*Mean*	*s.d.*	*Total Obs*	
Dummy=1 if firm has invested in R&D	12257	29.44	45.58	13549	13.55	34.23	25806	47.5
Dummy=1 if firm uses licensed technology	12257	10.28	30.37	13549	5.15	22.11	25806	47.5
Log of total number of last year's employees	12257	4.126	1.577	13549	3.710	1.548	25806	47.5
Dummy=1 if foreign owned ($\geqslant$10 of assets)	12257	14.89	35.60	13549	11.27	31.62	25806	47.5
Average capacity utilization over the last year	12257	74.74	20.48	13549	72.97	22.11	25806	47.5
Dummy=1 if exporter (exports over sales$\geqslant$10)	12257	38.51	48.66	13549	28.69	45.23	25806	47.5
Log average years of education of enterprise's labor force (imputed)	12257	2.305	0.564	13549	2.232	0.714	25806	47.5
Log average years of education of enterprise's labor force	9150	2.303	0.652	9437	2.229	0.855	18587	49.2
Incidence of core NTBs by industry (of tariff lines subject to NTBs; imputed)	12257	7.28	14.10	13549	6.45	14.47	25806	47.5
Incidence of core NTBs by industry (of tariff lines subject to NTBs)	8940	9.68	13.77	9813	8.88	14.03	18753	47.7
Index of applied tariffs and their dispersion (imputed)	12257	−0.127	0.506	13549	−0.022	0.721	25806	47.5
Index of applied tariffs and their dispersion	9920	−0.153	0.534	10841	−0.027	0.787	20761	47.8

Note: All differences in the means across the two groups are statistically significant.
Obs=number of observations.
Source: ICS and BEEPs surveys, www.enterprisesurveys.org.

defined as the (log of the) number of firms per capita. Although this variable does not directly measure market concentration, together with the variable on the regulatory environment this variable sheds light on the role of policy and economic factors that determine market structure, as they measure variables that affect the ease of entry into existing product markets. The data limited our sample to 40 countries, but below we also discuss results based on a broader sample of 58 countries, which was derived by imputing the missing values of the business density variable by exploiting the observed correlations between this variable and the other country characteristics.

Some studies, such as Criscuolo et al (2005), also treat explanatory variables measured at a higher level of aggregation than the firm level as exogenous factors, but these are measured with data from the firm surveys themselves. Our approach is different in this regard, as we use objective data from other sources. The use of aggregate variables derived from the same data set as the firm data can be assumed to be exogenous only under certain conditions, namely firms' deviations from the average must be orthogonal to the average and normally distributed with expected value of zero. We do not have to make any assumptions in this regard, because our data are objectively measured at the country level from data from other sources. The disadvantage of our approach is that we have fewer degrees of freedom to estimate the relevant coefficients of the variables measure at the national level, which is limited by the number of countries.

Some of the surveys did not include certain data. The average years of education of the labor force was not available in nine surveys. Table 1 reports the average and the standard deviation of the log of the number of years of education variable for two samples. One is the original sample of more than 18,000 firms and the other is the sample of over 25,000, which corresponds to the one used in the estimations. The larger sample was constructed by imputing the education variable by using the observed correlations between education and the other firm-level characteristics, except the dependent variable (the dummy variable for product innovation). Table 1 shows the resulting sample average and dispersion, which are very similar to those of the original reduced sample. In the subsamples of firms reporting a product innovation, the averages are 2.305 vs 2.303 and 0.564 vs 0.652 in the standard deviation. For the subsamples of firms that did not report a product innovation, the averages are 2.232 vs 2.229 and the standard

deviations are 0.714 vs 0.855. In both cases, the differences in the averages are not statistically significant, but the addition of thousands of observations from nine countries allows us to study the cross-country determinants of product innovation rates with more precision.

The trade-policy variables also turned out to limit the sample of countries. Hence we imputed the missing values of the NTB and tariff index with industry dummies and the other country variables, but not with the firm-level variables. Again, Table 1 shows that the within-group averages and standard deviations of the original data and the imputed values are strikingly similar. We return to this issue later.

