Domestic patent rights, access to technologies, and the structure of exports

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Abstract. Recent years have seen major reforms in patent laws around the world. We study the effects of variations over time and across countries in the strength of domestic patent rights (PRS) on exports in high-R&D goods. Adopting a generalized factor-proportions framework, we interact industry research intensity with national PRs. Countries with stronger PRs have significantly greater exports in research-intensive sectors. These effects are positive in emerging and developing economies but smaller than in developed economies. The sensitivity of high-R&D exports to PRs rises with inward flows of patent applications, FDI employment, and intra-firm trade with multinational firms.

JEL Classification: D23, F13, F14, O34

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Acknowledgments. We are grateful for the comments of Jeffrey Bergstrand, Bruce Blonigen, Catherine Mann, Alan Spearot, and two anonymous referees. We acknowledge financial support from the Hong Kong Polytechnic University Internal Competitive Research Grant (A-PK28). Keith Maskus is serving as Chief Economist of the U.S. State Department from October 2016 through October 2017 but the work in this paper was completed before beginning that position.

1. Introduction.

The last two decades have seen major reforms in the strength and enforcement of patent laws throughout the world, largely due to the demands of technologically advanced nations for stronger protection in their export markets (Maskus 2012). One primary factor is the 1995 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) at the World Trade Organization, which required significant changes in minimum norms of protection for intellectual property rights (IPRs). Many developing, emerging, and transition economies had a limited history of protecting IPRs prior to that time and were required to phase them in over time. Also important are U.S. and European Union (EU) demands for elevated patent and copyright standards in regional trade agreements (RTAs) negotiated with developing-country partners. Even many high-income countries have enacted more rigorous laws, often due to similar RTAs or simply joining the EU. These various changes affected a major increase in protection across the world between 1995 and today.

A central question is how associated changes in patent rights (PRs) have affected international trade among countries. One major objective of TRIPS, as spelled out in its Article 7, and various RTAs was to deploy stronger IPRs in the developing world in order to increase technology transfers to those countries, which would assist in their economic development.[1] Such claims are highly controversial in light of the two-edged nature of exclusive patent rights: they may facilitate technology transfer even as they make learning through imitation more costly. Moreover, such impacts are likely to differ by industry and country, meaning the issue is inherently empirical.

The extent to which stronger PRs attract greater technology flows, whether through imports of high-technology goods or foreign direct investment (FDI), has been the subject of a considerable literature, as noted below. However, this literature has largely ignored how such diffusion might expand productivity and exports, including among emerging and developing economies. We study this question in a flexible econometric framework that envisions the strength and enforcement of national patent laws as an exogenous institutional endowment affecting the relative advantage of countries in producing and exporting R&D-sensitive goods. In addition, we consider the contribution to trade specialization of various channels through which technology transfer occurs in order to isolate the impact of PRs and to investigate interactions between them.

Our data comprise detailed sectoral manufacturing exports, compiled at the three-digit SIC level, for 102 countries at five-year intervals from 2000 to 2010. We combine these with information on patent laws and enforcement, research intensities by sector, and a range of other factor endowments and intensities. Sectoral channels of technology inflows we consider include patent applications, employment in local affiliates of U.S. firms, and intra-firm trade in inputs.

Our analysis turns up a number of interesting findings. First, we find strong evidence that the policy shift toward stronger patent protection has significantly boosted

[1] Article 7 of TRIPS states, in part, that "The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge…"

exports in relatively R&D-intensive industries over the period, a result that holds also for patent-intensive goods. Second, there is evidence that these impacts grew between 2000 and 2005, roughly in line with implementation of TRIPS obligations, before perhaps diminishing in 2010. Third, these relative export effects are positive but smaller in upper-middle-income and lower-income economies than in the developed countries. Finally, the sensitivity of high-R&D exports to patent protection is stronger in countries with industrial sectors receiving relatively larger numbers of inward patent applications, greater FDI affiliate employment, and higher ratios of intra-party imports with U.S.-based multinational enterprises. These results suggest that such flows are important channels of technology learning.

2. Prior literature and analytical background.

Since the initial paper by Maskus and Penubarti (1995), several authors have studied how patent laws affect imports, with mixed results (Smith 1999, Smith 2001, Co 2004, Park and Lippoldt 2003, Awokuse and Yin, 2010). In a notable analysis, Ivus (2010) found that patent reforms required by TRIPS in 18 developing nations with larger mandated policy changes significantly raised their imports of high-technology products in comparison with countries that adopted smaller changes. Delgado, Kyle and McGahan (2013; DKM) found a similar outcome, considering knowledge-intensive goods to be “treatment” products with regard to TRIPS.

Virtually all of this literature studies the impacts of domestic patent reforms on merchandise imports, arguing that such reforms should alter the demand for imported goods and technologies. However, it misses the important point that strengthening PRs ultimately could expand export capacity in countries that absorb and deploy foreign technical information (Yang and Maskus 2009, He and Maskus 2012, Branstetter, Fisman and Foley 2006; BFF). Indeed, Branstetter, Fisman, Foley and Saggi (2011; BFFS) found evidence, in a small number of countries, that those nations increase the number of commodity categories in which they export in the years after a basic patent reform. Briggs and Park (2014) similarly noted that foreign affiliates of U.S. multinationals see significant growth in exports and licensing. In contrast, Shin, Lee and Park (2016) found that as importing countries adopt more stringent IPR protection, the impact of local technological expansion on the bilateral exports of partner nations is diminished. Put differently, as technological sophistication increases in emerging countries they may find their exports blocked by patents abroad.

Despite this evidence, how changes in national PRs have influenced exports across many countries and products has not been investigated systematically. We study this issue by relating national exports at the detailed industry level, incorporating interactions between factor intensities and exporter factor endowments. Our innovation is to consider the protection of patent rights to be an institutional endowment, which we interact with a measure of industry industrial research intensity to investigate their contribution to sectoral specialization and export performance.

The primary channel through which domestic patent protection may affect industrial development is by inducing more inward technology transfer via trade, FDI, and licensing of intellectual property rights (Maskus 2012). Received theories of endogenous technology transfer find that stronger patent protection can encourage inward investments and licensing in response to a diminished local imitation threat and reduced contracting costs (Lai 1998, BFF 2006, BFFS 2011, Yang and Maskus, 2001, Antras 2005). Indeed, through imitation and learning by doing from inward FDI, firms in developing countries may become sufficiently productive to innovate and export new products (He and Maskus 2012). Static models with strategic behavior support similar conclusions, depending on market circumstances and the potential for learning spillovers (Taylor 1994, Yang and Maskus 2009). Moreover, patent rights positively encourage technology transfer in complex products by raising the degree to which knowledge is shared across distance (Keller and Yeaple 2013).

Beyond these impacts associated with technology transfer is the potential for stronger patent rights to induce more domestic innovation. The evidence on this point is mixed (Park 2008a), though work by Chen and Puttitanun (2005) and Qian (2007) suggests that domestic patent reforms are associated with the filing of more patent applications at the United States Patent and Trademark Office by enterprises in middle-income nations above certain income and education thresholds.

3. Empirical specification and data.

3.1. Basic specification.

With this background, consider how we might test the hypothesis that reforms in patent rights expand high-technology exports. In countries where patents are weak *ex post* there should be *ex ante* underinvestment in sectors where intellectual property protection (and adequate contract enforcement) is important for bringing in technologies, absorbing them into production, and developing local improvements. This underinvestment implies, in turn, that countries will have smaller production and exports in sectors that rely relatively more on protection, other things equal. Put differently, countries with stronger patent rights should have relatively more output in high-technology goods that rely on patents. This difference should show up in the structure of comparative advantage in trade.

