How National and International Financial Development Affect Industrial R&D

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Abstract

We examine the impacts of both domestic and international financial market development on R&D intensities in 22 manufacturing industries in 18 OECD countries for the period 1990-2003. We take account of such industry characteristics as the need for external financing and the amount of tangible assets. Multiple forms of domestic financial development are important determinants of R&D intensity but only foreign direct investment is significant among alternative measures of international financial development. We find the strongest effects for private bond-market capitalization, while FDI, private credit by banks, and stock-market capitalization have similar effects in terms of magnitude.

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1. Introduction

One of the most fundamental issues in economic development is how important the maturation and deepening of financial markets are for growth. This issue has been much debated since its reintroduction into the literature by King and Levine (1993). According to Levine (2005), a consensus has been reached that more developed domestic financial markets stimulate economic growth. Presumably this linkage stems from gaining better access to credit, which allows easier financing of investment projects, which in turn leads to productivity growth.[1] At a deeper level, however, it is important to study the specific channels through which access to finance enhances economic growth.[2] In this paper we consider one particular type of investment, namely research and development (R&D), and its association with national and international financial market development. It is prominently argued that more investment in R&D stimulates technological progress, which provides the foundation for the bulk of economic growth (Griliches, 1998; Acemoglu, 2009).

Our specific focus is asking how firms' R&D intensities respond to country-wide financial development when such firms are in industries that rely heavily on external finance or have limited tangible assets.[3] Are financially dependent companies more likely to have higher R&D intensities when national capital markets develop or when there is greater access to international financial markets? If so, financial development and financial access provide key reasons why enterprises in countries with deeper markets invest more in R&D than do their counterparts in other nations. Additionally, industries with low proportions of tangible capital,

[1] King and Levine (1993) focus on the impact of credit markets in their study of cross-country growth, while Levine and Zervos (1998) show the importance of both stock markets and credit markets.

[2] For example, Beck, et al. (2000) analyze impacts on total factor productivity, physical capital accumulation, and private savings, while Pang and Wu (2009) consider efficient capital allocation.

[3] R&D intensity is defined as expenditures on research and development relative to output at the industry level and is endogenous in our conception. We take this terminology from the OECD and stress that it is not a purely technology-driven measure describing the tendency of a sector to produce high-technology goods.

meaning plant and equipment expenditures, tend to be those with higher proportions of intellectual capital. If the R&D intensities of those sectors also rise with capital-market sophistication then financial development supports higher innovation in knowledge-based endeavours.

We follow the influential approach developed by Rajan and Zingales (1998) to link financial development and investment in R&D. Those authors interact several indicators of financial development (on the country level) with a measure of external financial dependence (on the industry level) to explore the relationship between financial development and economic growth. We apply this approach to analyze the impact of various forms of financial development on R&D intensities across industries, accounting for sectoral financial dependence and tangibility.

Prior work on financing investments at the firm level also motivates our study (Aghion, et al. 2004; Hall, 2002; Hall and Lerner, 2010). This research has demonstrated that firms first tap internal funds in order to maintain control rights over their innovations. As they need additional capital to fund R&D expenditures, however, they turn to external funds, first accessing bank credit and then equity markets.[4] This apparent hierarchy of finance specific to innovation motivates our explicit consideration of both credit and equity measures, such as liquid liabilities, private credit, stock market and private bond market capitalization.

We also include variables that describe international financial market development (portfolio investment, foreign direct investment (FDI), and foreign debt), which has been ignored in this line of research. This is an important consideration as recent work has documented a positive link between the integration of financial markets across countries and economic growth

[4] See Myers (1984), Myers and Majluf (1984) and Leland and Pyle (1977) regarding this pecking-order logic for general investments. Harris and Raviv (1991) offer a useful review.

(Eichengreen, 2001; Kose, et al. 2009). Nevertheless, very little focus has been placed on whether openness to international capital markets may affect innovation and growth through financing R&D.[5] The standard conception is that FDI is a direct source of technology transfer and may induce greater local innovation through learning spillovers (He and Maskus, 2012; Keller and Yeaple, 2010). However, there has been considerable growth in the internationalization of R&D as multinational firms establish research affiliates abroad (Gammeltoft, 2006). Further, affiliates may be financed via a mix of ownership and debt (Kesternich and Schnitzer, 2010). It is therefore of interest to study how access to international financial sources may affect innovation.

