The Impact of Patent Protection and Financial Development on Industrial R&D

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Abstract

Stronger protection of patent rights is thought to spur innovation through securing returns to R&D investments. Those investments must be financed, however, suggesting that the responsiveness of R&D to patent reforms varies with financial development levels. We examine the joint impact of domestic and international financial-market development and patent protection on R&D intensities in 22 manufacturing industries in 20 OECD countries for the period 1990-2009. We show that stronger patent rights increase R&D intensities in patent-intensive industries, accounting for the need for external financing and the amount of tangible assets. The primary impact varies across types of financial development: patent protection raises R&D in high-patent industries where countries have more limited equity and credit markets. In contrast, in countries with more developed bond markets industry R&D is more sensitive to patent rights. Interestingly, patent rights in countries that are more exposed to foreign direct investment increase R&D intensities at all levels of financial development.

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1. Introduction

Largely under pressure from the United States and the European Union, emerging and developing countries around the world have, in the last 20 years, strengthened their laws protecting intellectual property rights (IPR) to an unprecedented degree (Maskus, 2012; Deere, 2009). Policymakers in most countries proclaim the benefits of patent protection in promoting innovation, while the strength of IPR laws and the volume of patent applications are important components of international rankings of national technological capacity.[1]

Given this confident policy emphasis, it seems surprising that empirical and historical evidence of a positive impact of patent laws on innovation is mixed (Moser, 2013). Cross-country regressions, even those involving industry-level data, fail to find a consistent effect of national patent rights on either patent applications or R&D expenditures (Maskus, 2012). At best, this literature suggests that patent protection is positively correlated with innovation measures in developed economies, with little effect in developing countries except as it affects inward technology transfer (Schneider, 2005; Chen and Puttitanun, 2005; Allred and Park, 2007; Hall, 2014). There is some evidence that patent laws undergird international patenting and R&D in pharmaceuticals in developed countries and in emerging countries where there is a reasonably high degree of education or human capital (Qian, 2007; Kyle and McGahan, 2012).

In this context, the responsiveness of R&D to patent rights (PR) seems to depend on broader economic and industrial characteristics. This idea is unsurprising but little explored in the empirical literature, which simply considers economic development to be a crude determinant of this relationship without unpacking the mechanisms underlying it. One could

[1] See World Bank, *World Technology Indicators*, at http://data.worldbank.org/topic/science-and-technology, the World Intellectual Property Organization, *World Intellectual Property Report*, at http://www.wipo.int/edocs/pubdocs/en/wipo_pub_944_2015.pdf, and World Economic Forum, *Global Competitiveness Report*, at http://reports.weforum.org/global-competitiveness-report-2015-2016.

imagine several such mechanisms, ranging from governance problems and economic uncertainty that discourage R&D investments in developing countries to limited endowments of technical personnel.

Our purpose is to explore carefully one likely determinant of the variability in the patents-innovation relationship across countries and industries, the role of financial development, categorized by several domestic and international measures of finance. Because R&D investments are expensive and uncertain, they generally must be financed. This suggests that the sophistication of various types of financial markets could influence the ability of patent laws to incentivize R&D. To be sure, previous literature has explored the impact of financial development on industry R&D but without drawing a link between such development and legally enforced patent rights (e.g., Maskus, et al., 2012). Thus, we explore the impact of national patent protection on industry-level R&D performance, tying together the importance of IPR and the development of financial markets.

To study this question, we utilize and extend the methodology of Rajan and Zingales (1998), which they applied to determinants of industry output growth, to focus on R&D intensities in manufacturing industries. Our extended specifications allow us to examine how industry expenditures on R&D among OECD economies respond to the protection of intellectual property at the country level. As described below, we interact an index of patent protection, combining both legal rights and the enforcement environment, with a measure of patent intensity at the industry level. Our measure of patent rights is based on that in Hu and Png (2013), whose analysis shows that patent protection is important for ensuring output growth in patent-intensive sectors.

Thus, we extend the basic patents-innovation literature by examining whether stronger patent protection affects R&D intensities at the industry level, conditioned on financial development. The essential argument, which we develop below, is that stronger domestic legal protection of the rights to exploit patents raises the likelihood that firms will be able to appropriate returns to R&D. This factor should apply more forcefully in the most patent-intensive industries, which is where we should observe the greatest increases in R&D effort. Moreover, the extent of this increase could vary across types of financial development because innovation, proxied here by its input measure R&D, displays different sensitivities in this regard. We argue that strengthening PR may be particularly important where financial markets are relatively less developed. Limited financial development correlates with greater inefficiencies in allocating scarce funding resources to productive investments, including for innovation (Hall and Lerner, 2010). By raising the certainty that the exclusive rights to produce and sell innovation outputs (patentable products and processes) can be protected, potential lenders and investors have greater incentives to fund promising R&D projects. While this would be true also in economies with more developed financial systems, the marginal effects are likely weaker given the greater efficiency of capital allocation.

Thus, building on the analysis in Maskus, et al. (2012), which shows that both domestic and international financial market development positively affect R&D intensities, we examine the joint influence of patent protection and financial development. Importantly, we control for two key industry characteristics, the reliance on external finance and the amount of tangible versus intangible assets, and their effects on R&D intensities via financial development. Failure to control for these basic relationships would risk conflating the effects of patent rights with, for example, asset tangibility, which is a critical source of loan collateral. We then estimate how our measure of patent rights, interacted with patent intensities, further determines R&D propensities.

Our analysis offers two primary contributions to the literature on determinants of innovation and R&D investment. First, we deepen the analysis of how enforceable patent laws influence R&D spending, both by distinguishing industries by patent intensities and by controlling for critical channels of potential finance. This approach unearths consistent and robust evidence that stronger patent rights increase R&D in the most patent-intensive sectors among OECD countries.

Second, our main contribution is to examine differences in this relationship at higher versus lower levels of financial development indicators, measuring both the depth of domestic markets and the connection to international markets. Industries in countries with low financial development might show differential R&D responses to the level of patent protection, depending on the types of financial development. For example, patent-sensitive industries in countries with more limited financial development are likely to experience relatively larger increases in access to R&D funding through financial channels, such as equities and bank lending, that feature active investor monitoring aimed at resolving principal-agent problems. This is less likely to emerge in arm's-length financial channels, such as bond financing. We develop this logic in the next section.

Consistent with these ideas, our results indicate that enhanced patent protection tends to have a positive impact on R&D intensity for more patent-intensive industries for observations associated with below-median private credit and stock market capitalization, indicating that IPR may be particularly important when domestic financial markets are less developed. The results are similar for international financial openness as measured by external debt and portfolio equity.

In contrast, a positive relationship between PR and R&D intensities is found at all levels of openness to foreign direct investment (FDI) liabilities. The depth of private bonds markets, on the other hand, shows significantly positive impacts of patents on R&D intensity in relatively patent-intensive sectors only for those observations with above-median financial development. This difference suggests that stronger patent laws induce innovative industries to participate more fully in arm's-length financing only where financial markets are efficient.

The importance of financial development in supporting innovation and economic growth has been widely studied, with the literature pointing, among other factors, to removing credit constraints on firm entry, reducing the misallocation of innovation capital, and establishing contracts that improve monitoring and reduce opportunism (Aghion, et al., 2007; Buera, et al., 2011; de la Fuente and Marin, 1996; Morales, 2003). We aim to add empirical content to one potentially important mechanism, which is that patent protection could interact with financial development in influencing R&D expenditures. Specifically, stronger PR could both incentivize more R&D and, by reducing inefficiencies in innovation financing, expand access to funds to pay for greater investments.

Our analysis is most closely related to Ang and Madsen (2012). They estimated a knowledge-production function, in which the annual number of patent applications by country depends on the existing stock of knowledge, national R&D orientation, and financial development, along with various controls, including legislated patent rights. They found a positive impact of financial development, measured as the ratio of private credit to GDP, on the growth of patent applications. They also discovered a generally negative relationship between national patent protection laws and applications growth, suggesting that stronger PR may deter innovation on average.[2] In an extended specification they considered the interaction between financial development and patent laws, finding no effect.

In our view, this approach to studying the joint impacts of patents and financial sophistication is unduly limited for several reasons. First, patent applications are a partial and noisy measure of innovation because not all ideas are patented and most applications cover elements that fail to achieve a market. Second, patent applications are an outcome of R&D, which is the variable presumed to be stimulated by financial development. Third, as noted below, the basic measure of patent laws used by Ang and Madsen (2012) fails to account for the enforceability of rights, which can be misleading.

Fourth, focusing on cross-country patent applications fails to account for the wide differences in the dependence of industrial sectors on access to finance for engaging in R&D (Rajan and Zingales, 1998; Maskus, et al., 2012). Put differently, aggregate country regressions may mask significant – and informative -- influences for individual industries. A final observation is that it is important to study the possibility that different forms of financial development matter for R&D. For example, Hall and Lerner (2010) and Kerr and Nanda (2015) discuss the broad literature on the financing of innovation, describing the role that various forms of external equity and credit markets may play. These last two concerns are the most fundamental and the ones at which we aim our research. Thus, our approach is to estimate the separate and joint influences of financial development in various manifestations and enforceable patent rights on industry-level R&D intensities, which should offer a more comprehensive picture of the underlying processes.

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[2] There is a large and diverse literature on this point, with no real consensus emerging from empirical studies. See Moser (2013) and Maskus (2012) for reviews.

In the next section we develop our main argument and the empirical hypotheses it supports. In Section 3 we set out the econometric methodology and describe our data, while we discuss the results in Section 4. We report the results of several robustness checks of our benchmark specification in Section 5. We offer concluding remarks in Section 6.

2. Theoretical framework and empirical hypotheses

We study the joint impacts of patent protection and various modes of financial market development on R&D intensity in industries that differ in three key characteristics. First, firms in different industries register patents with varying intensity. Second, industries depend on external finance for their investments to differing degrees. Finally, industries are characterized by varying proportions of tangible assets in their overall balance sheets. Measuring these differences at the industry level allows us to focus on our main hypothesis. Specifically, greater patent protection should be associated with greater R&D in industries that rely more heavily on patents, and this relationship should vary with levels of national financial development.

In our regression analysis we allow financial markets to affect R&D intensities for those industries that rely more on external finance or have less tangible assets. Conditioned on these variables, we analyse the second part of the hypothesis by exploring how measures of financial development may affect the relationship between patent protection and R&D by examining those observations above or below the median for each such measure. Domestic financial conditions include private credit, stock-market capitalization, and bond-market capitalization, while international financial conditions include external debt, portfolio equity, and FDI. Each of these indicators is measured in relative terms at the national level by dividing the financial variable by GDP.