Nunn (2007) made a similar point regarding the effectiveness of contract enforcement in determining comparative advantage. In this context, he viewed the adequacy of contracts as a national endowment, similar to the capital stock. Countries with larger contract "endowments" should have relatively more exports in sectors where legal security is important. Indeed, he found that countries with strong contracting environments specialize in industries where relationship-specific investments are important. Similarly, Levchenko (2007) found that the quality of contracting institutions was a significant determinant of bilateral sectoral exports to the United States. We argue that patent rights are similarly a national institutional endowment of enforceable security regarding investments in technology transfer and innovation.

Thus, we adopt the following specification, which relates exports to determinants of comparative advantage.[2] Our estimates involve cross-sectional data

[2] This approach modifies Romalis (2004), which set out a many-country, general-equilibrium trade theory

in each of three years to reflect the long-run nature of this theory, along with panel estimation of the pooled data.

$$\ln(X_{cj}) = \alpha_c + \alpha_j + \theta_1 ln(K_c) * k_j + \theta_2 \ln(S_c) * s_j + \theta_3 \ln(PR_c) * r_j + \sum_{m=1}^{3} \theta_m \ln(V_{mc}) * v_{mj} + \varepsilon_{cj} \quad (1)$$

Here, X_{cj} is total exports to the world of country c in industry j. Variable K_c is the country's capital stock (relative to its labor force) and S_c is each country's relative skilled-labor endowment. The variables k_j and s_j are measures of the physical-capital intensity and skilled-labor intensity of each industry, assumed to be the same across countries.

The variable PR_c is each nation's patent-rights endowment as defined below, while r_j is a sectoral research and development (R&D) intensity. We focus on research sensitivity, rather than the propensity of industries to register patents, for several reasons. First, patent protection is presumed in theory to encourage R&D investments, which are inputs parallel to capital and skill intensity, suggesting that applying common industry R&D intensities across countries appropriately captures comparative-advantage effects. In contrast, whether firms in different industries choose to patent is highly idiosyncratic across countries. Second, R&D intensities are readily computed at the SIC level whereas the translation of patent categories to the industry classification faces difficult measurement problems (Lybbert and Zolas 2014). Third, while there remains debate about this question in the literature, recent firm-level evidence finds a strongly positive correlation between patenting and research expenditures (Artz, Norman, Hatfield and Cardinal 2010, Hagedoorn and Cloodt 2003). Finally, there are no available measures of sectoral patent intensities that vary over time, making their use problematic.[3]

The specification in equation (1) includes additional interactions between three country characteristics V_{mc} and associated industry characteristics v_{mj}, as noted below. It also incorporates country and industry fixed effects. The former absorb the direct effects of national endowments and additional unmeasured national characteristics, such as infrastructure (Romalis 2004). The latter effects account for any unmeasured variables affecting sectoral exports, such as each country's industrial policy and global trade and FDI policy. As noted, we also estimate a panel version of these specifications, in which case we include country-year and industry-year fixed effects.

This approach is derived from an underlying factor-proportions explanation of comparative advantage. Thus, if any of the θ coefficients is positive, as expected in the model, it indicates that the country has greater exports in industries that more intensively use the corresponding endowment.[4] Our basic test focuses on whether θ_3

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combining the continuum-of-goods, factor-proportions model with monopolistic competition. The interaction terms between industry and country characteristics were first introduced by Rajan and Zingales (1998) to test whether manufacturing industries that tend to use more external financing develop faster in countries with deeper financial markets.

[3] Nonetheless, as described below, we also estimate our models with a time-invariant measure of sectoral patent intensities and achieve similar results.

[4] A full specification would include both endowments and endowment-intensity interactions, with the former

is positive and significant, which would imply that countries with stronger PRs specialize in more R&D-intensive sectors. In this context, we lag the patent-rights interaction by five years to reflect the fact that such legal reforms likely take time to influence technological activity. For consistency we lag the capital stock, skills, and other interaction terms in the same way.

Because legal reforms in patents were phased in over time we consider the possibility that their impacts may vary with years. Thus, we analyze changes in the regression coefficients over time using cross-sections in 2000, 2005, and 2010 to study whether PRs have become more important in the era of reforms. Finally, in extended specifications we incorporate additional interactions of lagged variables measuring national exposure to inward technology transfer, including foreign patent applications, intra-party trade, and FDI employment, with our patent variables.

3.2. Data and variables.

The empirical analysis is carried out with detailed data covering 102 countries and up to 115 three-digit SIC manufacturing industries every five years from 1995 to 2010.[5] We use each country's exports from 2000 to 2010, measured in thousands of U.S. dollars (in year 2000 prices), which we compile from the United Nations, COMTRADE database. For this purpose we deployed a concordance between the HS classification, version 2, to the US 1987 Standard Industrial Classification (SIC), developed for four-digit industries, which were aggregated to the three-digit level. Because our explanatory variables are lagged five years we employ data on them from 1995 to 2005.

To test the model we need measures of patent-rights endowments by country and R&D intensities by industry. Our R&D intensity is expenditures on research and development as a percentage of industry sales for three-digit SIC categories, taken from the COMPUSTAT database. These ratios are industry averages for five year periods, including each year of our sample. We label it r_j in our analysis.

Turn next to the endowment of patent rights in each country. A primary component is the GP index of patent laws as compiled initially by Ginarte and Park (1997). This exists for five-year intervals from 1960 through 2010. The GP index takes on values between zero and five, with higher numbers reflecting stronger levels of protection. The index consists of five categories: coverage of fields of technology, membership in international patent agreements, provisions for loss of protection, legal enforcement mechanisms, and patent duration. Each category takes a value between zero and one and their sum gives the overall value of the index for a particular country.

The GP index has been used widely to measure the strength of patent laws and their changes over time. However, it is limited in that it considers only the presence or absence of particular legal provisions and does not account for the efficacy of administrative and judicial enforcement mechanisms. Thus, some countries may have relatively high GP indexes but the effective enforcement of patents is weak. For

essentially accounting for general-equilibrium Rybczynski effects, which could be positive or negative. However, these are subsumed in the country fixed effects here, leaving just the interaction impacts, which are positive in theory.

5 There are 136 SIC manufacturing industries but it was not possible to compute R&D intensities for more than 115 of them from the COMPUSTAT data.

example, in 1990 Malawi had a substantially higher index than Singapore, but the latter nation scores higher on implicit measures of enforcement.

To deal with this issue we follow Hu and Png (2013) in combining GP with the Fraser Institute's index of legal systems and property rights.[6] We use this index, which ranges from zero to ten, for the five-year intervals from 1995 to 2005. It is based on three aspects of protection: legal security from confiscation of property rights, viability of contracts, and rule of law. These components are compiled from surveys of international business executives published in the *International Country Risk Guide*.

Thus, our measure of patent-rights endowments is the product of the two variables: $PR = GP * Fraser$. This product should capture the scope of effective protection. A country with zero contract enforcement effectively does not protect patents, regardless of its legal rules. On the other hand, patent laws do matter and are likely complementary to enforcement efforts in their overall effects.

Following Romalis (2004), the skill intensity of an industry is measured as the ratio of non-production workers to total employment in each industry. Data on nonproduction workers and total employment are from the U.S. Census of Manufactures, aggregated to the three-digit level. We compute skilled-labor endowments for each country based on measures of average educational attainment for the population aged 25 and over, as reported initially by Barro and Lee (2001). These figures are available from the Center for International Development at Harvard University.[7] In the estimation we define the relative human capital stock as the ratio of the population over 25 that completed at least a secondary education to the population in this group that did not complete high school.