Summary Statistics

Table 1 presents descriptive statistics for firms from 68 countries, the sample used in the econometric analysis discussed below. The number of firms by country appears in the Appendix. The data show diverse international product innovation rates, ranging from about 6.8% in Nepal to 77.8% in Peru. It is noteworthy that the percentages for countries with a gross domestic product per capita above the World Bank's high-income country threshold of $14,000 (purchasing-power adjusted as of 2000, which are identified with an asterisk in Table A1) are not above the cross-country average of 48.8% or the average for the overall sample of firms, which is 47.5%, as reported in Table 1.

Table 1 also shows that a large share of firms that reported new products also report R&D expenditures. In the total sample, 60% of firms with product innovation also report R&D, whereas only 15% of non-innovative firms report some R&D expenditures. This pattern holds for most countries individually for R&D, but also for licensing, export status, and foreign ownership. China is the exception. In this country, the percentage of non-innovative firms that report R&D expenditures, licensing payments, exporting, and foreign ownership is higher than among innovative firms. The data for China are consistent with product-level export data that suggest that mainland China introduced comparatively few new export products during 1994–2003 (Klinger & Lederman, 2006).

There is no clear relationship between trade policies and the share of innovative firms across countries, however. For example, Argentina appears with 75% of firms being innovative, but it also utilizes numerous non-tariff barriers (NTBs) covering, on average across the eight manufacturing sectors, slightly over 29% of its tariff lines. In contrast, Bolivia has a low NTB coverage rate of about 3%, but only 43% of firms reported a product innovation. It remains to be tested whether trade distortions affect the probability of product innovation after controlling for firm and country characteristics.

A TWO-STAGE MULTILEVEL EMPIRICAL MODEL OF THE PROBABILITY OF PRODUCT INNOVATION

Because of the dichotomous nature of our variable of interest, the empirical model of the probability of product innovation can be written as

$$P(y_{isc} = 1 | X_{isc}, X_{sc}, X_c) = \Phi(\beta' X_{ics} + \alpha' X_{sc} + \delta' X_c + \eta_s + \eta_c + \varepsilon_{isc} + \varepsilon_c) \quad (1)$$

where P is the probability of observing a value of 1 for product innovation, y. Subscript i represents firms, the s's are eight manufacturing sectors, and c's are countries. The X's are matrices of the relevant explanatory variables, measured at the three levels of aggregation (firms, sectors, and countries). The β, α, and δ are the parameters to be estimated with a probit estimator, which assumes a standard normal distribution of estimation errors. ε_{isc} is therefore the standard white noise error. Below we report results that are robust to heteroskedasticity of regression errors clustered around the observations of each country, ε_c. This correction is important to ascertain the statistical significance of parameters associated with industry and country variables when the dependent variable is a micro unit (Moulton, 1990).

The analysis proceeds in two stages. In the first stage, we discuss partial correlations of firm-level characteristics and industry trade-policy variables measured, which are estimated in models that also control for industry, year, and country effects by including corresponding dummy variables for each industry, year, and country (the η's in Eq. (1)). We recover the predicted probability rates by countries from this estimation, which are reported in the last column of Table A1 in the Appendix. The second stage explores national determinants of the average probabilities of product innovation. That is, country characteristics can affect the probability of product innovation by incumbent firms not only directly, but also by affecting firm-level characteristics that in turn help determine product innovation probabilities. The regression errors in this second-stage model are unknown, because the dependent variable is an estimate. Consequently