Financing constraints may be particularly restrictive for R&D relative to other forms of investment.[6] According to Brown, et al. (2009), innovative firms (those with high R&D expenditures) tend to have few tangible assets that can serve as collateral for credit. R&D expenditures largely go to salaries and wages for scientists and researchers. These human-capital investments cannot be collateralized. Further, firms may wish to protect their proprietary information over innovation, and thus may be unable or unwilling to offer sufficient signals about the effectiveness of their intended R&D programs to credit providers. These issues motivate the inclusion of a measure of asset tangibility into our analysis.

The relationships between innovation and economic growth, and between financial development and economic growth, have been explored in a wide swath of literature. However, there are far fewer studies of the effects of financial development on innovation as a specific channel by which the former may stimulate growth. Aghion, et al. (2010) provide one such link with a theoretical model that explores the impact of financing constraints on the composition of

[5] Henry (2000) focuses on investment as a specific channel by which equity market liberalization may affect growth.
[6] See Hall (1992), Himmelberg and Petersen (1994), Mulkay, et al. (2001), and Bond, et al. (2005) for evidence that R&D faces financing constraints.

investment. Financial frictions may limit economic growth by reducing long-term investment in R&D during economic downturns. Aghion, et al., (2008) provide related firm-level evidence. They show that R&D investment is pro-cyclical, rising with firms' sales in the presence of firm-specific credit constraints. This link is particularly pronounced for enterprises with greater external financial dependence and fewer tangible assets.

Using aggregate data, Carlin and Mayer (2003) study the relationship between R&D intensity at the industry level and national institutional variables describing the structure of countries' financial systems. In particular, these authors interact accounting standards, bank concentration and control of voting rights with equity finance dependence, bank finance dependence, and skill dependence to look at the effects on growth, fixed investment and R&D investment. They provide initial evidence on the relationship between domestic financial institutions and R&D expenditures, showing broadly that better accounting standards and more developed credit markets positively impact investment in R&D for those industries that rely more on external equity. They find little impact on R&D from the development of equity markets.

Our paper contributes to this literature in several ways. First, we deploy alternative measures of financial development to describe more fully the impacts on R&D intensities of such different dimensions as private credit, stock markets, private bond markets, portfolio investments and foreign direct investment. Second, this menu permits us to derive novel findings based on two classifications of the data: a differentiation between national and international sources of finance and a categorization of financial systems as bank-based or market-based. Third, we calculate the implied impacts of financial development on R&D propensities.

To preview, our findings point to a strong association between domestic financial market development and R&D intensity. However, among sources from the international capital markets only FDI seems to be a major factor in financing research and development. As to bank-based versus market-based financial systems, we find significant effects for varieties of both systems. However, we obtain the strongest effect for market-based (direct) forms of finance. Regarding quantitative impacts, the R&D intensity of an industry that is heavily dependent on external sources of finance in a country with well developed domestic financial markets is more than 0.4 percentage points higher than that of an industry that relies less on external sources of funding in a country with poorly developed financial markets. This difference is about 20 percent of the average R&D intensity in our industry sample. The largest difference arises as the private bond market becomes larger, with our estimates suggesting as much as a 45-percent expansion of R&D intensity in industries located in a country with extensive bond-market capitalization versus those located in one with little capitalization.

A fourth contribution is that, to our knowledge, this is the first paper to include a measure of asset tangibility in the context of financial market development and R&D investments. We find that industries with fewer tangible assets generally benefit more from financial market development than industries that are endowed with more tangible assets.[7]

In the next section we formally introduce the hypotheses we test and lay out the econometric methodology to do so. We then describe the data we use in Section 3 before we discuss our results in Section 4. In Section 5 we report the results of several robustness checks of our benchmark specification. We offer concluding remarks in Section 6.

2. Hypotheses and econometric approach

[7] Braun (2003) and Manova (2008) have used tangibility in analyzing financial constraints in international trade.