Before offering a simple theory and developing statistical hypotheses, we discuss the concept of financial development and how each of our measures relates to it. In the innovation literature, limited financial development is associated with the inefficiency of resource allocation for investment (see, for example, Hall and Lerner, 2010; Kerr and Nanda, 2015; and Brown, et al, 2012). Investments in R&D are particularly subject to inefficiency, resulting in potential constraints on financing projects, because they inherently feature asymmetric information and moral hazard problems.

Information asymmetries arise from the fact that an inventive firm has better information about the characteristics of its R&D program, and the likelihood that its expenditures will generate successful outcomes, than do potential investors. It follows that external investors will demand a premium for R&D projects, relative to ordinary capital investments, because they cannot readily distinguish between good and bad projects.[3] This issue is particularly acute in R&D, given the longer-term and uncertain nature of such projects. Moreover, attempts to resolve this problem through greater disclosure requirements within funding contracts can be ineffective because of the appropriability problem inherent in the knowledge products generated by R&D expenditures. Firms may be reluctant to reveal much about the ideas they are developing for fear that competitors would copy them or engage in competitive innovation (Bhattacharya and Ritter, 1983).

Two implications follow immediately. First, firms seeking finance for R&D likely face higher costs of external capital than internal capital, reflecting an uncertainty premium on the former. Moreover, evidence suggests that investors supplying arm's-length finance demand even higher returns to compensate them for R&D uncertainty (Hall and Lerner, 2010). Second,

[3] Hall and Lerner (2010) compare this to the familiar lemons problem in markets with uncertain quality, as analyzed by Akerlof (1970).

this problem is mitigated in environments with better appropriability, which typically means stronger patent rights. Indeed, one of the major functions of patents is to encourage post-invention public disclosure through patent applications. However, enhanced appropriability, whether through stronger patents or better-enforced trade secrets, should also encourage more ex ante revelation by inventors to potential funders, where there is a contractual relationship between them (e.g., with bank lending). In this context, PR facilitate contracting that can both encourage R&D and market entry of new products, building markets for technology, as emphasized by Arora, et al (2001). In addition, there is an increasing tendency for banks to lend funds for R&D, while accepting patents as collateral (Mann, 2017). Most significantly, Chava, et al (2017) find evidence that firms with significant patenting success and higher-quality patents receive cheaper bank loans than otherwise similar firms. These authors argue that enhanced patent rights make intellectual property more certain and increase lenders' control rights, reducing the cost of innovation finance.

Moral hazard exists in R&D investments because of the separation of ownership (investors) from managers (those investing in R&D), generating principal-agent problems when goals are inconsistent. Particularly relevant in this context is the tendency of risk-averse managers to invest too little in uncertain and longer-term R&D projects when, for example, shareholders and institutional owners might prefer more risk (Hall and Lerner, 2010; Ang and Madsen, 2012).

Typically, two solutions are advanced to address these problems. First is to write contracts that shift management behavior in directions that are more congruent with ownership preferences and to deter short-term opportunism. It is evident that the ability to do so depends on the effectiveness of contract enforcement. Second is to increase the willingness of investors to engage in effective monitoring of managers as they perform R&D. In this context, bank lending and equity financing (particularly if there is more concentrated share ownership, as occurs with institutional investors) are more likely to support efforts in upfront diligence and within-term monitoring than are bond markets. For example, evidence suggests that firms with highly diffuse ownership are less innovative, implying that monitoring reduces moral hazard of this type and encourages investment in innovation (Francis and Smith, 1995).

We summarize and illustrate this theoretical review in Figures 1A and 1B, which are heuristic demonstrations of its primary points about patent rights and the extent and sources of financial development.[4] The first diagram pertains to a country in which financial markets are highly developed and information difficulties do not constrain the ability of firms to access funds. This is depicted by firms facing a horizontal supply-of-funds schedule, which permits them to gain external funds at the same marginal cost as internal funds, c^0. Figure 1A also depicts two firm types, one with low patent intensity (LP) and one with high patent intensity (HP). Both are financially unconstrained and their R&D programs are at points A and C, respectively.[5]

The second diagram relates to a country where financial markets are less developed and information problems generate inefficiency, as reflected by firms facing upward-sloping supply-of-funds curves, causing patent-intensive innovative firms to observe an external cost of funds exceeding their internal costs. Indeed, if patent-intensive firms have greater R&D demand they are likely to face a higher marginal external cost, given the increased information asymmetries

[4] These figures are adapted from Hall and Lerner (2010).
[5] We show the patent-intensive firm's R&D demand curve exceeding that of the low-patent firm, which is reasonable if the firms are of similar size. What matters for our analysis, however, is that the former firm's demand for R&D shifts further in response to a strengthening of patent rights, as discussed below.

about invention potential and monitoring difficulties arising from intangibility and effort.[6] Thus, we depict the low-patent firms to be relatively unconstrained regarding R&D finance, but patent-intensive firms to be constrained. Again, initial R&D programs are illustrated at points A and C.

Now suppose these countries choose to strengthen their legal and enforceable patent rights, which we consider to be our policy shock. The earlier analysis suggests that the shock would have the following effects. First, given the evidence reviewed above, stronger PR may have limited direct impacts on R&D in low-patent sectors. Indeed, the effects could be negative if more rigorous exclusive rights raise the cost of inventing around patents or acquiring know-how (Maskus, 2012). However, stronger PR should raise R&D expenditures in the most patent-intensive sectors, such as pharmaceuticals and industrial chemicals. We depict this idea through an outward shift in the R&D demand curves for patent-intensive firms in Figures 1A and 1B.

This standard claim, that stronger patent protection should induce more innovation among high-patent sectors, underlies nearly all prior empirical analysis of patent laws and R&D. However, it ignores the potential impacts of patent rights on the availability of funds. Thus, a second effect is that, by virtue of raising appropriability, stronger PR can diminish the reluctance of inventive firms to reveal private information about their R&D programs to potential investors, presumably increasing the willingness of banks and shareholders to extend financing.[7] Moreover, greater certainty about patent ownership and the potential for collateralization reduce the costs of external finance, at least through such direct relationships as bank credit, equity, and

[6] For purposes of illustration we do not directly depict the possibility that some firms may be more dependent than others on external financing, or may have relatively more tangible assets. In the estimation approach we incorporate these controls and industry fixed effects to capture such differences.

[7] Better protection of patent rights may also facilitate firms applying for patents, which has been shown to provide a signal of innovation that attenuates financing constraints (Conti, et al., 2013; Hottenrott, et al., 2016).

venture capital. Finally, improved contract enforcement can enhance incentives for monitoring innovative effort, raising R&D.

These arguments imply that the strengthening of patent rights not only expands R&D demand among higher-patenting firms, it effectively increases the supply of external finance coming from banks and direct investors. We show this as an outward shift in the supply curves in Figures 1A and 1B, resulting in an expansion of R&D in patent-sensitive sectors from point C to point D in each diagram, with a relatively larger gain in the constrained case.

The key insights are as follows. First, stronger patent laws do not necessarily increase R&D spending on average across all industries, though they should expand such investments in patent-intensive sectors. Second, the relative increase in R&D in patent-intensive industries compared to other sectors should be larger where markets involving direct financing relationships are less well developed, because PR contribute to the amelioration of information problems and moral hazard. Put differently, the increasing availability of financing to higher-patent sectors complements the direct increase in R&D incentives in markets with lower financial development by more than it does in markets with higher financial development. This effect should be more pronounced where financing involves bank lending and equity investments.

In contrast, bond financing would not be facilitated in the same manner, because it is arm's-length in nature, removing any incentives that PR might otherwise create for lenders to raise monitoring or borrowers to be more forthcoming about potential success. Thus, in the financially constrained markets of Figure 1B, there would be no induced expansion of the supply curve and the increase in R&D would be muted, rising from point C to point E. It follows that bond-financed R&D is likely to be more responsive to patent rights in countries with more fully developed markets.

We take these ideas to our econometric work by specifying the following testable hypotheses.

Hypothesis One: The direct coefficient of PR on R&D in the control sectors (those with lower patent intensities) could be positive or negative.

Hypothesis Two: The coefficient on an interaction term between patent rights and industry patent intensities should be positive in all markets.

Hypothesis Three: That same interaction coefficient should be more significant in markets with relatively low financial development, where the sources of finance involve direct lending or ownership relationships, but more significant with respect to bonds in countries with high financial development.

The third hypothesis stems from our argument that stronger and better enforced patent laws should expand the availability of financing in R&D programs, where success is uncertain and financing is subject to information failures. To our knowledge, this claim is novel in the literature and our econometric approach aims to shed light on it.

3. Econometric methodology and data

Our econometric methodology relates R&D intensities to various country-industry interactions. It builds on the influential work of Rajan and Zingales (1998) and is similar in nature to that in Maskus, et al. (2012), who interact industry variables (external financial dependence and asset tangibility) with several country variables capturing the degree of financial market development to examine the impact of R&D intensities across countries and time.[8] Our contribution here is to consider also the impact of the interaction of industry patent intensity and national patent protection on R&D propensities.

In this context, we include three industry characteristics in our regression analysis. The first is industry patent intensity, measured as the number of U.S. patents awarded to an industry relative to total industry sales in the United States, a variable developed by Hu and Png (2013). Patent intensity forms a regressor of critical interest for the analysis. The second is external financial dependence, which captures the industry's ability to generate cash flow sufficient to finance investment projects, such as R&D. We adopt the Rajan and Zingales (1998) definition of dependence and use the statistical measure in Maskus, et al. (2012). The third characteristic is asset tangibility, which measures the amount of tangible assets (such as equipment and plants) in an industry. Such assets may serve as collateral, allowing easier access to credit. External dependence and tangibility are considered in the literature to be industry characteristics that are largely external to the firm. It is important to include them in our analysis because they directly influence the relationships between R&D programs and financial markets. Thus, failing to include them would risk a significant omitted variable bias.