Table 2 Determinants of the probability of product innovation by incumbent firms (marginal effects from the probit estimator)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
	Dependent variable: If firm developed new product=1				
Dummy=1 if firm has invested in R&D	0.184		0.181	0.181	0.179
	(10.69)**		(11.10)**	(11.09)**	(10.37)**
Dummy=1 if firm uses licensed technology		0.111	0.101	0.101	0.101
		(4.30)**	(4.32)**	(4.31)**	(4.28)**
Log of total number of last year's employees	0.075	0.086	0.073	0.073	0.075
	(6.28)**	(6.58)**	(5.92)**	(5.88)**	(5.59)**
Log of total number of last year's employees squared	−0.004	−0.004	−0.004	−0.004	−0.004
	(2.32)*	(2.33)*	(2.24)*	(2.23)*	(2.19)*
Dummy=1 if foreign owned (⩾ 10% of assets)	−0.012	−0.022	−0.020	−0.020	−0.022
	(0.87)	(1.54)	(1.40)	(1.39)	(1.45)
Average capacity utilization over the last year	0.001	0.001	0.001	0.001	0.001
	(2.55)*	(2.37)*	(2.56)*	(2.56)*	(2.62)**
Dummy=1 if exporter (exports over sales ⩾ 10%)	0.049	0.053	0.048	0.048	0.046
	(3.34)**	(3.53)**	(3.30)**	(3.23)**	(2.88)**
Log of average years of education of the enterprise's labor force	0.055	0.052	0.054	0.054	0.053
	(2.20)*	(2.12)*	(2.17)*	(2.17)*	(2.18)*
Index of average applied tariffs by sector and their dispersion				0.008	0.009
				(1.05)	(1.15)
Index of incidence of non-tariff barriers by sector				−0.046	−0.049
				(0.71)	(0.68)
Year, industry (eight), and country dummies included	Yes	Yes	Yes	Yes	Yes
Manufacturing industries	8	8	8	8	8
Countries	68	68	68	68	58
Observations	25806	25806	25806	25806	24362
Observed average probability	0.475	0.475	0.475	0.475	0.477
Predicted probability with average of explanatory variables	0.471	0.470	0.471	0.471	0.474

* significant at 5%; ** significant at 1%.
Absolute value of robust *z* statistics in parentheses. Estimation errors are clustered by countries.
Intercepts are not reported. Sample in model 5 excludes firms from countries with a GDP per capita (US$ PPP) above $14,000.
Note: The results in Table 2 include the average number of years of education of workers employed by each firm. The China and Indonesia surveys do not have these data. We imputed this variable for the missing observations based on the observed correlation between labor education and the other firm characteristics. Table 1 presents the summary statistics for these variables with and without the imputed values, which have very similar means and standard deviations.

the standard errors from these regressions are bootstrapped, whereby each specification is estimated 50 times with randomly selected subsamples of the data set. The resulting distribution of estimated parameters yields the statistical confidence intervals.

This two-stage approach provides confidence about the robustness of the results concerning firm-level and trade-policy determinants of the probability of product innovation, because the country dummies control for any country-level determinants of the probability of product innovation by incumbent firms, not just the variables motivated by the existing literatures. We discuss the two sets of results separately, although some of the three sets of hypotheses are captured by variables measured at the three levels.

While the estimated partial correlations among the firm-level variables could be due to endogeneity, the results concerning the sector- and country-level variables are less likely to be contaminated by this problem. If each individual firm is too small to determine – for example, the level of a country's trade protection or its aggregate level of patents accumulated since 1963 – then the corresponding empirical relationships are likely to be due to causal effects.

FIRST-STAGE RESULTS: THE ROLE OF FIRM CHARACTERISTICS AND INDUSTRY TRADE POLICIES

The results from the estimation of five versions of Eq. (1) with the appropriate set of country, industry, and year dummy variables are presented in Table 2.

The table reports the marginal coefficients, or the elasticities calculated at the sample mean, associated with the probit coefficients of the continuous explanatory variables. The coefficients on dichotomous explanatory variables represent the effect of changing status.

The first specification includes the dummy variable for R&D investments, but excludes the one for licensing foreign technologies. The latter is included in the second model. The third includes both. Columns 4 and 5 contain the results from specifications with the trade-policy variables, but the latter utilizes a smaller sample of firms from countries with GDP per capita below $14,000 (PPP) in the year 2000. This change in sample does not affect the estimated coefficients in a meaningful way, thus suggesting that the results might reflect robust relationships among the variables in both developing and developed economies. Furthermore, we estimated all model specifications reported in Table 2 with alternative subsamples of the data, first excluding firms from African countries and then excluding observations from East Asia and the Pacific countries. These results, which are not reported for the sake of brevity, confirmed the robustness of the results presented in Table 2.

Evidence on Global Engagement

Licensing is statistically significant with positive coefficients, even when the R&D variable is included simultaneously. In fact, the estimated marginal effects are consistently estimated across all specifications reported in Table 2.