We define the ratio of capital stock in industry j to value added as the measure of capital intensity. We estimate capital stock figures in each U.S. industry from 1995 to 2010 by the perpetual inventory method using capital expenditure data from the U.S. Census of Manufactures. The annual physical capital stock of industry j is determined as follows:

$$K_{j,t} = I_{j,t-1} + (1-\delta)K_{j,t-1}$$

where δ is the depreciation rate, assumed to be 6%.[8] The variables $I_{j,t-1}$ and $K_{j,t-1}$ are, respectively, capital expenditures and capital stocks in the previous year. The initial capital stock of each industry is estimated by

$$K_{j0} = \frac{I_{j0}}{(g_j+\delta)}$$

where g_j is the average annual growth rate of capital expenditure in sector j. The initial year is 1970.

National capital endowments are taken to be the aggregate capital stocks listed

6 Available at http://www.freetheworld.com/release.html.
7 See www.cid.harvard.edu/ciddata/ciddata.html.
8 Nadiri and Prucha (1996) estimate the long-run depreciation rate of capital and equipment for the U.S. total manufacturing sector to be 5.9% over the period 1960-1988, comparable to corresponding estimates from the U.S. Bureau of Economic Analysis. A 6.0% rate corresponds to a 16-year lifetime of capital and equipment under linear depreciation, consistent with estimates used by the U.S. Bureau of Labor Statistics (2006). This is a reasonable approximation to average capital lifetimes across OECD economies in our data period (OECD, 2009). Note that varying the rate within a reasonable range has little impact on our estimates, largely because the selection does not much affect relative capital-intensity rankings across sectors.

in the Penn World Table, version 8.1 (Feenstra, Inklaar and Timmer 2015). These figures are in dollars, converted at PPP exchange rates, and we deflate them to 2005 prices with the U.S. GDP deflator. To provide a relative endowment measure, these capital stocks are divided by national labor forces, which are taken from the World Bank, *World Development Indicators*.[9]

It is possible that other factors also affect the pattern of specialization and trade. Thus, we include additional interactions, as noted by the terms $\ln(V_{mc}) * v_{mj}$ in equation (1). The first is the product of the log of per-capita real income in each country and the share of value added in the total value of shipments in each industry using U.S. data. We label this variable $Y_c * v_j$. This interaction accounts for the possibility that high-income countries may specialize in high-value-added industries. National income levels are measured by real GDP per capita at PPP rates, taken from the Penn World Tables. Data on value added and the value of shipments are from the National Bureau of Economic Research, Manufacturing Industry Productivity Database, again aggregated to the three-digit SIC.

The second additional variable is an interaction of the log of per-capita real income and the Grubel-Lloyd index, which measures the level of intra-industry trade in each industry. This index is defined as $gl_j = 1 - \frac{|IMP_j - EXP_j|}{IMP_j + EXP_j}$, where IMP_j and EXP_j are U.S. imports and exports of industry j. We label this interaction variable $Y_c * gl_j$ and it accounts for the possibility that high-income countries tend to specialize in industries with high levels of intra-industry trade.

A third country-industry interaction we include in extended specifications is designed to control for national institutional capacity, which likely is correlated with patent rights. Thus, we include, as a measure of institutional quality, the "rule of law" index developed by Kaufmann, et al (2010) and included in the World Bank's World Governance Indicators. We interact this variable with Levchenko's (2013) measure of industry sensitivity to institutional efficiency, defined as the sector's share of intermediate inputs that cannot be bought on organized exchanges and is not reference-priced.[10] This composite variable is labeled $I_c * i_j$.

To summarize, each of our primary explanatory variables consists of an interaction term between a national variable (patent rights, endowments, average income, and institutional quality) and an industry variable (R&D intensities, factor intensities, value-added shares, the Grubel-Lloyd index, and institutional sensitivity). The industry variables are all computed with U.S. data and assumed to share a common ranking across industries in all countries.[11]

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9 http://data.worldbank.org/data-catalog/world-development-indicators

10 On these matters see Rauch (1999) and Nunn (2007).

11 This practice is common in the literature, stemming back to Rajan and Zingales (1998), primarily due to the scarcity of sectoral intensity data outside the United States. Papers that use U.S. data for intensities include Romalis (2004), Nunn (2007), Levchenko (2007) and numerous others. It is consistent with the basic notion in the factor-proportions model that industry factor-intensity rankings are identical across countries, even if the levels vary. We note that, using R&D and output figures for 18 countries from the OECD's STAN database, covering up to 22 sectors in the International Standard Industrial Classification (ISIC), the correlations between R&D ratios in the United States and each country ranged between 0.48 and 0.88 in 2000 (calculated by the authors). All of these correlations are significant at the one-% level. This database is available at http://www.oecd.org/sti/ind/stanstructuralanalysisdatabase.htm.

3.3. Summary statistics.

The data are summarized in Tables 1 to 3. In Table 1 we list summary statistics for the industry-level R&D intensity measure and its correlations with other industry characteristics. The average R&D intensity rose slightly from 1.7% to 1.9% of sales between 1995 and 2005. There is considerable dispersion in this measure, with the top sector featuring a 17% R&D intensity in 2005. The R&D intensity is highly correlated with skill intensity and modestly so with the Grubel-Lloyd index and institutional dependence. There is essentially no correlation between R&D intensity and capital intensity.

In Table 2 we list summary statistics for the measure of patent rights and correlations with other endowments and national characteristics. Recall that PR is the product of GP and the Fraser Institute index. It rose from an average of 17.46 to 21.83 over the period, with considerable variation across countries. The figures show that PR is highly correlated with skill endowments, per-capita GDP, and institutional capacity (rule of law). In this regard, failing to include these other endowment-intensity interactions in the trade regressions could overstate the contributions of patent rights to exports.

For further perspective in Table 3 we list the average R&D, capital, and skill intensities across subsectors of broad goods categories: textiles and apparel (TEXT), chemicals (CHEM), pharmaceuticals (PHAR), industrial machinery (MACH), transport equipment (TRAN), and measuring and controlling instruments (MEAS). Pharmaceuticals have the highest intensities of all types, while measuring instruments are also relatively research-intensive.

4. Empirical results.

As an initial descriptive matter, we explore whether countries that tend to specialize in R&D-intensive industries have stronger patent rights. For this purpose we calculate, for each country in each year, its direct "R&D intensity of trade," which we define as the share of each sector's exports in total exports for country *c* weighted by that sector's R&D intensity index.[12] We then regress these specialization indexes (ES) on our measure of patent rights, lagged five years, expressing the results as standardized beta coefficients.[13] As shown in Table 4, there are strong positive correlations, which remain stable over time, between the protection of patents and export specialization in R&D-intensive goods across countries. Thus, the raw data suggest that as countries strengthen their patent rights they tend to increase export specialization in sectors with greater R&D intensities.

4.1. Baseline results.

Turn next to the primary regression specification, which explains trade specialization

[12] Note that this specialization index is different from the dependent variable in equation (1), which is log of sectoral exports. This initial regression with the specialization index is simply illustrative.

[13] Through most of the analysis we use beta coefficients, which measure the impact of a one standard deviation perturbation of one variable on the dependent variable, to standardize their interpretation. For comparison purposes we also present level coefficients for our main regressions below.

by the interactions of factor endowments and factor intensities, or between analogous interactions between national characteristics and sectoral dependence measures. The basic prediction to test is that export volumes in R&D-intensive sectors increase with the strength of patent rights across countries, other things equal. In Table 5 we present OLS results in each year of the sample and also with those years pooled into a panel. Because the number of countries and industries vary over time due to missing trade or endowments data, we distinguish between full samples and samples with fixed country-industry entries in each pair of regressions. We include country and industry fixed effects in each annual cross-section estimation and country-year and industry-year fixed effects in the panel. Again, in order to permit comparisons across variables all results are presented as standardized beta coefficients.