We regress R&D intensity on these interaction terms, the industry share in GDP, and a set of country, industry, and year dummies. The model we estimate is

$$R\&D\ intensity_{j,k,t} = \beta_0 + \beta_1\left(patent\ intensity_k * patent\ protection_{j,t}\right) +$$

$$\beta_2\left(external\ financial\ dependence_k * financial\ market\ development_{j,t}\right) +$$

[8] Related applications of the Rajan and Zingales (1998) approach to study different aspects of financial development within heterogeneous industries or firms include Claessens and Laeven (2003) who focus on property rights and growth, and Carlin and Mayer (2003) who study differential effects on growth, physical investment, and R&D investment. Seitz and Watzinger (2017) also include measures of financial development and tangibility in their study examining the combined impact of contract dependency and the rule of law on R&D investment.

$$\beta_3(tangibility_k * financial\ market\ development_{j,t}) +$$

$$\beta_4(industry\ share_{j,k,t}) + \beta_5(patent\ protection_{j,t}) +$$

$$\beta_6(financial\ market\ development_{j,t}) + \eta_j + \eta_k + \eta_t + \varepsilon_{j,k,t} \qquad (1)$$

where *j* denotes country, *k* denotes industry, *t* is the year index, and $\varepsilon_{j,k,t}$ describes the error term. We include the direct effect of financial development and the patent protection indicators separately. While these effects are partially captured by the country and time fixed effects, we include them here for completeness. Alternative estimations excluding these variables register very similar coefficients on the interaction terms. Note that we do not include the patent intensity, external financial dependence, or tangibility measures individually since their measures are time-invariant and country-invariant and therefore captured by the industry fixed effects.

The country indicator η_j captures country characteristics that are time invariant. The year dummies capture all effects that countries and industries face in common, such as global booms and busts and international trade liberalization. Industry output shares are included to control for different production mixes, arising from comparative advantage, across countries (Maskus, et al., 2012). Identification of β_2 and β_3 results from variation across countries and time of the financial development indicators and variation across industries in external financial dependence and asset tangibility. Consistent with Maskus, et al. (2012), we expect β_2 to be positive and $\beta_3$to be negative.

To restate our central hypotheses, we have no expectations about the sign of β_5, the direct coefficient of national patent rights (Hypothesis One). Our main focus is on β_1, the interaction between patent intensity and patent protection, which we expect to have a positive impact on R&D intensities (Hypothesis Two). Finally, when we split the sample based on financial development, we anticipate that β_1 will be positive for observations below the median when the financial measure relates to direct lending or ownership relationships, such as bank lending, stock-market capitalization, and international portfolio equity liabilities (Hypothesis Three).

Turning to data, we calculate R&D intensities as total industry R&D expenditures, relative to industry output, for 22 manufacturing industries in 20 countries from 1990 to 2009.[9] Data on R&D expenditures comes from the OECD's Analytical Business Enterprise and Research (ANBERD) database, ISIC Revision 3.1, with our industries defined at the two-digit level. Industrial research and development is defined as R&D activities carried out in the business enterprise sector, regardless of the origin of funding. Industry production (gross output at current prices) is from the OECD's STAN database, ISIC Rev. 3.1. Industry share in GDP is computed as industry production divided by GDP, taken from the World Bank's *World Development Indicators* (2013).

While R&D intensities and industry shares vary across countries, industries, and time, the rest of our explanatory variables fall into two general categories. The first category contains country-level measures that vary across time but not across industries. They include the measures of domestic and international financial development studied in Maskus, et al. (2012). We update these variables to our sample period using the World Bank's *Financial Development and Structure Dataset 2013* and the figures in Lane and Milesi-Ferretti (2007) *Updated and Extended External Wealth of Nations Dataset 1970-2011*. All financial-development indicators are expressed relative to GDP.

We use a variety of measures that capture the size of domestic financial markets, including private credit by deposit money banks, stock-market capitalization, and private bond-market capitalization. The first indicator, private credit, measures credit issued to the private

[9] Using R&D expenditures as a share of value added provides similar results. Further, implementing a log transformation of the R&D measure as the dependent variable also provides similar results.

sector by banks. To capture the size of the stock market, we use each country's stock-market capitalization, which equals the value of listed shares. Similarly, for the bond market, we use bond-market capitalization, which equals the amount of outstanding domestic debt securities issued by private entities.

To describe international financial development we use the components of a measure of *de facto* (as opposed to *de jure*) international financial integration, focusing on external liabilities relative to GDP (Lane and Milesi-Ferretti, 2007). While international financial market integration is often captured by a broad measure that includes the sum of both external assets and external liabilities, we use just the external liability measures here. These components consist of the accumulated capital inflows to a country, corresponding to access to international financing. The individual components consist of portfolio equity, FDI equity, and external (foreign) debt. Portfolio equity liabilities measure foreign ownership shares of domestic firms and mutual funds, where ownership is below 10 percent. FDI measures international ownership shares of domestic firms, greenfield investment, and property investment, where the controlling stake is above the 10% ownership threshold. The international debt category consists of portfolio debt securities, bank loans and deposits, and other debt instruments.

Our primary focus is on the role of the protection of intellectual property rights in determining R&D. For this purpose, we adopt the country-level patent protection variable from Hu and Png (2013). We construct this index, denoted as PR to indicate patent rights, as the following product:

$$PR = GP * FI \tag{2}$$

Here, GP is the index of national patent laws developed by Ginarte and Park (1997) and Park (2008). The GP index is the unweighted sum of five categories of patent laws, with each component scored from 0 to 1.[10] Higher levels of the index indicate that a country has adopted more stringent patent protection in various dimensions (Ginarte and Park, 1997). However, Hu and Png (2013) point out that the GP index itself does not reflect the actual enforcement of patents and propose the multiplied index to account for *effectively enforced* patent rights.[11] In this context, FI is the Fraser Institute's index of the independence and depth of the legal system and the enforcement of property rights and contracts. This index is derived from the *International Country Risk Guide's* survey of business executives and includes three categories: legal security of private ownership rights, viability of contracts, and the rule of law (Gwartney and Lawson, 2001). Because the GP index is computed only every fifth year between 1960 and 2010, we hold the PR measure constant between estimation periods to preserve the maximum number of observations.[12]

The second category of explanatory variables includes industry characteristics, calculated from U.S. data, which do not vary across countries or time. We include characteristics from Maskus, et al. (2012), namely external financial dependence and tangibility. The measure for each industry's external financial dependence comes from Klapper, et al. (2006) and follows the definition in Rajan and Zingales (1998). This measure is calculated with figures for U.S. companies over 1990-1999 using Standard and Poor's Compustat database. A firm's external dependence is defined as the ratio of capital expenditures less cash flow from operations over capital expenditures. The value for the median firm in each industry is taken as the industry value. Firms with higher cash flow are able to use internal funds to finance capital expenditures,

[10] The five categories of patent laws are extent of coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms, and duration of protection (Ginarte and Park, 1997).
[11] Maskus and Yang (2018) use this formulation to study the impact of patent rights on the sectoral distribution of exports across countries.
[12] Using linear interpolation to replace missing observations between observation years does not significantly change the results.

including R&D, and are thus likely to be less dependent on external finance. The data from Compustat are calculated at the four-digit SIC level and then converted to the two-digit ISIC (Rev. 3.1) codes to match the R&D data.

A firm's asset tangibility is defined as net property, plant, and equipment relative to the total book value of assets and is calculated by Maskus, et al. (2012) (following Braun 2005) using U.S. data from Compustat over 1990-1999. Tangibility is a proxy for each industry's share of physical assets in total capital stock. Again, the value for the median firm in each industry is taken as the industry value. The original data are on the four-digit SIC level and are then reclassified to match the two-digit ISIC codes.

One central question this paper aims to answer is whether more patent-intensive industries invest relatively more in R&D in countries with stronger patent protection, while accounting for the importance of financing for innovation. To measure industry-level patent intensity, we use the measure from Hu and Png (2013), which utilizes the number of patents awarded to an industry, relative to total industry sales, for the United States. The number of patents is drawn from the NBER Patent Database (Hall, et al., 2001), integrated with sales data from Compustat, and averaged from 1979 to 2000. For synchronization with our two-digit ISIC (Rev. 3.1) R&D-intensity data, we convert the patent-intensity measure from three-digit to two-digit ISIC groups by taking the average patent intensity within three-digit subgroups. Table 1A shows the three industry characteristics, along with average R&D intensity, for each industry (ranked by average patent intensity). Tables 1B and 1C provide overall summary statistics and correlations among the variables, respectively.[13]

[13] Further details on data construction and sources are in Table 1D.

Following Rajan and Zingales (1998), we assume that financial dependence, tangibility, and patent intensity are characteristics that represent inherent technological differences across industries that do not differ across countries or time. For example, it may be that actual levels of industry patent intensity differ numerically across the world. However, our less stringent assumption is that the ranking of *relative* patent intensities across industries is the same in all countries.[14] This assumption motivates the use of U.S. data to create an accurate ranking of industries based on the three characteristics identified above. Interacting these industry characteristics with country-level variables allows identification of the response of industry-level R&D intensities to the joint variation in country measures and associated industry values.

An evident concern with our specification is the potential for reverse causality from the industry-level R&D intensities to the country characteristics, particularly the patent protection variable. This is a relevant concern if those industries that invest relatively more in R&D are able to lobby for greater patent protection at the country level. This problem could be even more worrisome if we used patent intensities measured for each country in the relevant interaction term. In that case, both the national and industry characteristics might be influenced by the proportion of R&D expenditures in each industry.

We believe that this concern, while valid, is sufficiently mitigated in our approach. First, because we use aggregated U.S. firm-level data to rank industry patent intensities, the likelihood that industry R&D investments in other countries would affect this ranking is considerably reduced. Second, the national patent protection variable is constructed by using both the GP and FI components. Even if the patent laws (captured by GP) were influenced by industry lobbying,

[14] This assumption is standard in international trade and widely used in that literature to study country-industry interaction effects in explaining trade. See, for example, Nunn (2007), Levchenko (2007), and Maskus and Yang (2018).

the general enforcement of contracts and the rule of law (captured by FI) is far less likely to be driven by industry R&D expenditures. Such components of the Fraser Institute index are typically seen as country institutional variables that may be slow to change and are not likely to be affected directly by industry activity. Third, the fact that our PR variable is computed at the beginning of each time period and applied for the following five years also should mitigate concerns about reverse causality. This timing effectively makes PR pre-determined and precludes any contemporaneous impacts of R&D expenditures on the policy variable.[15]

Note that we exclude the United States from the regression analysis because we take data from publicly listed firms there to calculate the financial dependence and tangibility measures and the patent intensity per industry. This leaves 20 countries in the panel, including Belgium, Canada, Czech Republic, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, the Republic of Korea, Mexico, Netherlands, Norway, Poland, Portugal, Spain, and the United Kingdom. Note that there are emerging countries in the data, such as Hungary, Poland, Korea, and Mexico, which might be expected to have more limited financial development. However, there are no developing economies, implying that we do not incorporate cases with potentially quite restricted financial development.