A result that goes against the global engagement hypotheses concerns the variable on foreign ownership, which is not significant in any specification. This result is consistent with IB literature that suggests that the performance of an international joint venture (IJV) depends on the relatedness of its products with those of its parent companies (Luo, 2002), which implies that product diversification by IJVs is desirable only when the parent companies are introducing new products. In contrast, the export-status variable is significant and positive across all models. The marginal effect of exporting appears to be somewhat lower than the aforementioned effect of licensing. Overall, Hypothesis 1 is accepted, with the exception of the foreign ownership variable.

The coefficients concerning tariffs and non-tariff barriers are not statistically different from zero. Thus Hypothesis 2 is rejected thus far. It remains to be seen whether cross-country differences in tariffs and non-tariff barriers matter. In any case, the estimated models perform well overall, as reflected in the predicted sample probabilities of innovation, which are strikingly close to the observed sample probabilities. The country-specific predicted probabilities compared with the observed probabilities reported in Appendix Table A1 reveal that our models are quite adequate.

Evidence on Information Spillovers

The effect of R&D is statistically significant. The effect of R&D is substantially larger than the effect of licensing. The former implies that investing in R&D is associated with an increase of 0.18% in the probability of product innovation by incumbent firms, whereas the effect of licensing is closer to 0.10%. As expected, the level of education of the labor force is positively correlated with the probability of product innovation, with consistently estimated marginal effects across all specifications reported in Table 2. Hypothesis 3 is thus accepted, and Hypothesis 4 is discussed in the following section.

Evidence on Market Structure

The size of firms, captured by the number of employees, appears to be positively correlated with the probability of product innovation. However, there are severely diminishing returns to scale, because the estimated coefficient is less than unity, and the squared term is significantly negative. The combined effect of these two coefficients of increasing employees by 1% at the sample mean entails less than a 0.07% increase in the probability of innovation in all models, except model 2, where the effect is less than 0.08%. The total marginal effect is equal to the coefficient on the log number of employees minus two times the absolute value of the coefficient on the squared term, which is −0.008 or −0.8%. This effect would be lower for firms that are bigger than the average. This evidence is inconsistent with the market structure Hypothesis 5. It is more consistent with information spillovers models, such as Klette and Kortum (2004). The validity of Hypotheses 6 and 7 is discussed below.

SECOND-STAGE RESULTS: THE ROLE OF THE NATIONAL CONTEXT

Table 3 presents results concerning the contextual (country-level) determinants of the predicted probabilities of product innovation. The first three

Table 3 Country-level determinants of the average predicted probability of product innovation by incumbent firms

	(1)	(2)	(3)	(4)	(5)
	Dependent variable: country-average predicted probability of new product				
Explanatory variables:					
Average tariff index	−0.104	−0.246	−0.247	−0.105	−0.124
	(1.48)	(2.95)**	(3.93)**	(1.20)	(1.74)
Average core NTB coverage ratio	−0.039	0.018	0.019	−0.039	−0.096
	(0.17)	(0.06)	(0.07)	(0.20)	(0.45)
Real manufacturing GDP growth	−0.402	−0.499	−0.504	−0.402	−0.419
	(1.42)	(1.94)	(1.91)	(1.64)	(1.56)
Log of cumulative patent density (per capita)	0.030	0.055	0.054	0.031	0.027
	(1.98)*	(3.56)**	(3.46)**	(2.38)*	(1.71)
Index of entry/exit regulation	0.018	−0.012	−0.013	0.018	0.013
	(0.41)	(0.22)	(0.22)	(0.40)	(0.25)
Index of institutional quality	−0.061	−0.064	−0.065	−0.061	−0.066
	(2.18)*	(2.79)**	(2.19)*	(3.19)**	(2.28)*
Index of infrastructure	−0.004	−0.125	−0.13	−0.004	−0.051
	(0.08)	(2.46)*	(1.92)	(0.10)	(0.79)
Log of business density		−0.005	−0.006		
		(0.19)	(0.26)		
Log of real GDP per capita (PPP)			0.009		0.058
			(0.13)		(1.09)
Imputed log of business density				−0.001	−0.006
				(0.04)	(0.16)
Constant	0.811	1.083	0.992	0.814	0.293
	(4.45)**	(5.60)**	−1.58	(5.16)**	(0.59)
Adjusted R-squared	0.15	0.42	0.40	0.13	0.15
Observations	57	39	39	57	56

z statistics in parentheses; standard errors are bootstrapped with 50 random iterations for all estimations.
* significant at 5%; ** significant at 1%.
Note: We imputed the values for the trade-policy indicators for the countries without such data, so as to increase the sample of countries that appears in the econometric estimation reported in Table 3. Table 1 presents the summary statistics for these variables with and without the imputed values, which have very similar means and standard deviations.