In the first column we show the simple regression coefficient in year 2000 between exports and the five-year lagged value of PR, which is 0.30 and highly significant. In the second and all remaining columns we include the other endowment and policy interactions. This reduces the PR interaction coefficient in 2000 by nearly half, to 0.18, but it remains highly significant. It is notable that both the Grubel-Lloyd index interaction and the value-added interaction have considerable explanatory power, with significant and stable coefficients throughout our regressions. This is true also of the interaction between national institutional quality and sectoral contract dependence in the final row. Recalling the high correlation between PR and institutional quality, it is striking that the strongly positive influence of the former variable remains intact when both are in the regressions.

Our primary result is that the coefficients on the patent-rights interaction are positive and significant throughout. Thus, countries have greater exports in relatively R&D-intensive industries as they strengthen the scope of their exclusive patent rights. In terms of economic significance, consider the impact of $\ln(PR) * r$ in the 2000 fixed sample, with the beta coefficient 0.21. In order to focus on policy changes, hold r fixed at its mean in 1995 (0.017).[14] Consider a one standard deviation (11.43) rise in patent rights, from the sample average of 20.16 (about the level of South Africa in 1995) to 31.59 (about the level of Singapore in 1995). In turn, the average of bilateral exports by sector would increase from $18.62 million to $20.52 million.[15] Put differently, a near-doubling of patent rights would expand average sectoral exports by 10.18%. In this regard, changes in the scope of patent protection have significant impacts on the volume and pattern of exports.

4.2. TRIPS effects?

It is also of interest to see if this relationship has strengthened over time, which is plausible in light of the international increases in patent protection associated with TRIPS, as discussed earlier. Thus, consider the coefficient on patent rights in each

[14] Recall that we used lagged values of $\ln(PR) * r$ and therefore base these computations on 1995 data.

[15] The level coefficient implied by the standardized OLS coefficient is 12.12 (see Table 6). The initial mean of $\ln(PR) * r$ is 0.017*ln(20.16) = 0.051, while the new mean becomes 0.017*ln(20.16+11.43) = 0.059, for a change of 0.008. The average of $\ln(X)$ is 16.74, making average bilateral exports $\exp(16.74)$ = $18,624,715. Predicted average bilateral exports after the increase in PR become $\exp(12.12 * 0.008 + 16.74)$ = $20,521,014, implying an increase of $1,896,299.

year going forward. It is important to note that in our fixed sample nearly all countries were compliant with TRIPS requirements by 2005, with many developing and emerging countries achieving compliance between 1995 and 2000.[16] In this context, if globalization matters for the sensitivity of exports to patent scope, we would expect to see a rising coefficient on the interaction term.

Considering first the regressions in which samples change over time due to entry of poorer countries, we see a rise from 0.18 in 2000 to 0.22 in 2005 before falling back to 0.12 in 2010. On this score it seems that the sensitivity of exports in more R&D-intensive goods went up with implementation of TRIPS in the earlier years but diminished in the longer term, though remaining significantly positive. In the fixed sample, however, we find that the PR coefficient rose from 0.21 to 0.27 in the initial period of legal compliance but remained stable in 2010. This finding suggests that the standardized impact of patent protection grew larger over the period, especially among those economies that were compliant with TRIPS relatively early.[17]

It can be difficult to interpret shifts in standardized coefficients because they derive from underlying regression relationships and standard errors, both of which may change over time. Thus, we list the same regressions with level coefficients in Table 6. With this specification we find weaker evidence of an increase in the fixed-sample coefficient between 2000 and 2005, with again some moderation by 2010. Thus, while the impact of patent rights is sustained throughout, the evidence of growth in the relationship is limited in this specification. In this view, if TRIPS had a particular impact on export specialization it was evidently achieved early in the period.

4.3. Impacts by country technology levels and income levels.

Our results to this stage verify that strengthening patent protection increases exports in R&D-intensive goods, pointing to an important role for patent scope in encouraging investments or learning in such industries. This finding is consistent with the results in Ivus (2010) and DKM (2013), both of which relied on this insight for their identification work, albeit in different empirical contexts.

The beta coefficients in Table 5 represent the average sectoral export effects across all countries in the sample, standardized for comparability. An important question is whether this impact varies by country types. Specifically, we investigate whether there is a difference in this sensitivity of R&D-intensive exports to patent rights between highly research-oriented economies and those with lower research expenditures, and between countries of different income or development levels.

For this purpose, we use data from the World Bank's *World Development Indicators* to construct the ratio of R&D expenditures to GDP for each available country, with figures from the year closest to 1996. We define high-R&D countries to be those

[16] We construct national compliance dates for our sample from Delgado, et al (2013), Park (2008b) and Hamdan-Livramento (2009). By the terms of TRIPS, the least-developed countries, which constitute much of our expanded sample over time, have been excused from compliance throughout the period.

[17] It is possible to consider timing of TRIPS compliance as an alternative measure of patent rights. Thus, we performed similar regressions where the primary interaction involved R&D intensities with a binary variable that was zero before compliance and unity after compliance. This approach also found positive and significant effects of patent rights on export composition, albeit with lower coefficients (which are not comparable to those in Table 5). Results are available on request.

with a ratio in excess of 1.5%, medium-R&D countries to be those with ratios between 0.3% and 1.5%, and low-R&D nations to be those with ratios below 0.3%. Regarding economic development, we divide countries into high-income, upper-middle-income, lower-income and least-developed countries, using World Bank classifications as of 1995. These breakdowns are detailed in Appendix Table A1, where the parenthetical H, M, and L indicate national R&D ratios. Inspection of these categories shows that there are meaningful differences between income rankings and R&D rankings.

Our econometric framework is useful for testing whether impacts vary by technology and income groupings in a rigorous manner. Recall that the coefficients in our interactions between patent rights and R&D intensities measure the compositional question of whether exports of high-R&D industries are higher where patent rights are stronger, a finding already established. To reinforce this question, however, we add a straightforward extension by constructing a triple interaction involving the product of patent rights, R&D intensity, and either a binary variable selecting those countries in our sample with low and medium levels of technological investments (ML) or a pair of binary variables selecting either upper-middle-income (UMI) nations or low-income and least-developed countries (LI).

The results of these specifications are in Table 7, where, to save space, we report only the panel regressions and suppress the coefficient estimates of the control variables.[18] The initial pair of columns depict the regressions with technology interactions (R&D expenditure ratios). As noted, the interaction between patent rights and research intensity remains positive and highly significant, with an estimate of 0.16 in the fixed panel. This is somewhat lower than the beta coefficient in the final column of Table 5. One likely reason is that adding an interaction effect featuring a binary indicator often generates collinearity with the primary variable, making its standardized coefficient somewhat fragile (Schielzeth 2010). In this context, the magnitudes of the primary coefficients across tables are not readily comparable.

However, it is meaningful to compare interaction effects within tables. Thus, the second row lists coefficients for the triple interaction with the dummy for medium- and low-R&D countries. These estimates are significantly negative, suggesting that the sensitivity of exports in high-R&D sectors to variations in patent scope are lower in the medium-technology and low-technology nations. However, the overall effects remain distinctly positive. The implication is that within each group of countries stronger patent rights induce more exports of goods with higher R&D ratios, but this impact is markedly diminished in the ML countries. Thus, the sensitivity of trade to patent protection is greater among the highest-spending R&D countries, affirming their greater comparative advantage in high-technology goods.