We study the different impacts of financial market development on R&D intensity in industries that (i) depend on external finance to different extents and (ii) are characterized by varying degrees of tangible assets in their overall balance sheets. Our hypotheses are that more developed financial markets should be associated with greater R&D in industries that (i) rely more on external finance and (ii) have less tangible assets to use as collateral.

The first industry characteristic – external financial dependence – captures the industry's ability to generate cash flow to finance investment projects, such as R&D. As Rajan and Zingales (1998) argue, this measure should be determined to a large extent by industry-specific factors that are external to the firm. For instance, it is plausible to argue that projects differ across industries with respect to "initial project scale, the gestation period, the cash harvest period, and the requirement for continuing investment" (Rajan and Zingales, 1998, p. 563). In our regressions, we expect a positive coefficient on the interaction term between financial development and sectoral external financial dependence.

The idea behind the second industry characteristic – asset tangibility – is that industries with a high degree of tangible assets, such as equipment and plants, should be able to access credit more easily, and at lower cost, because they have more collateral with which to guarantee such credit. Hence, we expect a negative coefficient on the interaction term between financial development and asset tangibility because industries with a greater presence of intangible assets, such as intellectual capital, should gain relatively greater access to capital as financial markets deepen. Like external dependence, tangibility is an industry characteristic largely external to the firm.

The approach we use follows the influential work by Rajan and Zingales (1998) in interacting industry variables (external financial dependence and asset tangibility) with several

country variables capturing the degree of financial market development.[8] We thus regress R&D intensity on these interaction terms, the industry share in GDP, financial market development, and a set of country, industry and year dummies. The model we estimate is

$$\begin{aligned} R\&D\ intensity_{j,k,t} = {} & \beta_0 + \beta_1(external\ \ financial\ dependence_k * \ financial\ market\ development_{j,t}) \\ & + \beta_2(tangibility_k * \ financial\ market\ development_{j,t}) \\ & + \beta_3(industry\ share_{j,k,t}) + \beta_4 * (\ financial\ market\ development_{j,t}) \\ & + \eta_j + \eta_k + \eta_t + \varepsilon_{j,k,t}, \end{aligned} \qquad (1)$$

where *j* denotes country, *k* represents industry, *t* is the year index, and $\varepsilon_{j,k,t}$ describes the error term. As Rajan and Zingales (1998) point out, the interaction terms deliver predictions about within-country differences across industries after controlling for country-, industry- and year-specific effects. We do not estimate the direct effect of external financial dependence or tangibility as they are captured by our industry indicators.

Time-invariant country characteristics are controlled for by our country indicator η_j. The year dummies capture all effects that countries and industries face in common, such as global booms and busts and international trade liberalization. Furthermore, we use figures on industry output shares to control for different industry patterns across countries.[9] This is an important inclusion since the industry shares control for national variations in comparative advantage that could affect the relationships between industry characteristics, financial development and R&D

[8] There are numerous applications of the Rajan and Zingales approach to study different aspects of financial development within heterogeneous industries or firms. For example, Manova (2008) applies the approach to international trade, Pang and Wu (2009) consider the efficiency of capital allocation, Cetorelli and Gambera (2001) examine banking market structure, financial dependence, and growth, Claessens and Laeven (2003) focus on property rights and growth, and Carlin and Mayer (2003) study differential effects on growth, physical investment, and R&D investment.

[9] To rule out autocorrelation in the error term, we alternatively used the share of industry output in 1990 instead of the annual values. Our results are robust to this change. Similarly, taking out annual industry share entirely has little effect on the coefficients of the two interaction terms.

intensity.[10] In contrast to Rajan and Zingales (1998), and more closely related to Manova (2008), we do not take average annual growth rates but instead use the annual levels for the years 1990-2003. Hence, identification of β_1 and β_2 results from variation across countries and time of the financial development indicators and variation across industries in external financial dependence and asset tangibility. According to our hypotheses, we expect β_1 to be positive and β_2 to be negative.