columns report results derived from the sample of countries with available data; the last two columns use imputed values of the business density variable to examine how results change in a broader sample of countries under the assumption that the underlying correlations among the explanatory variables remains constant (but, obviously, not necessarily the correlation with the dependent variable).

In the first model, the strongest results concern the patent density and the institutional quality variables. The former appears with a positive marginal effect, thus providing support for the information spillovers Hypothesis 4. The result on institutional quality is counter-intuitive, but it is logical under a market structure view whereby incumbent firms can prevent entry by competitors by requesting special favors from the government in ways that are not captured by the other control variables, such as regulations or trade policies, which are not significant in this specification.

The second specification includes the business density variable, which reduces the sample. The tariff index now appears with a negative and significant coefficient. The patent and institutional variables retained their statistically significant effects, but the estimate of the effect of patent density is larger than in the previous model. The infrastructure index now appears with a surprisingly significantly negative coefficient, which could be a feature of the sample. When the level of development, proxied by the GDP per capita variable, is included, the results remain virtually unchanged.

To study the impact of the small sample of countries in models 2 and 3, the results reported

in columns 4 and 5 use imputed data for business density, as previously discussed. In model 4 the patent density and institutional variables again survive, retaining their statistical significance. The estimated coefficient on the patent-density variable, however, is not similar in magnitude to the estimate in the similarly large sample of specification 1. Also, the infrastructure index is now not statistically significant, suggesting that the previously discussed negative coefficient was due to the small sample. In the fully specified model under column 5, the tariff variable recovers some of its significance, as it is negative at the 10% level. The patent density variable is less significant, but remains positive and statistically different from zero at the 10% level. The growth of manufacturing GDP in years preceding the firm surveys is consistently estimated with a negative coefficient, which is statistically different from zero at the 10% level in specifications 2 and 3.

The results on the regulatory index and the business density variables stand out for their lack of statistical significance in all of the specifications. These results indicate that the standard channels through which the market structure hypotheses are expected to be present remain ambiguous, and thus Hypotheses 6 and 7, which posit that the effects of these variables should be ambiguous, are confirmed.

CONCLUSIONS REGARDING THE SEVEN HYPOTHESES

An interdisciplinary literature from economics and IB on global engagement suggests that firms innovate when they can import technologies and know-how from abroad. Another literature focuses on information spillover effects of innovation, be it R&D-driven innovation, product innovation driven by a process of "discovering" profitable products, or by adopting foreign technologies. A market structure literature predicts both a positive and a negative relationship between incumbent-firm innovation and the threat of entry by competitors.

The global engagement and information spillovers hypotheses are supported by the evidence: exporting status and licensing foreign technologies seem robustly correlated with firms' probability of introducing a new product, but industry-level trade-policy distortions or foreign ownership do not have an independent effect. Knowledge density (the stock of patents per capita) is robustly correlated with product innovation rates. The evidence on market structure is mixed: Neither business density nor regulations that raise the costs of entry by firms are robustly correlated with product innovation probabilities. The size of firms is a significant correlate of product innovation, but the magnitude of this effect is small, and declines with firm size. Good governance, however, tends to be negatively partially correlated with product innovation rates, which may reflect the ability of incumbent firms to influence public policy so as to deter entry through means that are not captured by the regulatory environment. That is, in countries with poor governance, state capture by incumbent firms might hamper entry by new firms, thus raising the probability of product innovation by incumbents.

From a policy perspective, the probability of product innovation seems to be counter-cyclical, and thus the budgets of programs to stimulate product innovation need to be protected during downturns, so as to prevent the demise of firms that could have survived through retooling in terms of product innovation. The latter might have social benefits that greatly exceed the private returns, because private agents can benefit from the knowledge embodied in the product innovations of their competitors, as suggested by the information spillovers literature. Trade-policy distortions seem to reduce national product innovation rates, although it is international rather than inter-sector differences in tariffs that affect the probability of product innovation. Hence an open trade environment with a dynamic and dense export sector seems to be an important ingredient for maintaining an innovative private sector.