Similar results are found with the country-income breakdown in the final two columns. Incorporating two triple interactions reduces the primary coefficient even more, but it remains highly significant. The coefficients on both the UMI and LI interactions are negative, indicating a lower sensitivity of high-R&D exports to patent

[18] The annual regressions with these specifications generate coefficients that are qualitatively consistent with the panel outcomes, albeit somewhat less significant due to the limited sample sizes. In all cases the control-variable coefficients are highly consistent with those in Table 5, with those on the GL index, value added, and institutions uniformly positive and significant. Results are available on request.

rights in UMI and low-income and least-developed nations. Nonetheless, the overall impacts remain positive in all country groups. In this context, even in developing countries we find that stronger patent rights in the TRIPS era have expanded relative exports in higher-R&D industries.

4.4. Using patent-intensity measures.

As discussed earlier, we emphasize the advantages of sectoral R&D intensities over patent intensities as measures of technological orientation. Nevertheless, we estimate our basic specifications with a variable, derived from Hu and Png (2013), capturing relative industry-level patent grants to check for robustness of the PR impacts.[19] Those authors employed data on U.S. patent grants from the NBER Patent Database (Hall, Jaffe and Trajtenberg 2001) to enterprises in the COMPUSTAT database. Sales and patents were aggregated to the three-digit SIC level, from which patent intensities were computed as sectoral patent grants divided by real industry sales. Because there was considerable variability in these ratios over time and across industries the authors took the average for each sector over 1979 to 2000. Thus, this measure exists at the disaggregated three-digit level, consistent with our trade data, but is constant over time for each industry.

The results from substituting this patent intensity (labeled p_{cj}) for R&D intensity are given in Appendix Tables A2 and A3. As may be seen, this change has little impact on our coefficient estimates. Using patent intensity in Table A2 we find modestly lower coefficients than in Table 5 but all remain highly significant. Comparing Table A3 with Table 7 the results are also consistent and remain significant. Thus, our primary results remain robust to this alternative measure of technology orientation.

4.5. Adding potential channels of technological learning.

Such results are interesting but, like the bulk of this literature, leave aside a large question: what factors may explain the export expansion in the wake of domestic patent reforms? A number of hypotheses could be advanced about it and a full resolution requires extensive microeconomic data to observe how domestic firms may react to policy changes. Here we hope to initiate this investigation by arguing that, in addition to any domestic investments induced in research and production capacity in R&D-intensive goods, patent protection may attract inward technology transfers that directly or indirectly increase local productivity in higher-technology sectors. One straightforward means of examining this hypothesis is to incorporate sectoral measures of lagged technology flows into the interactions between patent rights and R&D intensity. Positive coefficients on these triple interactions would suggest that the sensitivity of high-technology exports to patent rights is enhanced by incoming technological information.

For this purpose we construct sectoral measures of three types of technology inflows. The first is the ratio of non-resident patent applications, by sectoral technology class, registered in each country to domestic GDP per capita, recognizing

[19] We are grateful to Albert Hu for providing these data.

that such patents are often a source of local technical change (Eaton and Kortum, 1996).[20] We aggregate these over the prior five years to achieve a relative inward patent stock. For example, in year 1995 the measure is $NP_{cj} = (\sum_{1990}^{1994} PAT_{cjt})/Y_{c,1994}$, where PAT_{cj} indicates the number of non-resident applications in sector j and Y is per-capita GDP. This offers a country-sector-specific measure of the prevalence of inward applications, scaled by income. These applications data are taken from the on-line database of the World Intellectual Property Organization.

A second measure is based on the idea that within-firm trade in goods from a parent country to an affiliate often embodies advanced technologies. Keller and Yeaple (2013) argued that firms face costs in transferring intangible knowledge across locations, suggesting that spillovers from such trade may be limited. Nonetheless, they included the GP index in their regressions involving the share of intra-firm trade, finding a significantly positive impact. Thus, we include, at the industry level, each country's share of intra-party imports of manufactures from the United States in total manufacturing exports from the same country. In these regressions we exclude the United States as an exporter. The data on intra-party trade, which we collected from the Bureau of Economic Analysis, are available for the years 1996 to 1999 and annually after 2002. We use the 1996 ratio for 1995 and the 1999 ratio for 2000.

Our third indicator is industry employment in the local affiliates of U.S. parent companies, divided by the national local labor force. Affiliates are defined as non-bank firms that are majority-owned by U.S.-headquartered parents. We develop sectoral measures from the 1994, 1999, and 2004 benchmarks surveys of the U.S. Bureau of Economic Analysis.[21] It is well established in the empirical literature that FDI serves as a potential source of information spillovers, tending to raise local productivity (Keller 2004).

In Table 8 we list the results from including these additional triple interactions, entered singly into separate regressions and in combination. Again we report only the panel regressions to save space.[22] Sample sizes vary because some sectoral observations are missing for the technology variables. In the first three columns we exclude the development-related interaction terms. We find that including the non-resident patent variable (NP_{cjt}) actually increases the coefficient on patent rights (in comparison with the final column in Table 5), and it remains highly significant. Similarly, introducing intra-party trade (IPT_{cjt}) raises the basic coefficient slightly.

Interestingly, the triple-interaction coefficients on both patent applications and intra-party trade are significantly positive. This suggests that the responsiveness of high-R&D industry exports to patent rights is enhanced in countries with greater sectoral scaled inward patent flows and greater intra-party trade ratios. In contrast,

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[20] Converting patent applications from the broad International Patent Classification to our SIC basis required developing a concordance, which is necessarily rough. Details are in the data appendix.
[21] See the Data Appendix for details.
[22] Results for other samples are qualitatively similar and are available on request. In Table 8 we suppress the estimates for other control variables but they are included in the regressions and achieve results very close to those in earlier tables.

inclusion of affiliate FDI employment reduces the primary patent rights coefficient to 0.14, though it remains highly significant. The triple-interaction coefficient is significant and comparable to the other channels introduced. Moreover, in column (4) all of the diffusion channels have comparably high and significant impacts. These results suggest that all three potential means of learning from foreign technologies raise the sensitivity of high-technology exports to patent protection, but the extent of the relationship overall depends on the form of information diffusion.

The final four columns repeat this analysis but include the interactions with the UMI and LI dummy variables. The impacts of the technology channels in the triple-interactions remain intact. The results on the income-group interaction are essentially unchanged from Table 7 for the UMI group, which is true also for the LI aggregation with respect to scaled patent applications. However, including the FDI measures (intra-firm trade and employment) eliminates the significance of the LI interaction coefficients, perhaps because these variables are poorly measured at the sectoral level in such countries.

We caution that, as described in the data appendix, the sectoral measures for patent applications and FDI employment are rough, given limited data availability. Thus, we also ran regressions using the corresponding national measures.[23] These include total non-resident patent applications across all classes divided by GDP, the national ratio of intra-party trade across manufacturing industries, and total inward FDI stock by industry in each country as a percentage of local GDP in 1995, 2000, and 2005. Figures on patent applications and intra-firm trade were aggregated from the same sources mentioned earlier, while the FDI stock data were taken from UNCTAD (2014).

The findings from these regressions were similar to those in Table 8, though the interpretation refers to technology inflows at the national, rather than the sectoral, level. We find that inclusion of the national triple-interactions has little impact on the basic patent-rights coefficients, which remain highly significant. Both the national patent-applications ratio and national intra-party trade generated positive and significant coefficients of comparable magnitudes to those in Table 8. The only difference is that the coefficients on inward FDI stocks were insignificant.