The OECD R&D expenditure data by industry for ISIC Rev 3.1 are available for years 1987-2010, although there are many missing values for 2010. Further, there were numerous missing observations for earlier years in the financial structure database. Thus, we restrict our analysis to the period 1990-2009. Finally, we focus on the set of 22 manufacturing industries

[15] Robustness checks using the lagged value of PR produce similar results to those presented here. For this purpose we use PR from the prior 5-year period in place of its current value (e.g., we use the 1995 value for 2000-2004, and correspondingly for other periods). The coefficients on the patent-rights interaction variable remain similar in size, sign, and significance as those reported in Tables 2 and 3 below.

because the few service industries for which data are available have very different values of financial dependence and tangibility in comparison with the manufacturing data.[16]

4. Results

We focus on our hypotheses regarding relationships between patent protection and R&D intensities, across a variety of financial development variables measured at the national level. Importantly, we study how this relationship differs for observations where different types of financial markets are more or less well developed. We use the median value of the financial market development variables to split the sample.

We report results using standard errors clustered at the country level. Studies that apply the Rajan and Zingales (1998) method to analyze country-industry panel data differ with respect to their choice of standard errors. Maskus, et al. (2012) and Hu and Png (2013) report results with robust standard errors, while Igan, et al. (2016) report standard errors clustered at the country-industry level and Seitz and Watzinger (2017) do so at the country level. Because the inclusion of country, industry, and time fixed effects may not fully control for within-cluster error correlation, we take a conservative approach by clustering at the country level, the highest degree of aggregation.[17]

4.1. Patent protection and R&D activity

Table 2 reports baseline results for specification (1) using the domestic financial development variables (private credit, stock-market capitalization, and private bond-market capitalization, all relative to GDP). Table 3 lists outcomes for the international financial

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[16] Manufacturing industry ISIC Rev. 3.1 code 37 (recycling) is not included because there is not a direct concordance between the SIC industry classification (for the U.S. data used to calculate the tangibility and external financial dependence measures) and the ISIC Rev. 3.1 industry classification (for the R&D expenditures).
[17] This approach is advocated by Cameron and Miller (2015).

integration measures (FDI equity, external debt, and portfolio equity, also scaled by GDP). In both tables, the first column for each financial development variable indicates the effects across the full sample. The main variable of interest is the interaction between the effective extent of patent rights (PR) and patent intensity. As described above, we also interact the measures of domestic financial development or international financial market integration with both the external financial dependence and tangibility variables.

In the full-sample regressions, we find that the direct impact of PR is essentially zero in all cases. This result is consistent with Hypothesis One, reflecting the idea that patent protection has cross-cutting effects on innovation investments, with any stimulus to invention by the average firm being largely offset by costs raised against imitators. By contrast, the coefficients on the interaction between patent intensity and patent protection are uniformly significant and positive, while consistent across financial development measures at 0.05 to 0.06.[18] Thus, while the effect of PR in lower-patent sectors is insignificant, it becomes positive at higher patent-intensities across all types of financial development. This finding is robust to including the levels of various forms of domestic and international financial development. Thus, more patent-intensive industries have higher R&D intensities in countries with stronger patent rights. This result confirms Hypothesis Two, that better patent protection, and enforcement of such protection, has a positive impact on investments in innovation among high-patent industries.

4.2. Patent protection and R&D activity at various levels of financial development

Tables 2 and 3 also report the relationship between R&D intensity and PR when considering high or low values of the different forms of financial development. In particular, the second and third columns for each measure of financial development show the effects when we

[18] We comment on the economic significance of such results below.

split the observations into those above and below its median level. For example, considering private credit, the first column of Table 2 shows the effects for the full sample and the second and third columns list those for observations above and below the median, respectively. This exercise is then repeated across the other indicators, as noted in Tables 2 and 3.

Generally, the measures of private credit, stock market capitalization, external debt and external portfolio equity liabilities provide similar results.[19] In countries that are below the median of financial development for these measures there is evidence that the interaction between the national patent policy and industry patent intensity has a significantly positive impact on R&D intensities. This finding indicates that for countries with more limited financial development, measured in these dimensions, patent protection is important in facilitating R&D investments in those industries using patents more intensively. Because these measures all relate to various forms of direct lending or ownership, the findings are consistent with Hypothesis Three. In terms of the simple theory in Figure 1B, the response seems to be particularly sensitive in countries where financial markets are less developed and, presumably, more prone to information-based inefficiencies. In addition, as countries with relatively limited financial development strengthen their patent laws, patent grants may be more likely to serve as collateral in securing loans, as analysed in Mann (2017) or Amable, et al. (2010).

In contrast, patent rights appear to have little impact in inducing greater R&D investments in patent-intensive sectors in countries with more developed financial markets, as suggested by the insignificant coefficients on the patent-interaction variable. Thus, the prospect

[19] An alternative measure of the depth of financial markets, liquid liabilities relative to GDP, provides similar results to those for the private credit variable. Liquid liabilities consist of currency plus demand deposits and interest-bearing liabilities of banks and other financial intermediaries. Alternative international financial measures, using the sum of external assets and external liabilities for each component, provide similar results to those presented here.

of gaining patents may be less important in markets where R&D may be efficiently financed otherwise, as suggested in Figure 1A.

Private bond markets seem to work differently, however, in that countries with above-median bond market development show significantly positive impacts of patent rights on R&D intensity in relatively patent-intensive sectors. Those observations with below-median values of private bonds have an insignificant patent interaction. Consistent with our hypotheses, arm's-length financing seems relatively unresponsive to patent laws where bond markets are limited, leaving a relatively larger effect on R&D investments in high-patenting industries where those markets are fully developed. Because patent values may be recoverable in bankruptcies, for example, arm's-length debt becomes more prevalent in highly developed markets.

It is interesting to note that the depth of foreign direct investment operates to complement patent rights in all markets. Specifically, we find a positive impact of patent protection on R&D intensities at all levels of FDI engagement. This suggests that greater reliance on FDI for investment purposes reinforces patent rights for all countries and enhances the ability of patent rights to induce relatively more R&D in high-patent sectors. This is a novel finding in the literature and suggests that additional research on such joint effects would be of interest.

For each of the regressions shown in Tables 2 and 3, we also estimate the model shown in specification (1) using Seemingly Unrelated Estimation with the "suest" command in Stata. This approach is appropriate for use with clustering on the standard errors and allows us to compare coefficients across the two subsamples. We report the results of the Chow test with the corresponding $\chi 2$ value at the bottom of Tables 2 and 3. In all cases, we reject the null that the data can be better represented by a single equation, thus indicating that the blocks of coefficients on each subsample are statistically different from one another.[20]

Although the focus of this paper is how the interaction of patent protection and patent intensity affects R&D, our results also unearth certain nuances regarding financial dependence and tangibility. Based on prior work by Maskus, et al. (2012), we expect the coefficients of the other interaction terms, β_2 and β_3, to be positive and negative, respectively. The logic is that industries that are more dependent on external financing will innovate more in countries that are more financially developed. Similarly, industries that have fewer tangible assets, and therefore more limited collateral, will benefit from being in a country with more developed financial markets. However, in many of the specifications in Tables 2 and 3, these coefficients are either statistically insignificant or, in a few cases, have the incorrect sign.

To investigate this result further, we remove our main variable of interest, PR*(patent intensity), to consider the original specification in Maskus, et al. (2012). When this interaction is omitted, β_2 and β_3 become statistically significant, with correct signs, for all of the full- sample specifications with domestic financial development, except for stock market capitalization (where β_3 is insignificant).[21] This may indicate the importance of the patent interaction as an omitted variable in prior work or may suggest an unexplored relationship between the three interaction terms. Indeed, financial dependence and patent intensity have a small positive correlation coefficient (0.31), while tangibility and patent intensity have a negative correlation

[20] We also conducted the analysis using a triple interaction between PR, patent intensity, and the financial development variable in each case (see appendix tables A2 and A3). The results indicate the same conclusions as those highlighted by the above-median and below-median samples. The split-sample approach offers a cleaner exposition of the results. Our results for the above-median and below-median financial development variables are akin to those in Seitz and Watzinger (2017). They show that the interaction between contract dependence (as an industry characteristic) and intellectual property rights is a significant predictor of R&D intensities for those industries with relatively many inputs versus those with relatively few inputs.

[21] Results are available on request.

coefficient (-0.34). Intuitively, patent-intensive industries may be more likely to rely on external financing for R&D investment. They may also have fewer tangible assets, rendering granted patents an alternative potential source of collateral.[22] It is interesting to note, however, that there is no clear pattern between the financial development measures and PR. Appendix Table A1 shows averages by country (across time) for patent rights and each of the financial development variables.

While the coefficients on financial dependence and asset tangibility are sensitive to the inclusion of the interaction on PR and patent intensities, we note that the reverse is not true. Regressions excluding these characteristics do not change our primary results showing that patent-intensive sectors have higher R&D shares in countries with stronger PR, with the effects depending on the levels and types of financial development.[23]

4.3. Magnitudes of response

We next offer some analysis of the economic size of the effects indicated by the coefficients in Tables 2 and 3. The coefficient estimates are not directly comparable across the different regressions. Thus, in Table 4, we calculate implied magnitudes, where the first line in each case illustrates the change in R&D intensity associated with a one standard deviation increase in the patent protection index (PR).[24] For example, using the overall average patent intensity of 0.017, an increase in PR by one standard deviation (7.862) contributes positively to R&D intensity by 0.0491*0.01703*7.862*100 = 0.657 percentage points when the full-sample coefficient (0.0491) in the private credit case is used.

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[22] We also conduct this exercise for the international financial variables. However, β_2 and β_3 remain insignificant for the full sample. This is consistent with Maskus, et al. (2012), who find limited evidence of international capital markets as a determinant of industrial R&D except for FDI.

[23] Results are available on request.

[24] Our computations are based on estimated coefficients that are significant from Tables 2 and 3, using the calculation method from Hu and Png (2013).

Put in the context of the average R&D intensity (1.7 percentage points) across all countries, industries, and time, the impacts in Table 4 are substantial in economic terms. To provide further context, consider moving an average R&D-intensity industry (e.g., machinery and equipment) from a median-PR country (e.g., Italy) to a high-PR country (e.g., Germany). This exercise suggests an increase of about 0.7 percentage points in R&D intensity, raising it to 2.4 percent.