ACKNOWLEDGEMENTS

The author thanks the impeccable research assistance provided by Daniel Chodos and Javier Cravino. Roberto Alvarez, Bruce Blonigen, Pablo Fajnzylber, Rodrigo Fuentes, Alvaro González, José L. Guasch, J. Humberto López, Marcelo Olarreaga, Arjen Van Witteloostuijn, and two anonymous referees provided insightful comments on earlier drafts. Financial support from the World Bank's Latin American and Caribbean Regional Studies Program is gratefully acknowledged. The views expressed in this paper do not represent the views of the World Bank or of its member countries. All remaining errors are the responsibility of the author.

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APPENDIX

See Table A1.

Data Sources for Industry-Trade-Policy and Country-Level Variables Used in Regressions Presented in Table 3

Tariff index. The composite index was estimated as the first principal component derived from factor analysis of the trade-weighted applied tariffs and their standard deviations within each manufacturing industry. The data come from Nicita and Olarreaga (2006). The cross-country regressions use national averages of the industry averages.

NTB coverage rate. The variable measures the percentage of tariff lines that are subject to non-tariff barriers, which includes price control measures, finance control measures, and quantity control measures. The data come from Nicita and Olarreaga (2006). The cross-country regressions use national averages of the industry averages.

GDP per capita in 2000. Penn World Tables database.

Average real manufacturing GDP growth 1998–2003. The data come from the World Bank's database on *World Development Indicators* (WDI).

Stock of patents accumulated during 1963–2000 per worker. The variable is the total number of utility patents granted to the first innovator residing in each country and cited in the patent application at the US Patent and Trademark Office (USPTO) during this period. The data come from Lederman and Saenz (2005). The number of workers is the population 15–64 years of age in 2000. These data come from the World Bank's WDI.

Regulation index. The composite index was estimated as the first principal component derived from factor analysis of the difficulty of firing index,