In any event, these various results point out the interesting possibility that the potential of stronger patent protection to move resources into high-technology exports is associated positively with inward technology flows. Additional research on this hypothesis seems warranted.

4.6. A note on endogeneity.

Our various estimates are based on ordinary least squares, raising concerns about potential endogeneity from trade patterns to patent protection. It is plausible that countries with comparative advantages in high-technology industries would select stronger patent rights, leading to bias in the OLS coefficients. We argue, however, that these concerns are largely mitigated here by several factors. First, as noted earlier, the considerable majority of our countries in the sample are emerging and developing economies, which overwhelmingly remain net importers of high-technology goods and

[23] Results are available on request.

therefore have few domestic economic interests in strong protection. Thus, for these countries the recent legal reforms in intellectual property rights associated largely with TRIPS and PTAs may be considered essentially exogenous. This argument is consistent with the assumptions made by DKM (2013), BFF (2006), BFFS (2011) and others. The notion that TRIPS engineered policy changes in developing countries that moved them away from non-cooperative Nash patent regimes finds empirical support in Lai and Yan (2013).

Second, while it is only a partial solution to this problem, the fact that we lag the patent interaction term (and other interaction terms) by five years gives us some confidence that these variables are determined before current trade allocations. Third, each of our annual regressions contains a full set of country and industry fixed effects, while the panel regressions incorporate both country-year and industry-year fixed effects. This is a rigorous specification that sweeps out nearly all additional variation that could generate omitted variable bias.

For these reasons we choose to report the OLS results, which we think are more reliable than instrumental variables estimation with large instrument sets.[24]

5. Summary and conclusions.

In this paper we provide an initial empirical assessment of the effects of patent rights and enforcement norms on the pattern of exports, using the factor-proportions model. This is an important question in assessing the impacts of the recent globalization of intellectual property rights. We study this question with regressions of the levels of sectoral trade performance on effective patent rights, controlling for other determinants of trade and including fixed effects for countries and industries in annual cross sections and country-year and industry-year dummies for the panel estimation.

The empirical results conform broadly with the underlying hypothesis that stronger PRs can boost export performance in sectors that are relatively more R&D-intensive. Moreover, we find that the effects of stronger PRs on exports are strongest in countries with high R&D shares and developed countries. However, the positive effects persist, albeit at lower levels of sensitivity, for countries with lower R&D investment ratios and developing and emerging economies. In addition, there is some evidence that the relationship grew stronger between 2000 and 2005, a period in which many emerging and developing economies implemented their TRIPS obligations. Finally, we find that countries with relatively more inward sectoral patent applications and industry-level intra-firm imports from U.S. multinational enterprises have a higher sensitivity of R&D-intensive exports to changes in patent protection. This is a novel result that should invite more analysis going forward.

[24] We did experiment with instrumental variable estimation, choosing as instruments each country's legal origin, whether based on colonial status or other historical relationships (La Porta, Lopez-de-Silanes, Shleifer and Vishny 1998, 1999), following Nunn (2007) and Ivus (2010). Our instruments, used in a first-stage estimation of all variables incorporating patent rights, were dummies for British, French, Socialist and German legal origins, interacted with R&D intensities, along with all control variables and fixed effects. With this many instruments, however, the regressions were over-identified and generated unreliable coefficients. In general, the IV estimates produced second-stage coefficients that were positive and considerably larger than their OLS counterparts, while still significant, as found also by Nunn (2007) with respect to contract enforcement. This suggests that our reported results may be somewhat conservative.

We stress that a positive impact of patent rights on high-technology exports, while suggestive of some structural transformation in the economy after policy reforms, is not an indication of national welfare gains. Our analysis is restricted to the simple positive question of sectoral trade impacts and, therefore, does not address such fundamental questions as variety changes in trade, price impacts from stronger patents or the effects of patent reforms on domestic innovation and profits. Thus, while policymakers in emerging countries should find the present findings of interest, they need to think more broadly about how to meet other development challenges arising from their intellectual property policies (Maskus 2012).

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TABLE 1
Summary statistics for R&D intensity

	1995	2000	2005
Mean (r)	0.017	0.0191	0.0194
Std. Dev. (r)	0.021	0.025	0.028
Min (r)	0.000	0.000	0.000
Max (r)	0.114	0.136	0.168
Corr (r,k)	0.04	-0.06	0.01
Corr (r,s)	0.43	0.62	0.61
Corr (r,v)	0.11	0.14	0.19
Corr (r,gl)	0.21	0.28	0.22
Corr (r,i)	0.30	0.36	0.35
# observations	115	111	110

TABLE 2
Summary statistics for patent rights

	1995	2000	2005
Mean (PR)	17.46	20.03	21.83
Std. Dev. (PR)	11.34	11.70	10.53
Min (PR)	3.56	4.22	5.74
Max (PR)	42.94	44.90	43.90
Corr (PR,K)	0.37	0.34	0.29
Corr (PR,S)	0.60	0.60	0.60
Corr (PR,Y)	0.52	0.63	0.57
Corr (PR,I)	0.82	0.87	0.88
# observations	98	98	98

TABLE 3
Average factor intensities, selected industries

	1995	1995	1995	2000	2000	2000	2005	2005	2005
	r	*k*	*s*	*r*	*k*	*s*	*r*	*k*	*s*
TEXT	0.000	0.023	0.006	0.000	0.028	0.007	0.000	0.035	0.008
CHEM	0.003	0.131	0.056	0.004	0.178	0.056	0.003	0.127	0.054
PHAR	0.114	0.459	0.480	0.136	0.477	0.515	0.168	0.439	0.519
MACH	0.005	0.061	0.044	0.005	0.067	0.044	0.005	0.075	0.043
TRAN	0.005	0.095	0.037	0.005	0.109	0.036	0.005	0.117	0.039
MEAS	0.010	0.095	0.097	0.013	0.103	0.100	0.014	0.107	0.105

TABLE 4
Export specialization (ES) regressed on patent rights endowment

	2000	2005	2010
PR_{ct}	0.60*** (0.099)		
PR_{ct}		0.65*** (0.084)	
PR_{ct}			0.62*** (0.090)
Observations	68	85	79
R-squared	0.36	0.42	0.38

NOTES: Results are standardized beta coefficients. The patent rights variable is lagged 5 years. Robust standard errors are in parentheses. Coefficients are significant at 1% (***), 5% (**) or 10% (*).

TABLE 5
Patent rights and export specialization: basic specification

Dependent variable: log exports of countries by sector

Variable	2000	2000	2000 (fix)	2005	2005 (fix)	2010	2010 (fix)	Panel	Panel (fix)
$PR_{ct}*r_{jt}$	0.30***	0.18***	0.21***	0.22***	0.27***	0.12***	0.26***	0.18***	0.21***
	(0.025)	(0.029)	(0.031)	(0.030)	(0.037)	(0.037)	(0.044)	(0.019)	(0.022)
$K_{ct}*k_{jt}$		-0.05	-0.06	0.11***	-0.05	0.12***	0.04	0.06***	-0.00
		(0.037)	(0.039)	(0.034)	(0.043)	(0.035)	(0.041)	(0.020)	(0.023)
$S_{ct}*s_{jt}$		0.02	0.02	-0.02	0.02	0.03*	-0.01	0.00	0.01
		(0.017)	(0.019)	(0.015)	(0.019)	(0.017)	(0.019)	(0.010)	(0.011)
$Y_{ct}*gl_{jt}$		0.29***	0.25***	0.20***	0.23***	0.26***	0.32***	0.24***	0.27***
		(0.047)	(0.051)	(0.038)	(0.049)	(0.040)	(0.048)	(0.024)	(0.028)
$Y_{ct}*v_{jt}$		0.25***	0.26***	0.36***	0.24***	0.28***	0.29***	0.31***	0.29***
		(0.050)	(0.055)	(0.042)	(0.053)	(0.045)	(0.053)	(0.026)	(0.031)
$I_{ct}*i_{jt}$		0.14***	0.17***	0.10***	0.17***	0.12***	0.15***	0.12***	0.14***
		(0.016)	(0.017)	(0.014)	(0.018)	(0.015)	(0.017)	(0.009)	(0.010)
R^2	0.80	0.81	0.82	0.82	0.82	0.81	0.82	0.81	0.82
Obs. no.	6,752	6,752	5,964	8,586	5,964	8,068	5,964	23,406	17,892

Notes: Results are standardized beta coefficients. Explanatory variables are lagged 5 years. Robust standard errors are in parentheses. Coefficients are significant at 1% (***), 5% (**) or 10% (*). Annual regressions include country and industry fixed effects and panel regressions include country-year and industry-year fixed effects. Regression columns stating “fix” refer to unchanged country-industry samples over time.