The second line in each case in Table 4 takes into account the direct effect of the PR variable. For example, for those observations below the median level of private credit, PR carries a negative and significant coefficient. Thus, the impact of an increase in PR by one standard deviation contributes positively to R&D intensity by (0.0467962*0.01703+(-0.0006553))*7.862*100 = 0.111 percentage points. The inclusion of PR moderates the overall impact because it has a direct negative effect on R&D intensity. Note, however, that the PR term on its own is not consistently significant. Thus, the bold coefficients in Table 4 indicate those estimates where only the significant coefficients are used in the calculation.

For the domestic financial development variables, the response of R&D intensities for those observations below the median are positive and vary between 0.10 and 0.20 percentage points. When international financial development is measured by debt or portfolio equity liabilities, the calculated response of R&D intensities for those observations below the median vary between 0.03 and 0.10 percentage points, indicating that the direct negative impact of PR moderates the positive impact from the interaction of PR and patent intensity. When international financial development is measured by FDI, however, the impact is a positive 0.586 percentage points. The impact of bond-market development is larger than the others, with R&D intensities increasing by 1.145 percentage points in response to better patent protection for those industries that rely more on patents when bond markets are more fully developed. This may indicate the unique role of arm's-length bond financing for innovation.

We also may use the estimated total coefficients to get a sense of how PR affects R&D shares for industries of different patent intensities. Thus, the second pair of rows in each case compute the total effects for an industry at the 25th percentile of patent intensity with that at the 75th percentile. As may be seen, some of the estimates for the 25th percentile are negative and some are positive, suggesting an ambiguous impact. However, in all cases the estimates at the 75th percentile are significantly positive and considerably larger than those for the lower paten-intensity group. These findings are consistent with our Hypotheses 1 and 2.

Overall, these economic magnitudes underscore the heterogeneous impacts of various forms of financial market development on R&D investments, accounting for patent protection.

5. Sensitivity analysis and robustness

The various categories of domestic and international financial development provide nuanced insights into the responsiveness of R&D to better patent protection. However, it is also interesting to consider the implications of generalized financial development, which we study by constructing a summary measure based on principal-component analysis. We generate the first principal component for the domestic financial development variables and for the international financial development variables separately. For the domestic group, the weighting is fairly evenly spread across private credit, stock market capitalization, and private bond market capitalization. The first principal component explains about 70% of the within-group variation. For the international group, the weighting is fairly evenly spread across FDI, portfolio equity, and debt, while the first principal component explains about 69% of the relevant variation.

The results are presented in Table 5. As may be seen, using principal components delivers similar outcomes to those in Tables 2 and 3. The interaction between patent intensity and patent protection is positive and significant for the overall sample and for those observations where the principal component (PC1) is below the median value. These results hold for both the domestic and international financial development principal components. The principal component of financial development in each case shows that the protection of patent rights for industries that depend relatively more on patents is particularly important at lower levels of financial development. However, this aggregation masks the distinctive results found above for private bond market capitalization and FDI liabilities.

Next, there may be a concern that our results simply pick up differences in national income levels, which likely correlate with financial development. Thus, to control for the effects of country-income differences we include the log of real GDP per capita in the regressions as an additional explanatory variable. The results are in Tables 6 and 7. In most cases, the coefficients on income are not significant and its inclusion does not change the results for the patent interaction. Even where it is significant, as is the case for external debt, adding income does not change the findings on the patent interaction.

We also consider the sensitivity of our results to potential outliers. Note in Table 1B that sectoral R&D intensities have a mean value of 0.017 across countries, albeit with a high dispersion. In fact, the two highest values of R&D intensity (at 1.669 and 1.190) are both for Greece, which seems anomalous. Dropping the higher value but otherwise retaining Greece in the sample has no effect on the results. Further, dropping Greece from the sample altogether delivers results highly similar to those in the full sample for the interaction between patent intensity and the protection of patent rights.[25] Specifically, our primary results remain quite robust when using private credit, stock market capitalization, FDI, or external debt liabilities. One difference emerges, however. When financial development is measured by private bonds or portfolio equity liabilities, the results for both the above-median and below-median financial development samples have significantly positive interaction terms Note that this result for private bonds remains consistent with our arguments because the coefficient on the interaction term for the above-median sample is larger than that for the below median sample, affirming the relatively greater effect in the former.

Finally, previous literature on financing of R&D has indicated the importance of venture capital as a source of funds that may mitigate information problems or provide opportunities for monitoring of firm behavior (Hall and Lerner, 2010). Thus, we explore venture capital as an alternative financial development indicator, using a measure computed from data taken from Thomson-Reuters.[26] However, the available data provides a smaller sample size (4167 observations) and we lose a number of countries from our sample (Canada, Iceland, Japan, Korea, and Mexico). Generally, the results are consistent with what we report in Tables 2 and 3. In the full sample, the interaction between PR and patent intensity has a coefficient of 0.052 (but is only significant at 15.3%). In the split sample, the above median coefficient is 0.081 (with a p-value of 12.2%). The below median coefficient is 0.034 (with a p-value of 9.5%). The $\chi 2$ value on the Chow test indicates that it is appropriate to split the sample into the above- and below-median values. Overall, the venture capital results look similar to those reported for private credit in Table 2, albeit of marginal significance.

[25] Results are available on request.

[26] We are grateful to Sarah Imlau for helping us obtain this data. The particular variable we consider combines two measures of venture capital (denoted vcearly and vcexpand) to obtain the greatest data coverage.

6. Discussion and conclusions

We find that patent protection has a positive impact on R&D intensity for more patent-intensive industries for observations associated with below-median private credit and stock market capitalization, indicating that IPR may be particularly important when domestic financial markets are relatively less developed. This significance of patent rights where financial markets are relatively less developed presumably arises because those markets inefficiently allocate investment capital to R&D, problems that are evidently ameliorated by stronger patent protection. We show here that the impact of patent protection on R&D investment is important across both bank lending and external equity (at least as indirectly measured through depth of those markets). Because these both involve relationships between principals and agents, stronger patent laws seem to be effective at sorting out these information problems through improved contracts and monitoring.

In contrast, using bond markets as the indicator of financial development we find that patent rights are positively related to R&D intensities only for those observations where bond markets are better developed. Thus, bond financing may be particularly useful for allocating innovative capital where financial markets already efficiently fund R&D, permitting more arm's-length transactions.

Interestingly, our results are similar for measures of international financial development based on access to international portfolio equity or portfolio debt. These forms of finance are the international analogues to domestic principal-agent relationships. Where they are shallower, legal patent reforms and enforcement again play supporting and parallel roles in financing R&D.

Foreign direct investment behaves somewhat differently, with a positive impact of patent protection on R&D intensities at all levels of FDI exposure. Prior research finds that FDI flows are particularly responsive to patent rights among emerging and higher-income economies (Maskus, 2012). For present purposes, it is noteworthy that FDI often embodies direct access to global technological resources and within-firm funds for innovation, which may be a direct spur to local R&D investments across stages of financial development. Thus, our estimates point to an important complementarity between patent rights and FDI in encouraging R&D.

From a policy perspective, our findings contribute to the discussion about the interplay between patent protection and innovation finance. For many measures, we find that stronger and better enforced patent rights may compensate for limited financial development in that relatively patent-intensive industries in countries with shallower financial markets increase R&D in response to better patent protection.

While our primary explanation is that patent rights ameliorate asymmetric information, this finding also resonates with the literature examining patents as collateral. In particular, Mann (2017) argues that innovation tends to be more dependent on equity than debt. If so, strengthening the role of patents as collateral may allow firms with fewer tangible assets to shift more toward debt financing (e.g., private credit), as seems to happen in the most financially advanced nations. For example, using U.S. patent data, Fischer and Ringler (2014) describe the types of lenders using collateralized patents, with banks and finance companies comprising 54.5 percent of security arrangements but 75.3 percent of collateralized patents. This shift would decrease the reliance on equity, including venture capital, and perhaps open more innovative firms to debt finance for R&D (Amable, et al, 2010).[27] As Hall and Lerner (2010) point out, it may be difficult for a country to establish a venture capital market because it requires both investors and experienced venture fund managers.

[27] Also see Brown, et al. (2012) who discuss the importance of external equity financing for R&D and indicate the importance of strengthening shareholder rights in stimulating innovative activity.

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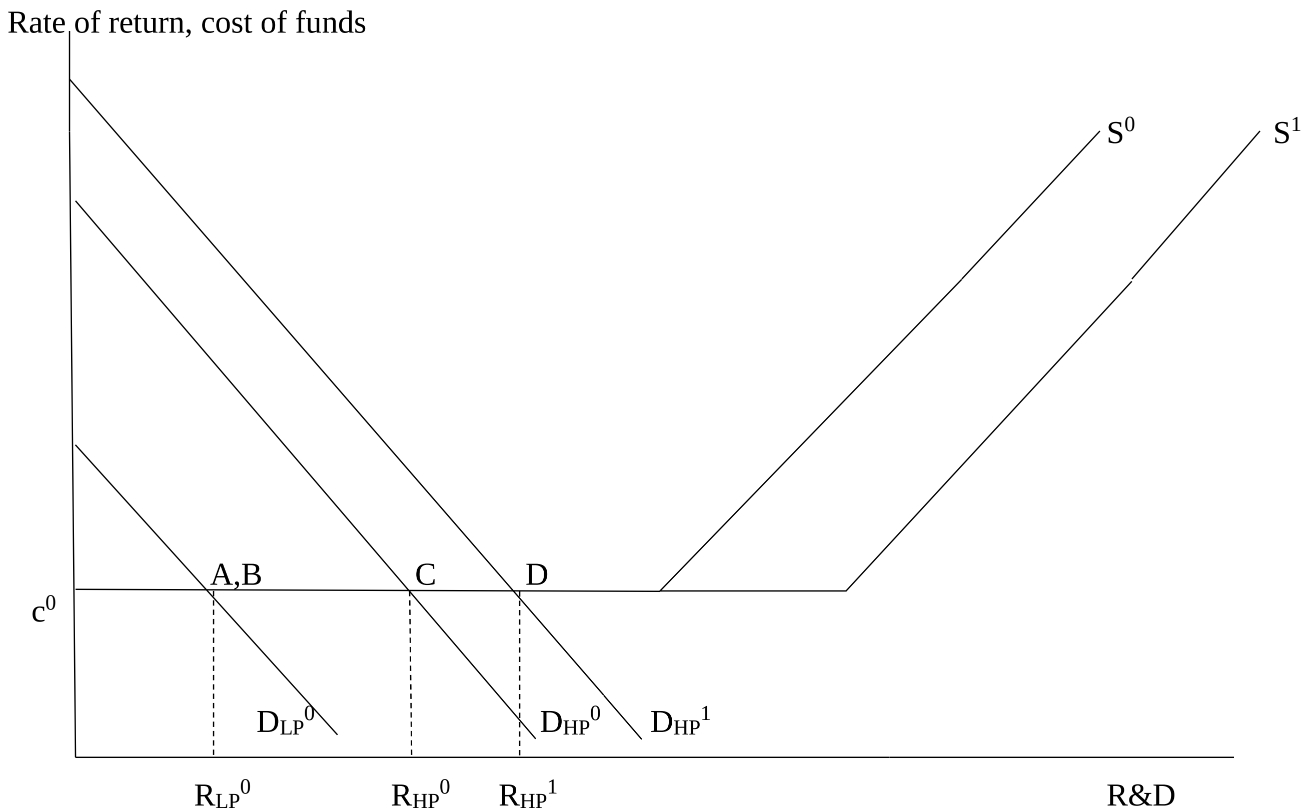