There are potential concerns about endogeneity and causality in equation (1), which we now address. As a basic observation, it is difficult to envision factors that would be general determinants of financial development and also drive variations in R&D intensity at the industry level. In addition, there are several technical reasons for arguing that causality problems are likely less important in our context. Note first that asset tangibility and external dependence measures are industry characteristics that do not vary over time or across nations. Moreover, they are calculated using U.S. data from 1990-1999. Thus, time-varying R&D expenditures at the industry level, which change annually over 1990-2003 for each country in the sample, are not likely to be causal for asset tangibility or external dependence computed for U.S industries. Still, we leave the United States out of the regression analysis to eliminate any feedback effect from U.S. R&D expenditures to these industry variables.

Second, financial development is endogenous to at least macroeconomic factors, which has been a paramount question in the literature analyzing the impacts of market deepening on growth. For example, the extent of economic expansion surely influences the demand for financial instruments and the capacity to invest in national financial development. In turn, any measures of financial development, including our own, are affected by other factors linking

[10] We explore the issue of comparative advantage in more detail in the robustness section below.

growth to financial market structure. In prior work these influences are often instrumented by such variables as an index for the rule of law, efficient governance, and bank regulation. In our case, however, we argue that this concern is considerably lessened since it seems unlikely that R&D intensity at the industry level is causal to the development of broad financial markets (though it might be for narrower measures, such as venture capital).

Third, it could be that the interaction terms between financial development and industry characteristics could suffer from a potential causality problem. Specifically, it is reasonable to suppose that the more developed are financial markets the less problematic are unobservable credit constraints, permitting firms to raise external finance without frictions. Suppose also that industries requiring higher amounts of outside capital also happen to have better investment prospects than those with lower dependence on external finance. Then the data will show both high national financial development and greater R&D propensities in sectors with high external dependence. A positive interaction coefficient then might not demonstrate a causal impact of credit constraints, which in this situation are absent in financially developed economies.[11]

As a practical matter this issue is a concern only if external dependence and R&D intensities become more correlated as credit constraints are relaxed. We check this possibility by ranking the six countries with the highest, and six with the lowest, indicators for each measure of financial development, then computing correlations between R&D ratios and external dependence across these country groups. These correlations are all positive and range from 0.24 to 0.44. However, there is no systematic pattern across types of financial development and in most cases there is no significant difference between the higher-ranked nations and the lower-ranked nations. Thus, there is no evidence in the data that sectors with higher external dependence also are more R&D-intensive in countries with well-developed financial markets.

[11] We are grateful to a referee for pointing this out.

With respect to asset tangibility, in our data this variable is negatively correlated with external dependence at the industry level. Thus, the concern expressed in the prior paragraphs does not exist, for if firms in industries with fewer tangible assets have better innovation opportunities, and therefore higher R&D intensities, this situation would not be conflated with the absence of credit constraints in highly financially developed economies. Our hypothesized negative coefficients on the interaction terms between asset tangibility and financial development would imply that the availability of collateral does matter for the ability to raise external capital, suggesting there is a causal effect of credit constraints on R&D. Nonetheless, we compute the correlations between asset tangibility and R&D intensities in our high-development and low-development sub-samples. These correlation coefficients are all negative and vary in a narrow range between -0.31 and -0.48. More importantly, there is again no systematic pattern in these correlations across countries grouped by levels of financial development.

For all these reasons, we argue that it is unnecessary in our specification to deploy an instrumental-variables approach. However, we undertake several robustness checks to raise confidence in our results. For example, one such check is to use lagged financial development variables in our baseline specification, which gave nearly identical results to those discussed below.

3. Data

R&D intensity is calculated as industry-level R&D expenditures as a share of industry output in each country for the years 1990 to 2003.[12] We take R&D expenditures from the OECD's ANBERD database, ISIC Revision 3, with our industries defined at the two-digit level.

[12] An alternative measure, R&D expenditures as a share of value added, provides similar results.

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. Industry share is defined as each industry's production relative to GDP. GDP data (in current local currency units) are from the World Bank's *World Development Indicators 2007*.

Our proxy for each industry's external financial dependence 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 capital expenditures minus cash flow from operations divided by capital expenditures. The idea is that higher cash flow makes a firm less dependent on external finance. This variable is calculated by Klapper, et al. (2006) and follows the definition in Rajan and Zingales (1998).[13] Specifically, we use the industry-level median (across firms) of the ratio of capital expenditures minus cash flow over capital expenditures, where the numerator and denominator are summed over all years for each firm before dividing. The data from Compustat are calculated on the four-digit SIC level and then converted to the two-digit ISIC codes to match the R&D data.