Table A1 Number of firms by countries and survey years

	Country name (survey year)	Number of firms	Percentage of global sample	Percent of firms with new product	Predicted percentage of firms with new product[b]
1	Albania (2000, 2004)	137	0.53	58.39	58.36
2	Argentina (2006)	642	2.49	75.08	75.10
3	Armenia (2002, 2005)	290	1.12	50.69	50.60
4	Azerbaijan (2002, 2005)	257	1.00	56.42	56.28
5	Belarus (2002, 2005)	97	0.38	75.26	75.26
6	Benin (2004)	142	0.55	34.51	34.30
7	Bolivia (2006)	362	1.40	75.97	75.89
8	Bosnia and Herzegovina[a] (2002, 2005)	137	0.53	59.85	59.52
9	Brazil (2003)	1,628	6.31	67.57	67.44
10	Bulgaria (2002, 2005)	106	0.41	61.32	61.19
11	Cambodia (2003)	55	0.21	63.64	63.50
12	Chile (2004)	684	2.65	44.88	44.77
13	China (2003)	1,324	5.13	26.28	26.29
14	Colombia (2006)	634	2.46	68.77	68.80
15	Costa Rica (2005)	339	1.31	52.51	52.49
16	Croatia (2002, 2005)	106	0.41	52.83	52.73
17	Czech Republic (2002, 2005)	149	0.58	41.61	41.47
18	Ecuador (2003)	123	0.48	63.41	63.21
19	Egypt, Arab Rep. (2004)	965	3.74	14.30	14.05
20	El Salvador (2003)	462	1.79	62.12	62.02
21	Estonia (2002, 2005)	67	0.26	53.73	53.67
22	Georgia (2002, 2005)	83	0.32	35.00	34.99
23	Germany[a] (2005)	220	0.85	45.78	45.82
24	Greece[a] (2005)	94	0.36	41.49	41.47
25	Guatemala (2003)	435	1.69	54.02	53.92
26	Guyana (2004)	149	0.58	46.31	46.40
27	Honduras (2003)	442	1.71	46.83	46.74
28	Hungary (2002, 2005)	405	1.57	33.83	33.92
29	Indonesia (2003)	595	2.31	35.29	35.14
30	Ireland[a] (2005)	172	0.67	51.16	51.19
31	Kazakhstan (2002, 2005)	402	1.56	35.57	35.59
32	Korea, Rep.[a] (2005)	213	0.83	46.01	45.93
33	Kyrgyz Republic (2002, 2003, 2005)	205	0.79	51.22	51.24
34	Latvia (2002, 2005)	59	0.23	44.07	43.96
35	Lithuania (2002, 2004, 2005)	245	0.95	45.71	45.61
36	Macedonia, FYR (2002, 2005)	99	0.38	46.46	46.40
37	Madagascar (2005)	269	1.04	38.66	39.46
38	Malawi (2005)	153	0.59	53.59	53.51
39	Mali (2003)	70	0.27	37.14	37.13
40	Mauritius (2005)	160	0.62	48.75	49.29
41	Mexico (2006)	1,117	4.33	34.38	34.28
42	Moldova (2002, 2003, 2005)	347	1.34	59.37	59.28
43	Nepal (2000)	207	0.80	6.76	6.82
44	Nicaragua (2003)	448	1.74	47.54	47.49
45	Oman[a] (2003)	91	0.35	36.26	36.18
46	Panama (2006)	236	0.91	55.93	55.95
47	Paraguay (2006)	375	1.45	67.73	67.86
48	Peru (2006)	360	1.40	77.78	77.94
49	Philippines (2003)	633	2.45	48.34	48.28
50	Poland (2002, 2003, 2005)	742	2.88	44.88	44.86
51	Portugal[a] (2005)	130	0.50	27.69	27.75
52	Romania (2002, 2005)	468	1.81	37.18	37.09
53	Russian Federation (2002, 2005)	272	1.05	54.41	54.34
54	Serbia and Montenegro[a] (2002, 2005)	149	0.58	51.01	50.99
55	Slovak Republic (2002, 2005)	65	0.25	53.85	53.85
56	Slovenia[a] (2002, 2005)	104	0.40	38.46	38.48
57	South Africa (2003)	562	2.18	68.51	68.55
58	Spain[a] (2005)	134	0.52	42.54	42.36
59	Syrian Arab Republic (2003)	507	1.96	41.22	41.14
60	Tajikistan (2002, 2003, 2005)	195	0.76	47.18	47.16
61	Tanzania (2003)	172	0.67	35.47	35.25
62	Thailand (2004)	1,377	5.34	50.40	50.35
63	Turkey (2002, 2005)	1,572	6.09	36.32	36.34
64	Ukraine (2002, 2005)	316	1.22	64.87	64.90
65	Uruguay (2006)	351	1.36	66.95	67.05
66	Uzbekistan (2002, 2003, 2005)	220	0.85	31.82	31.91
67	Vietnam (2005)	1,396	5.41	42.12	42.07
68	Zambia (2002)	84	0.33	55.95	55.70
	Totals	25,806	100.00	48.84	48.81

Source: Author's calculations based on data from the World Bank's *Enterprise Surveys* database, http://www.enterprisesurveys.org/.
[a] Countries with real GDP per capita > $14,000 (PPP), which are not in sample of Model 5 in Table 2.
[b] Predictions from Model 4 in Table 2, which are used as the dependent variable in Models of Table 3.

difficulty of hiring index, and starting a business time (days). These variables are the average by country for the years 2003, 2004, and 2005 (although some of these years may be missing for some variables for some countries). The data come from the World Bank's *Doing Business* database.

Infrastructure index. The composite index was estimated as the first principal component derived from factor analysis of the total road length in 2001 (km) (per square km of surface area) and main telephone lines (per 1000 habitants) in 2001. The data come from the World Bank's WDI.

Institutional index. The composite index was estimated as the first principal component derived from factor analysis of the control of corruption, political stability, and the rule of law. The data come from Kaufmann, Kraay, and Mastruzzi (2005).

Business density. Data are from Djankov et al (2007). This variable is defined as the number of firms per capita by country.

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Accepted by Arjen van Witteloostuijn, Area Editor, 19 January 2009. This paper has been with the author for three revisions.