Figure 1A. R&D in a Financially Unconstrained Market

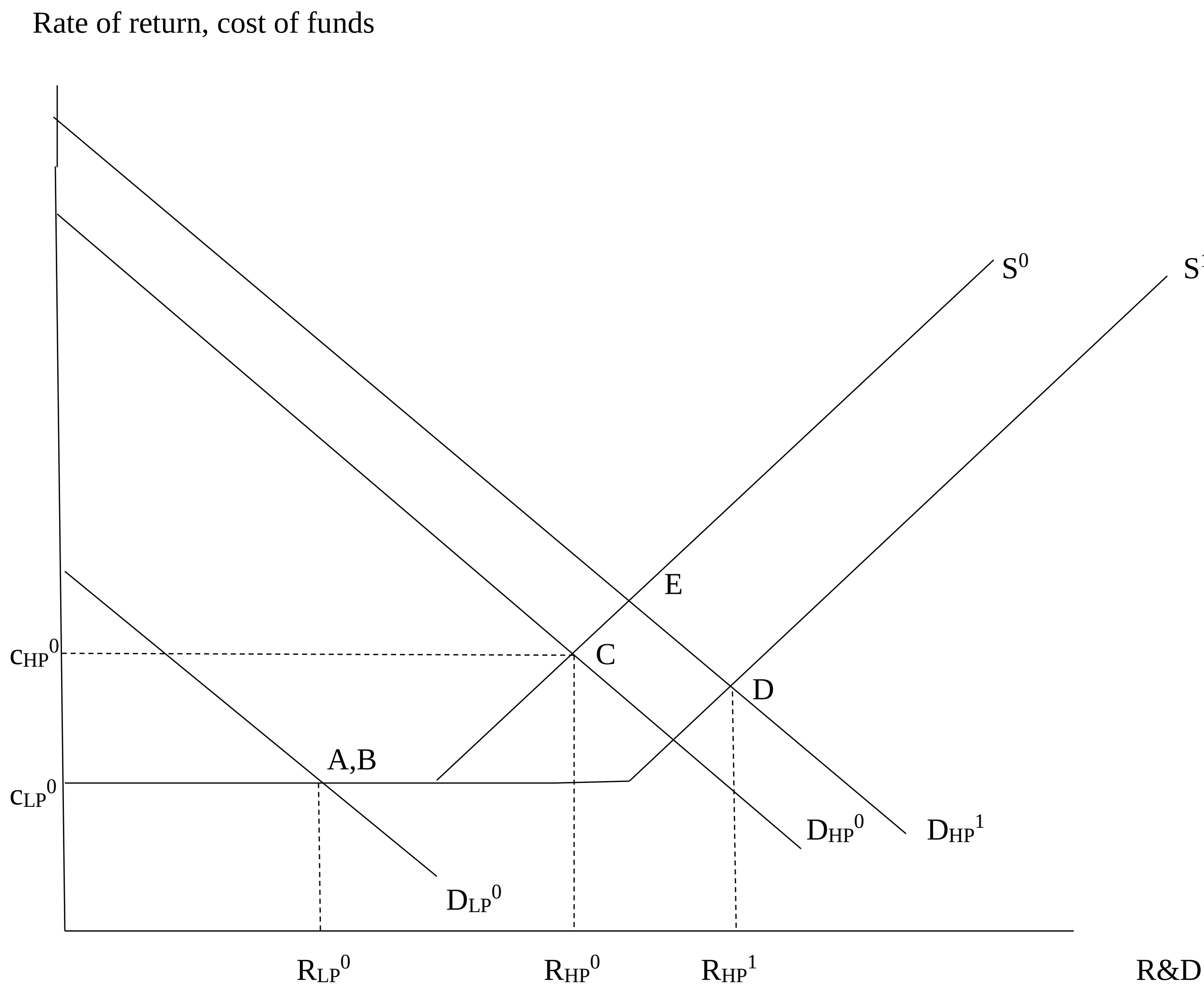

Figure 1B. R&D in a Financially Constrained Market

Table 1A: R&D intensities and industry indicators by industry

Industry	ISIC	Average R&D intensity	Patent intensity	External dependence	Tangibility
Electrical machinery and apparatus nec	31	0.028	0.052	0.137	0.209
Office, accounting and computing machinery	30	0.059	0.051	0.502	0.113
Radio, TV and communication equipment	32	0.065	0.034	0.328	0.159
Medical, precision and optical instruments, watches and clocks	33	0.047	0.033	0.643	0.145
Chemicals and chemical products	24	0.035	0.027	0.791	0.178
Wood and cork (except furniture)	20	0.002	0.025	0.156	0.447
Furniture, manufacturing nec	36	0.004	0.013	0.376	0.184
Other transport equipment	35	0.031	0.012	0.124	0.242
Machinery and equipment nec	29	0.017	0.012	0.076	0.209
Fabricated metal products (exc. mach, and equip.)	28	0.004	0.011	0.166	0.276
Rubber and plastics products	25	0.009	0.011	0.300	0.364
Coke, refined petrol. products and nuclear fuel	23	0.004	0.011	-0.044	0.611
Basic metals	27	0.005	0.011	0.147	0.410
Other non-metallic mineral products	26	0.005	0.011	-0.121	0.389
Leather, leather products and footwear	19	0.004	0.010	0.098	0.123
Motor Vehicles	34	0.018	0.010	0.394	0.273
Paper and paper products	21	0.003	0.007	0.123	0.504
Wearing apparel and fur	18	0.002	0.006	0.174	0.126
Textiles	17	0.005	0.006	0.262	0.343
Tobacco products	16	0.004	0.004	0.944	0.188
Publishing, printing and reprod. of recorded media	22	0.001	0.004	0.096	0.214
Food products and beverages	15	0.002	0.001	0.181	0.347

Average R&D intensity is the industry average over all years (1990-2009) and countries using data from the OECD ANBERD and STAN databases. Patent intensity is from Hu and Png (2013). External dependence is from Maskus, et al (2012). Tangibility is from Klapper, et al (2006). Further details are in Table 1D.

Table 1B: Summary statistics for industry variables and financial development variables

Variable	mean	Sd	min	max	N
R&D intensity	0.017	0.045	0.000	1.669	5,589
Industry share in GDP	0.027	0.028	0.000	0.232	5,589
Patent intensity	0.017	0.014	0.001	0.052	22
External dependence	0.251	0.242	-0.121	0.944	22
Tangibility	0.278	0.130	0.113	0.611	22
Private credit	0.835	0.410	0.128	2.728	5,589
Stock market capitalization	0.563	0.384	0.060	2.461	5,589
Private bond	0.311	0.333	0.001	3.034	5,589
FDI liabilities	0.315	0.324	0.003	2.039	5,589
Debt liabilities	1.047	1.095	0.198	9.017	5,589
Portfolio equity liabilities	0.254	0.498	0.005	4.465	5,589
PR	31.690	7.862	12.880	44.910	5,589

Table 1C: Correlations among financial development variables

	R&D intensity	Industry share in GDP	Private credit	Stock market capitalization	Private bond	FDI liabilities	Debt liabilities	Portfolio equity liabilities	PR
R&D intensity	1								
Industry share in GDP	-0.07	1							
Private credit	0.15	-0.03	1						
Stock market capitalization	0.11	-0.04	0.58	1					
Private bond	0.12	-0.01	0.67	0.39	1				
FDI liabilities	0.005	0.03	0.17	0.22	0.08	1			
Debt liabilities	0.08	-0.05	0.53	0.39	0.46	0.58	1		
Portfolio equity liabilities	-0.01	0.04	0.26	0.33	0.10	0.43	0.59	1	
PR	0.14	-0.03	0.57	0.6	0.3	0.33	0.42	0.39	1

Table 1D: Summary of data and sources

Variable	Type	Construction/Units	Source
R&D intensity	Country, industry, time	Share of industry output by country *j* in industry *k* in year *t* (1990 to 2009)	OECD ANBERD database ISIC Rev. 3.1/OECD STAN database ISIC Rev. 3.1
Industry share in GDP		Industry production relative to GDP (current local currency units) (1990 to 2009)	OECD STAN database ISIC Rev. 3.1/World Bank's World Development Indicators (2013)
Private credit	Country, time	Relative to GDP (1990 to 2009)	World Bank Financial Structure Database 2013 (Beck, et al 2000)
Stock market capitalization			
Private bond market capitalization			Lane and Milesi-Ferretti (2007) *Updated and Extended External Wealth of Nations Dataset 1970-2011*
FDI liabilities			
Debt liabilities			
Portfolio equity liabilities			
PR (Patent Rights)		GP * FI	From Hu and Png (2013). GP is the index of national patent laws developed by Ginarte and Park (1997) and Park (2008). FI is the Fraser Institute's index of the independence and depth of the legal system and the enforcement of property rights and contracts, derived from the International Country Risk Guide's survey of business executives (Gwartney and Lawson, 2001).
Patent intensity	Industry	Number of patents awarded to an industry relative to industry sales	From Hu and Png (2013). The numerator is from the NBER Patent Database and the denominator is from Compustat (average over 1979-2000).
External dependence		Industry-level median of the ratio of capital expenditures minus cash flow over capital expenditures, where the numerator and denominator are summed over all years (1990-1999) for each firm before dividing.	Klapper, et al (2006)
Tangibility		Industry-level median of the ratio of net property, plant, and equipment relative to the total book value of assets.	Calculated by Maskus, et al (2012) using Compustat data over 1990-1999.