TABLE 6
Patent rights and export specialization: basic specification, with level coefficients

Dependent variable: log exports of countries by sector

Variable	2000	2000	2000 (fix)	2005	2005 (fix)	2010	2010 (fix)	Panel	Panel (fix)
$PR_{ct}*r_{jt}$	18.30***	10.75***	12.12***	10.87***	12.64***	5.16***	10.49***	8.86***	9.70***
	(1.538)	(1.736)	(1.790)	(1.501)	(1.750)	(1.579)	(1.759)	(0.921)	(1.015)
$K_{ct}*k_{jt}$		-0.02	-0.03	0.06***	-0.02	0.07***	0.02	0.03***	-0.00
		(0.016)	(0.017)	(0.019)	(0.022)	(0.019)	(0.021)	(0.010)	(0.011)
$S_{ct}*s_{jt}$		0.23	0.18	-0.27	0.17	0.28*	-0.15	0.05	0.12
		(0.196)	(0.204)	(0.168)	(0.213)	(0.165)	(0.204)	(0.101)	(0.119)
$Y_{ct}*gl_{jt}$		0.43***	0.37***	0.30***	0.34***	0.37***	0.44***	0.36***	0.39***
		(0.071)	(0.075)	(0.057)	(0.072)	(0.057)	(0.066)	(0.035)	(0.041)
$Y_{ct}*v_{jt}$		0.76***	0.76***	1.11***	0.71***	0.83***	0.83***	0.92***	0.84***
		(0.151)	(0.160)	(0.126)	(0.155)	(0.131)	(0.153)	(0.078)	(0.090)
$I_{ct}*i_{jt}$		0.96***	1.11***	0.65***	1.07***	0.75***	0.92***	0.77***	0.86***
		(0.107)	(0.115)	(0.094)	(0.113)	(0.095)	(0.104)	(0.057)	(0.064)
R^2	0.81	0.81	0.82	0.82	0.82	0.81	0.81	0.81	0.82
Obs. no.	6,752	6,752	5,964	8,586	5,964	8,068	5,964	23,406	17,892

Notes: Results are level coefficients. Explanatory variables are lagged 5 years. Robust standard errors are in parentheses. Coefficients are significant at 1% (***), 5% (**) or 10% (*). Annual regressions include country and industry fixed effects and panel regressions include country-year and industry-year fixed effects. Regression columns stating “fix” refer to unchanged country-industry samples over time.

TABLE 7

Patent Rights and Export Specialization: Differences by Country R&D Ratios and Income Levels

Dependent variable: log exports of countries by sector

Variable	Panel	Panel (fix)	Panel	Panel (fix)
$PR_{ct}*r_{jt}$	0.14***	0.16***	0.12***	0.09***
	(0.020)	(0.023)	(0.011)	(0.028)
$PR_{ct}*r_{jt}*ML$	-0.05***	-0.05***		
	(0.007)	(0.007)		
$PR_{ct}*r_{jt}*UMI$			-0.03***	-0.04***
			(0.005)	(0.006)
$PR_{ct}*r_{jt}*LI$			-0.02***	-0.04***
			(0.005)	(0.007)
R^2	0.81	0.82	0.80	0.82
Obs. no.	23,406	17,892	23,406	17,892

Notes: Results are standardized beta coefficients. Explanatory variables are lagged 5 years. Robust standard errors are in parentheses. Coefficients are significant at 1% (***), 5% (**) or 10% (*). Panel regressions include country-year and industry-year fixed effects, along with all other controls. Regression columns stating "fix" refer to unchanged country-industry samples over time.

TABLE 8
Patent rights and export specialization: potential learning channels

Dependent variable: log exports of countries by sector

Variable	Panel	Panel	Panel	Panel	Panel	Panel	Panel	Panel
$PR_{ct}*r_{jt}$	0.33***	0.25***	0.14***	0.32***	0.22***	0.16***	0.11*	0.22***
	(0.037)	(0.033)	(0.041)	(0.052)	(0.049)	(0.044)	(0.057)	(0.079)
$PR_{ct}*r_{jt}*NP_{cjt}$	0.07***			0.09***	0.07***			0.11***
	(0.012)			(0.015)	(0.012)			(0.017)
$PR_{ct}*r_{jt}*IPT_{cjt}$		0.06***		0.04***		0.05***		0.04***
		(0.008)		(0.010)		(0.008)		(0.011)
$PR_{ct}*r_{jt}*FEMP_{cjt}$			0.07***	0.07***			0.07***	0.07***
			(0.006)	(0.007)			(0.006)	(0.008)
$PR_{ct}*r_{jt}*UMI$					-0.04***	-0.05***	-0.04***	-0.05***
					(0.009)	(0.008)	(0.009)	(0.012)
$PR_{ct}*r_{jt}*LI$					-0.02**	-0.01	0.01	-0.01
					(0.010)	(0.009)	(0.010)	(0.013)
R^2	0.79	0.80	0.80	0.79	0.80	0.80	0.80	0.79
Obs. No	8,953	8,901	8,620	5,675	8,953	8,901	8,620	5,675

Notes: Results are standardized beta coefficients. Explanatory variables are lagged 5 years. Robust standard errors are in parentheses. Coefficients are significant at 1% (***), 5% (**) or 10% (*). Panel regressions include country-year and industry-year fixed effects, along with all other controls.

Appendix

Data issues

In the text we mention all of our data sources, including for factor intensities, industry characteristics, and national factor endowments and policy variables. However, in several instances we had to develop or use concordances among data classifications or make specific sectoral assignments of broader ratios. In this appendix we outline these approaches, details of which are available on request.

Our primary source for exports was the UN COMTRADE database, from which we took data organized into the Harmonized System (HS), version 2 (1992), using the six-digit classification. There is no published concordance from HS to the U.S. Standard Industrial Classification (SIC, version 1987) at these levels, so we developed our own, assigning six-digit HS categories to four-digit SIC industries according to a weighting scheme. These exports were then aggregated to the three-digit SIC level to be consistent with our U.S. industrial data, used for computing factor intensities. The R&D data for firms, taken from COMPUSTAT, were also assigned to an SIC basis given the primary industry classifications given in that source.