Tangibility is a proxy for each industry's share of physical assets in total capital stock. Following Braun (2003), we calculate this variable using U.S. data from Compustat.[14] A firm's asset tangibility is defined as net property, plant, and equipment relative to the total book value of assets. We take the sum of the numerator and denominator over the years 1990-1999 before taking the ratio, in order to smooth any temporal fluctuations (and to match the calculation used for the external financial dependence figures). 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

[13] We thank Luc Laeven for providing us with the external financial dependence data.
[14] We thank Nathalie Moyen for assistance with the Compustat data to generate the tangibility measure.

reclassified to match the ISIC Rev. 3 two-digit codes. Tangibility has been shown to be positively associated with firms' debt obligations using U.S. data (see Braun, 2003).[15]

The measures for both external dependence and tangibility are calculated from U.S. data with the idea that they capture technological differences across industries and can thus be used to rank industries. Rajan and Zingales (1998) provide the central argument for using U.S. data. Specifically, because the United States has well-developed financial markets its levels of sectoral external dependence and tangibility are those that would exist under complete markets. Hence, these measures provide proxies for external dependence and tangibility that industries in other countries would achieve in the absence of other financial market frictions. It is important to note, however, that it is the ranking rather than the level that matters for identifying the coefficients in our regressions. Technological differences within the same industry across countries are likely to be small so that U.S. data can be used as a proxy for the ranking of industries in other countries.

We utilize a variety of measures of national financial development to capture varying aspects of both domestic and international capital markets. All domestic indicators are taken from the World Bank's *Financial Structure Database 2007*.[16] The international variables are taken from Lane and Milesi-Ferretti (2006). All indicators are expressed relative to GDP. In the benchmark specification, we use liquid liabilities, private credit by deposit money banks, stock-market capitalization, and private bond-market capitalization for the domestic dimension. We employ total external assets and liabilities, portfolio equity, FDI equity, and foreign debt to describe the international capital market dimension.

[15] Tangibility has also been used by Manova (2008) in her study on equity-market liberalization and international trade. Claessens and Laeven (2003) use a measure of asset intangibility (i.e., the ratio of intangible-to-fixed assets) and apply the Rajan and Zingales approach to focus on property rights and industry growth across countries.
[16] See Beck, et al. (2000) for details.

Liquid liabilities, which equal currency plus demand and interest-bearing liabilities of banks and other financial intermediaries, are the broadest measure of financial intermediation and are often referred to as the depth of financial markets in a country. Private credit focuses on credit issued to the private sector by banks, as opposed to credit issued to the government. Stock-market capitalization, which equals the value of listed shares, measures the size of the stock market. Similarly, bond-market capitalization, which equals the amount of outstanding domestic debt securities issued by private entities, measures the size of the private bond market.

The broadest measure of international financial development is the sum of external assets and external liabilities relative to GDP, which captures both the cumulative flows of capital and relevant valuation adjustments. This variable captures financial openness in a manner analogous to the standard measure of trade openness, which is the sum of exports and imports relative to GDP. Each component of this measure is calculated in a similar fashion. Thus, portfolio equity is the sum of external portfolio equity assets and liabilities, while FDI is the sum of FDI assets and liabilities relative to GDP. We also consider a measure of foreign debt, which is calculated as external debt assets plus liabilities (made up of portfolio debt and other investment), again relative to GDP.

The Lane and Milesi-Ferretti (2006) variables are standard *de facto* measures of international capital-market integration. Like our indicators of domestic financial development, they vary across countries and years. Further, the measures of international financial development are stock variables in the same way that the domestic financial development indicators are stock variables, thus making the types of financing directly comparable at the domestic and international level.

Other potential measures of international capital market openness are typically *de jure* measures that may be slow to change. For example, Manova (2008) uses the dates of equity-market liberalization as a measure of financial development in a study linking such liberalization to trade flows. Thus, her specification relies on the interaction between external financial dependence or tangibility and a dummy variable for the date when a country's stock market was liberalized. We believe it is preferable to use the actual measures of capital stocks to capture the level of international financial market development. Kose, et al. (2009) provide additional discussion of these *de facto* measures of capital-market openness in relation to alternative *de jure* measures. In particular, they argue that the stocks of assets and liabilities are preferable to using annual capital flows since the flows may be highly volatile and suffer from measurement error.