Table 2: Regression of R&D intensity on patent protection interacted with patent intensity across different domestic financial development variables interacted with external dependence and tangibility

	Private credit			Stock market capitalization			Private bond		
	(1) Full	(2) Above	(3) Below	(4) Full	(5) Above	(6) Below	(7) Full	(8) Above	(9) Below
Industry share in GDP	-0.123*	-0.160*	-0.090	-0.119*	-0.154*	-0.074	-0.113*	-0.118*	-0.115*
	(0.061)	(0.090)	(0.053)	(0.058)	(0.083)	(0.058)	(0.055)	(0.060)	(0.055)
PR*patent intensity	0.049*	0.074	0.047***	0.052**	0.024	0.050***	0.052**	0.086*	0.027
	(0.025)	(0.054)	(0.009)	(0.024)	(0.069)	(0.006)	(0.024)	(0.042)	(0.017)
PR	-0.001	-0.000	-0.001*	-0.001	0.001	-0.001**	-0.001	-0.001	-0.000
	(0.000)	(0.001)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.001)	(0.001)
Financial development*financial dependence	0.037	0.065	0.014	0.030	0.045	0.014	0.083***	0.106***	0.010
	(0.024)	(0.046)	(0.011)	(0.019)	(0.039)	(0.016)	(0.022)	(0.012)	(0.064)
Financial development*tangibility	-0.020	0.008	-0.086***	-0.008	0.031	-0.001	-0.005	0.026**	-0.004
	(0.016)	(0.028)	(0.025)	(0.019)	(0.029)	(0.030)	(0.026)	(0.010)	(0.150)
Financial development	0.003	-0.013	0.053*	-0.000	-0.018	-0.003	-0.012	-0.024***	-0.021
	(0.007)	(0.015)	(0.026)	(0.006)	(0.012)	(0.008)	(0.010)	(0.004)	(0.062)
Constant	0.034**	0.042	0.020	0.036**	-0.020	0.030**	0.036**	0.048**	0.039**
	(0.016)	(0.030)	(0.030)	(0.016)	(0.059)	(0.013)	(0.016)	(0.021)	(0.014)
Observations	5,589	2,812	2,777	5,589	2,787	2,802	5,589	2,812	2,777
R-squared	0.255	0.303	0.195	0.250	0.216	0.472	0.265	0.424	0.136
χ^2	49.50			67.85			1419.77		
(Prob> χ^2)	(0.00)			(0.00)			(0.00)		

Each specification includes country, industry, and time fixed effects. Standard errors clustered at the country level are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%. The χ^2 test is a Chow test of the split sample (where we reject the null that the data can be better represented by a single equation).

Table 3: Regression of R&D intensity on patent protection interacted with patent intensity across different international financial development variables interacted with external dependence and tangibility

	FDI liabilities			Debt liabilities			Portfolio equity liabilities		
	(1) Full	(2) Above	(3) Below	(4) Full	(5) Above	(6) Below	(7) Full	(8) Above	(9) Below
Industry share in GDP	-0.121*	-0.234**	-0.001	-0.143*	-0.257*	-0.042	-0.100**	-0.113	-0.075
	(0.060)	(0.099)	(0.049)	(0.071)	(0.123)	(0.048)	(0.047)	(0.080)	(0.052)
PR*patent intensity	0.058**	0.087**	0.044**	0.053*	0.024	0.077***	0.061**	0.052	0.065***
	(0.024)	(0.034)	(0.017)	(0.025)	(0.085)	(0.013)	(0.024)	(0.062)	(0.008)
PR	-0.001	-0.001***	-0.000	-0.000	0.001	-0.001***	-0.001	-0.001	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.001)	(0.000)
Intl financial development*financial dependence	0.006	0.015	-0.084	0.016	0.021	0.002	-0.008*	-0.008**	-0.136
	(0.013)	(0.012)	(0.058)	(0.014)	(0.016)	(0.030)	(0.004)	(0.004)	(0.204)
Intl financial development*tangibility	0.011	-0.012	0.290**	0.005	0.009**	-0.035	0.015	0.019**	-0.064
	(0.022)	(0.016)	(0.126)	(0.005)	(0.004)	(0.037)	(0.009)	(0.007)	(0.127)
International financial development	0.001	0.005	-0.153***	-0.003	-0.005	0.003	-0.004	-0.006***	0.061
	(0.008)	(0.006)	(0.042)	(0.002)	(0.003)	(0.013)	(0.003)	(0.002)	(0.056)
Constant	0.032**	0.069***	0.017*	0.033*	0.006	0.060***	0.035**	0.032	0.043***
	(0.014)	(0.017)	(0.009)	(0.016)	(0.066)	(0.011)	(0.016)	(0.035)	(0.012)
Observations	5,589	2,811	2,778	5,589	2,803	2,786	5,589	2,775	2,814
R-squared	0.246	0.339	0.218	0.253	0.205	0.569	0.246	0.205	0.473
χ^2	154.39			377.46			187.63		
(Prob> χ^2)	(0.00)			(0.00)			(0.00)		

Each specification includes country, industry, and time fixed effects. Standard errors clustered at the country level are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%. The χ^2 test is a Chow test of the split sample (where we reject the null that the data can be better represented by a single equation).

Table 4: Magnitudes of estimates

	Private credit			Stock market capitalization			Private bond		
At average patent intensity	Full	Above	Below	Full	Above	Below	Full	Above	Below
% points	**0.657**	**-**	0.627	**0.699**	**-**	0.666	**0.699**	**1.145**	**-**
% points with direct effect of PR	0.260	-	**0.111**	0.265	**-**	**0.220**	0.234	0.313	**-**
At 25th percentile			**-0.129**			**-0.035**		**0.706**	
At 75th percentile			**0.406**			**0.533**		**1.683**	
	FDI liabilities			Debt liabilities			Portfolio equity liabilities		
At average patent intensity	Full	Above	Below	Full	Above	Below	Full	Above	Below
% points	**0.782**	1.166	**0.586**	**0.708**	**-**	1.026	**0.817**	-	0.864
% points with direct effect of PR	0.345	**0.156**	0.315	0.323	**-**	**0.029**	0.335	-	**0.097**
At 25th percentile		**-0.292**	**0.361**			**-0.365**			**-0.234**
At 75th percentile		**0.704**	**0.861**			**0.511**			**0.504**

Calculations are based on estimated coefficients from Tables 2 and 3. The calculation method is from Hu and Png (2013). Each estimate illustrates the change in R&D intensity associated with a one standard deviation increase in the patent protection index (PR). The first line in each case utilizes only the interaction term as part of the marginal calculation. For example, using the overall average patent intensity of 0.017, an increase in PR by one standard deviation (7.862) contributes positively to R&D intensity by 0.0491*0.01703*7.862*100 = 0.657 percentage points when private credit (full sample) is used as the financial development measure. The second line in each case takes into account the direct effect of the PR variable. For example, for those observations below the median level of private credit, the PR variable carries a negative and significant coefficient. Thus, an increase in PR by one standard deviation contributes positively to R&D intensity by (0.0467962*0.01703+(-0.0006553))*7.862*100 = 0.111 percentage points. The inclusion of the PR variable moderates the overall impact as PR has a direct negative effect on R&D intensity. Note, however, that the PR term is not consistently significant. Thus, the bold estimates indicate cases where only the significant coefficients are used in the calculation. Compared with the average R&D intensity (1.7%) across all countries, industries, and time, these impacts are substantial in economic terms.

The second set of calculations considers the difference in the response of R&D for a firm in a low patent-intensity industry versus one in a high patent-intensity industry (i.e., comparing the 25th to 75th percentile of patent intensity). The numbers for below-median financial development correspond to the financially constrained market (Figure 1B), while those for the above-median financial development correspond to the financially unconstrained market (Figure 1A).

Table 5: First Principal Component for financial development

	Domestic PC1			International PC1		
	(1)	(2)	(3)	(4)	(5)	(6)
	Full	Above	Below	Full	Above	Below
Industry share in GDP	-0.120*	-0.132*	-0.107*	-0.132*	-0.252**	-0.018
	(0.058)	(0.074)	(0.055)	(0.063)	(0.110)	(0.044)
PR*patent intensity	0.047*	0.083	0.043***	0.057**	0.045	0.062***
	(0.025)	(0.049)	(0.014)	(0.024)	(0.070)	(0.016)
PR	-0.001	-0.001	-0.000	-0.001	-0.000	-0.001***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
PC1*financial dependence	0.015**	0.026***	0.007	0.005	0.007	-0.013
	(0.007)	(0.007)	(0.004)	(0.007)	(0.009)	(0.014)
PC1*tangibility	-0.004	0.003	-0.029***	0.004	0.005	0.062*
	(0.005)	(0.006)	(0.010)	(0.004)	(0.004)	(0.032)
First principal component (PC1)	-0.001	-0.005*	0.018**	-0.001	-0.002	-0.023**
	(0.003)	(0.003)	(0.008)	(0.002)	(0.001)	(0.010)
Constant	0.037**	0.048	0.032**	0.036**	0.042	0.042**
	(0.016)	(0.028)	(0.014)	(0.015)	(0.043)	(0.017)
Observations	5,589	2,814	2,775	5,589	2,793	2,796
R-squared	0.260	0.396	0.164	0.246	0.201	0.539

Standard errors clustered at the country level in parentheses: significance indicated by *** p<0.01, ** p<0.05, * p<0.1
PC1 denotes the principal component formed either from the domestic financial development variables or the international financial development variables.