A significant challenge was to assemble industry-level figures to compute ratios of inward patent applications at the sectoral (SIC) level. The World Intellectual Property Organization (WIPO) publishes an online patent database, organized according to their International Patent Classification (IPC). The IPC is defined by technology class, rather than industrial production like the SIC. Our approach was to assign the 34 IPC categories listing industry applications to 30 broad SIC sectors, using weights developed for this purpose. Non-resident patent applications in each country in these 30 sectors were summed over the five prior years and this sum was divided by local GDP per capita in the final year of that summation, to generate a broad sectoral patent ratio. This ratio was then assigned to each three-digit SIC subsector within the 30 broad categories. Thus, the sectoral variation in patent ratios exists at this broader level, although these measures differ across countries.

It is difficult to find detailed sectoral FDI data for more than a handful of countries. To achieve an approximate measure we rely on U.S. outward FDI data published by the Bureau of Economic Analysis (BEA) in the benchmark years 1994, 1999, and 2004, with these data used for 1995, 2000, and 2005, respectively. For these benchmark years the BEA publishes statistics regarding the operations of U.S. multinational enterprises in most countries of the world, broken down into seven (eight) broad manufacturing categories in 1994 (1999 and 2004). Even at this broad level a small number of observations are not disclosed for confidentiality reasons. Using the remaining observations, we assigned specific three-digit SIC industries to one of these broad sectors. We then computed the ratio of employment of U.S. majority-owned, nonbank affiliates to the local labor force in each country in each broad sector, applying that ratio to all subsectors. Again, therefore, the effective industrial variation in FDI employment is at the broad level of manufacturing sectors, though these vary across individual nations.

Appendix tables

TABLE A1
Countries in the sample

High-income	*Upper Middle Income*	*Low income*	*Least developed*
Australia (H)	Algeria (L)	Bolivia (M)	Bangladesh (L)
Austria (H)	Argentina (M)	Cameroon (L)	Benin (L)
Belgium (H)	Botswana (M)	Rep. of Congo (L)	Burundi (L)
Canada (H)	Brazil (M)	Cote d'Ivoire (L)	Central African Rep. (L)
Cyprus (L)	Bulgaria (M)	Ecuador (L)	Malawi (L)
Czech Republic (M)	Chile (M)	Egypt (L)	Mali (L)
Denmark (H)	China (M)	El Salvador (L)	Nepal (L)
Finland (H)	Colombia (L)	Ghana (L)	Niger (L)
France (H)	Costa Rica (L)	Guatemala (L)	Rwanda (L)
Germany (H)	Dominican Republic (L)	Guyana (L)	Senegal (M)
Greece (M)	Fiji (L)	Honduras (L)	Sierra Leone (L)
Hong Kong (M)	Gabon (M)	India (M)	Tanzania (M)
Hungary (M)	Jamaica (L)	Indonesia (L)	Togo (L)
Iceland (H)	Lithuania (M)	Iran (M)	Uganda (L)
Ireland (M)	Malaysia (M)	Jordan (M)	Zambia (L)
Israel (H)	Mauritius (M)	Kenya (M)	
Italy(M)	Mexico (M)	Morocco (M)	
Republic of Korea (H)	Panama (M)	Nicaragua (L)	
Japan (H)	Peru (L)	Pakistan (L)	
Luxembourg (H)	Poland (M)	Papua New Guinea (L)	
Malta (L)	Romania (M)	Paraguay (L)	
Netherlands (H)	Russian Federation (M)	Philippines (L)	
New Zealand (M)	South Africa (M)	Sri Lanka (L)	
Norway (H)	Turkey (M)	Syria (L)	
Portugal (M)	Trinidad & Tobago (L)	Thailand (L)	
Singapore (H)	Uruguay (L)	Tunisia (M)	
Slovakia (M)	Venezuela (L)	Ukraine (M)	
Spain (M)		Zimbabwe (L)	
Sweden (H)			
Switzerland (H)			
UK (H)			
USA (H)			

Note: Countries are designated as high R&D (H), medium R&D (M) and low R&D (L).

TABLE A2
Patent rights and export specialization using patent intensities

Dependent variable: log exports of countries by sector

Variable	2000	2000	2000 (fix)	2005	2005 (fix)	2010	2010 (fix)	Panel	Panel (fix)
$PR_{ct}*p_j$	0.28***	0.15***	0.16***	0.22***	0.16***	0.22***	0.20***	0.19***	0.18***
	(0.026)	(0.028)	(0.029)	(0.028)	(0.035)	(0.036)	(0.043)	(0.017)	(0.020)
$K_{ct}*k_{jt}$		-0.03	-0.04	0.12***	0.04	0.13***	0.08*	0.07***	0.02
		(0.037)	(0.039)	(0.034)	(0.042)	(0.035)	(0.042)	(0.020)	(0.023)
$S_{ct}*s_{jt}$		0.04***	0.04**	-0.01	0.02	0.03	0.03*	0.02*	0.03***
		(0.017)	(0.018)	(0.015)	(0.018)	(0.016)	(0.019)	(0.009)	(0.010)
$Y_{ct}*gl_{jt}$		0.29***	0.26***	0.20***	0.29***	0.24***	0.29***	0.24***	0.28***
		(0.047)	(0.051)	(0.038)	(0.048)	(0.040)	(0.049)	(0.024)	(0.028)
$Y_{ct}*v_{jt}$		0.24***	0.24***	0.36***	0.35***	0.27***	0.26***	0.30***	0.29***
		(0.050)	(0.055)	(0.042)	(0.053)	(0.044)	(0.054)	(0.026)	(0.031)
$I_{ct}*i_{jt}$		0.15***	0.17***	0.10***	0.14***	0.11***	0.11***	0.12***	0.14***
		(0.016)	(0.017)	(0.014)	(0.017)	(0.015)	(0.017)	(0.008)	(0.010)
R^2	0.81	0.81	0.82	0.82	0.82	0.81	0.81	0.81	0.82
Obs. no.	6752	6752	5964	8586	5964	8068	5964	23406	17892

Notes: Results are standardized beta coefficients. Explanatory variables are lagged 5 years. Robust standard errors are in parentheses. Coefficients are significant at 1% (***), 5% (**), or 10% (*). Annual regressions include country and industry fixed effects and panel regressions include country-year and industry-year fixed effects. Regression columns stating "fix" refer to unchanged country-industry samples over time.

TABLE A3
Patent Rights and Export Specialization: Differences by Country R&D Ratios and Income Levels Using Patent Intensities

Dependent variable: log exports of countries by sector

Variable	Panel	Panel (fix)	Panel	Panel (fix)
$PR_{ct}*p_j$	0.18***	0.15***	0.13***	0.10***
	(0.018)	(0.021)	(0.024)	(0.027)
$PR_{ct}*p_j*ML$	-0.02***	-0.03***		
	(0.007)	(0.008)		
$PR_{ct}*p_j*UMI$			-0.03***	-0.04***
			(0.006)	(0.007)
$PR_{ct}*p_j*LI$			-0.03***	-0.03***
			(0.008)	(0.009)
R^2	0.81	0.82	0.81	0.82
Obs. no.	23406	17892	23406	17892

Notes: Results are standardized beta coefficients. Explanatory variables are lagged 5 years. Robust standard errors are in parentheses. Coefficients are significant at 1% (***), 5% (**) or 10% (*). Panel regressions include country-year and industry-year fixed effects, along with all other controls. Regression columns stating “fix” refer to unchanged country-industry samples over time.

The Canadian Journal of Economics
La Revue canadienne d'économique

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Paper title: "Domestic Patent Rights, Access to Technologies, and the Structure of Exports"

Sources of financial support: The Hong Kong Polytechnic University Internal Competitive Research Grant (number A-PK28)

Interested parties that provided financial or in-kind support:
(An interested party is an individual or organization that has a stake in the paper for financial, political or ideological reasons.)

None

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The Canadian Journal of Economics
La Revue canadienne d'économique

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