Table 6: Sensitivity analysis – including log real GDP per capita (domestic financial development measures)

	Private credit			Stock market capitalization			Private bond		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Full	Above	Below	Full	Above	Below	Full	Above	Below
Industry share in GDP	-0.124*	-0.160*	-0.090	-0.120*	-0.154*	-0.074	-0.113*	-0.118*	-0.116*
	(0.061)	(0.090)	(0.053)	(0.058)	(0.083)	(0.057)	(0.054)	(0.060)	(0.055)
Log real GDP per capita	0.004	-0.017	0.002	0.008	-0.013	0.001	0.006	-0.003	0.027
	(0.021)	(0.023)	(0.019)	(0.023)	(0.018)	(0.017)	(0.023)	(0.015)	(0.040)
PR*patent intensity	0.049*	0.074	0.047***	0.052**	0.024	0.050***	0.052**	0.085*	0.027
	(0.025)	(0.054)	(0.009)	(0.024)	(0.069)	(0.007)	(0.024)	(0.042)	(0.017)
PR	-0.001	-0.000	-0.001*	-0.001	0.001	-0.001***	-0.001	-0.001	-0.001
	(0.000)	(0.001)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.001)	(0.001)
Financial development*financial dependence	0.037	0.065	0.014	0.030	0.045	0.014	0.083***	0.106***	0.010
	(0.024)	(0.046)	(0.011)	(0.019)	(0.039)	(0.016)	(0.023)	(0.012)	(0.064)
Financial development*tangibility	-0.020	0.009	-0.086***	-0.008	0.031	-0.001	-0.005	0.026**	-0.004
	(0.016)	(0.028)	(0.025)	(0.019)	(0.029)	(0.030)	(0.026)	(0.010)	(0.150)
Financial development	0.003	-0.012	0.053*	-0.001	-0.017	-0.003	-0.013	-0.024***	-0.009
	(0.007)	(0.015)	(0.025)	(0.006)	(0.012)	(0.008)	(0.010)	(0.004)	(0.052)
Constant	-0.005	0.210	-0.003	-0.049	0.113	0.025	-0.023	0.080	-0.237
	(0.224)	(0.232)	(0.205)	(0.242)	(0.217)	(0.183)	(0.238)	(0.150)	(0.414)
Observations	5,589	2,812	2,777	5,589	2,787	2,802	5,589	2,812	2,777
R-squared	0.255	0.303	0.195	0.250	0.216	0.472	0.265	0.424	0.137

Each specification includes country, industry, and time fixed effects. Standard errors clustered at the country level are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%.

Table 7: Sensitivity analysis – including log real GDP per capita (international financial development measures)

	FDI liabilities			Debt liabilities			Portfolio equity liabilities		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Full	Above	Below	Full	Above	Below	Full	Above	Below
Industry share in GDP	-0.122*	-0.233**	-0.003	-0.143*	-0.256*	-0.041	-0.101**	-0.113	-0.075
	(0.060)	(0.098)	(0.048)	(0.070)	(0.122)	(0.047)	(0.047)	(0.080)	(0.051)
Log real GDP per capita	0.011	-0.013	0.019	0.005	-0.045*	-0.025**	0.022	-0.013	-0.003
	(0.023)	(0.014)	(0.027)	(0.022)	(0.021)	(0.011)	(0.026)	(0.014)	(0.027)
PR*patent intensity	0.058**	0.087**	0.044**	0.053*	0.024	0.077***	0.061**	0.052	0.065***
	(0.024)	(0.034)	(0.017)	(0.025)	(0.085)	(0.013)	(0.024)	(0.062)	(0.008)
PR	-0.001	-0.001**	-0.001	-0.001	0.001	-0.001***	-0.001*	-0.001	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.001)	(0.000)
International financial development*financial	0.007	0.015	-0.083	0.016	0.021	0.003	-0.008*	-0.008**	-0.136
dependence	(0.013)	(0.012)	(0.059)	(0.014)	(0.016)	(0.030)	(0.004)	(0.004)	(0.203)
International financial	0.011	-0.012	0.291**	0.005	0.009**	-0.036	0.015	0.019**	-0.064
development*tangibility	(0.022)	(0.015)	(0.126)	(0.005)	(0.004)	(0.037)	(0.009)	(0.007)	(0.128)
International financial	0.000	0.005	-0.160***	-0.003	-0.004	0.007	-0.006	-0.005***	0.060
development	(0.008)	(0.005)	(0.044)	(0.002)	(0.003)	(0.013)	(0.004)	(0.002)	(0.055)
Constant	-0.078	0.199	-0.152	-0.020	0.451*	0.308**	-0.185	0.161	0.068
	(0.238)	(0.142)	(0.238)	(0.233)	(0.241)	(0.117)	(0.270)	(0.142)	(0.280)
Observations	5,589	2,811	2,778	5,589	2,803	2,786	5,589	2,775	2,814
R-squared	0.246	0.339	0.219	0.253	0.206	0.570	0.247	0.205	0.473

Each specification includes country, industry, and time fixed effects. Standard errors clustered at the country level are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%.

Table A1: Country Variable Averages: averages by country across time (ranked by the PR variable)

Country	PR	Private credit	Stock market capitalization	Private bond	FDI liabilities	Debt liabilities	Portfolio equity liabilities
Netherlands	40.80	1.21	0.92	0.45	0.56	1.59	0.57
Germany	40.07	1.08	0.42	0.47	0.18	0.91	0.13
Ireland	39.69	1.04	0.59	0.28	0.96	3.77	2.35
Canada	39.22	0.96	0.92	0.27	0.43	0.65	0.17
United Kingdom	38.79	1.24	1.28	0.15	0.28	2.12	0.40
Finland	38.42	0.68	0.91	0.28	0.18	0.86	0.55
Belgium	36.19	0.76	0.58	0.40	0.99	2.07	0.08
Japan	35.74	1.47	0.78	0.43	0.01	0.34	0.12
France	34.16	0.89	0.59	0.44	0.29	0.89	0.20
Norway	33.59	0.65	0.37	0.24	0.19	0.67	0.11
Italy	31.13	0.71	0.35	0.30	0.10	0.74	0.12
Iceland	29.86	1.29	0.78	1.18	0.25	2.68	0.07
Hungary	28.70	0.53	0.29	0.06	1.04	0.81	0.11
Spain	28.64	0.96	0.57	0.19	0.25	0.69	0.14
Korea	25.86	0.76	0.54	0.51	0.09	0.29	0.16
Portugal	24.29	0.96	0.30	0.18	0.25	1.02	0.13
Greece	24.00	0.47	0.49	0.02	0.11	0.73	0.09
Poland	23.32	0.26	0.19	0.00	0.25	0.36	0.04
Czech Republic	23.23	0.47	0.23	0.06	0.38	0.32	0.06
Mexico	15.20	0.17	0.25	0.09	0.20	0.28	0.10

PR: patent rights (calculated as PR=GP*FI)
Financial development variables as defined in the paper (all calculated relative to GDP)

Triple interaction results

In Tables A2 and A3, we include a triple interaction term to study the interplay between patent protection, patent intensity, and financial development directly. We construct binary versions of our domestic and international financial development measures, wherein financial development is equal to 1 if its value is at or above the median level of financial development and equal to zero if it is below the median level of financial development. We then interact this binary financial development variable with patent intensity and patent protection (PR). The addition of a triple interaction term requires the inclusion of all double interactions. We also include the non-binary interactions of financial development with external dependence and tangibility to maintain comparability with prior results. However, excluding these additional interactions does not qualitatively change the results.

Including the triple interaction provides additional insight by changing the interpretation of our original interaction term, PR*patent intensity. We now interpret this coefficient as the interaction of patent protection and patent intensity *when the binary financial development variable is zero*. In other words, if this coefficient is still positive and significant, it indicates that more patent-intensive industries invest more in R&D in countries with stronger patent protection laws where markets are less financially developed (that is, where the financial development binary term is equal to zero). We find this to be the case for all measures of financial development, with the exception of private bonds. For private bonds, R&D intensities are sensitive to patent intensity and IPR when this measure of financial development is higher. These results are consistent with our findings in Tables 2 and 3.

We repeated this exercise by reversing our binary component, allowing financial development to equal 1 if it is *below* the median level of financial development (and 0 otherwise). The reverse case generally confirms our findings, as the coefficient of PR*patent intensity is only significant for private bonds and FDI (note that we do not show these results separately in the tables below). This suggests that industries that rely more on patents invest more in R&D when financial development is higher for only the private bonds and FDI measures. The FDI variable generates a significant coefficient on PR*patent intensity for both directional exercises, suggesting that patent protection is important for R&D investments for those industries that rely on patents across all levels of FDI, consistent with our earlier findings.

Table A2: Regression of R&D intensity on patent protection interacted with both patent intensity and binary measures (=1 if equal to or above median level, =0 if below median level) of domestic financial development.

	(2) Private credit	(3) Stock market capitalization	(4) Private bond
Industry share in GDP	-0.126*	-0.119*	-0.107*
	(0.063)	(0.058)	(0.053)
PR*patent intensity	0.048***	0.049***	0.027
	(0.009)	(0.007)	(0.016)
PR	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
FD binary*PR*patent intensity	0.023	-0.025	0.058
	(0.054)	(0.068)	(0.042)
FD binary*PR	-0.000	0.000	-0.001
	(0.001)	(0.001)	(0.001)
FD binary*patent intensity	-0.979	1.246	-1.755
	(1.757)	(2.496)	(1.365)
FD binary	0.017	-0.017	0.034
	(0.024)	(0.033)	(0.024)
FD*financial dependence	0.039	0.028	0.082***
	(0.024)	(0.020)	(0.023)
FD*tangibility	-0.023	-0.001	-0.003
	(0.015)	(0.016)	(0.021)
FD	0.005	-0.001	-0.013
	(0.007)	(0.006)	(0.009)
Constant	0.031**	0.036***	0.024
	(0.013)	(0.011)	(0.017)
Observations	5,589	5,589	5,589
R-squared	0.256	0.253	0.269

Standard errors clustered at the country level are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%.
Note: FD binary = 1 when financial development is at or above the median level (and 0 otherwise); FD indicates the original financial development variable.

Table A3: Regression of R&D intensity on patent protection interacted with both patent intensity and binary measures (=1 if equal to or above median level, =0 if below median level) of international financial development.

	(1) FDI liabilities	(2) Debt liabilities	(3) Portfolio equity liabilities
Industry share in GDP	-0.118*	-0.135*	-0.101**
	(0.061)	(0.073)	(0.046)
PR*patent intensity	0.048**	0.079***	0.065***
	(0.018)	(0.013)	(0.009)
PR	-0.000	-0.001**	-0.001**
	(0.000)	(0.000)	(0.000)
FD binary*PR*patent intensity	0.039	-0.059	-0.013
	(0.035)	(0.085)	(0.061)
FD binary*PR	-0.001	0.000	-0.000
	(0.001)	(0.001)	(0.001)
FD binary*patent intensity	-1.664	1.812	0.501
	(1.061)	(3.051)	(2.184)
FD binary	0.028	-0.013	0.002
	(0.016)	(0.040)	(0.025)
FD*financial dependence	0.009	0.016	-0.008*
	(0.012)	(0.014)	(0.004)
FD*tangibility	0.002	0.003	0.015**
	(0.017)	(0.004)	(0.007)
FD	0.003	-0.002	-0.004
	(0.006)	(0.002)	(0.003)
Constant	0.025*	0.040***	0.037***
	(0.013)	(0.012)	(0.010)
R-squared	0.251	0.257	0.247

Standard errors clustered at the country level are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%.

Note: FD binary = 1 when financial development is at or above the median level (and 0 otherwise); FD indicates the original financial development variable.