We exclude the United States from the analysis because we have used publicly listed firms there to calculate both the external dependence and tangibility measures per industry. This leaves 18 countries in the panel.[17] The OECD R&D expenditure data by industry are available for the years 1987-2004, although there are many missing values for 2004. Due to missing observations for earlier years in the financial structure database, we restrict our analysis to the period 1990-2003. Furthermore, we focus on the set of 22 two-digit manufacturing industries because the few service industries for which data are available have very different values of external financial dependence and tangibility in comparison with the manufacturing data.[18]

<Tables 1a-c>

[17] Australia, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, Norway, Poland, Spain, Sweden, and the United Kingdom.

[18] We take out recycling (ISIC Rev. 3 code 37) from the OECD list of available manufacturing industries because there is not a relevant 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 industry classification (for the R&D expenditures).

Table 1a depicts the industry descriptions and the two industry variables (external financial dependence and tangibility) along with the average R&D intensity for each industry. Tables 1b and 1c, respectively, summarize descriptive statistics for the data we use in our benchmark specification and report correlation coefficients for the financial development variables. Note from the last table that liquid liabilities and private credit are highly correlated, presumably because they both represent broad measures of the size of domestic credit markets. The indicators for international capital-market integration are even more highly correlated. Interestingly, the correlations between the domestic and international variables are lower and often close to zero.

Note that in our regressions we interact all of the financial development variables with the same industry-level measure for external dependence or tangibility. This approach means that the correlations among the interaction terms exceed those between the financial development variables. We thus restrict our attention to one financial development variable at a time in the baseline specification, rather than simultaneously including multiple interaction terms over different financial development variables. In the sensitivity analysis, however, we explore various combinations of the financial development measures. In particular, we include both a debt measure and a stock-market variable simultaneously to see if there is some substitutability or complementarity among the different types of financial development.

4. Results

We discuss the role of domestic and international financial markets sequentially in the following two subsections, focusing attention on our two main hypotheses: (i) R&D intensity should be higher in industries that depend more on external finance in countries with more developed financial markets, and (ii) R&D intensity should be lower in industries that have more

tangible assets in countries with more developed financial markets. Hence, estimates of β_1 should be positive while estimates of β_2 should be negative.

4.1. Domestic financial market development

Table 2 reports baseline results for specification (1) using liquid liabilities, private credit, stock-market capitalization, and private bond-market capitalization (all relative to GDP) as indicators of domestic financial market development. Each of these variables is interacted with external dependence and tangibility. We observe first that β_1, the coefficient on the interaction term using external dependence, has a positive sign and is statistically significant in all cases. Second, the coefficient on the tangibility interaction term, β_2, has a negative sign and is significant in all cases, except for stock-market capitalization. Generally, the statistical significance is lower for the tangibility interactions than for the external financial dependence interactions. Thus, we find broad support for our two hypotheses.

Third, the estimates for external dependence, interacted with liquid liabilities, private credit, or stock-market capitalization, are very similar in magnitude across specifications. This is true as well for asset tangibility interacted with liquid liabilities and private credit. The size of the private bond market coefficients differ from these levels and exert the biggest effect on R&D intensity. For external dependence, the estimate is larger by a factor of three to four while for tangibility the estimate is larger by a factor of two. Finally, it is notable that we do not find a statistically significant direct effect of financial market development on R&D intensity. For completeness we retain the level variables in the regressions but note that the coefficients on the interaction terms are little changed by leaving out these direct effects.

<Table 2>

To gauge the economic significance of the estimates, we undertake the following thought experiment. We examine by how much the R&D intensity in the 75th percentile of external dependence (furniture; manufacturing n.e.c.) exceeds the R&D intensity in the 25th percentile of external dependence (pulp, paper and paper products) if the respective financial development measure is raised from the 25th to the 75th percentile of the distribution. Put differently, we ask by how much the R&D intensity of a high-dependence sector would exceed that of a low-dependence sector if both were moved from a country with low financial development to one with high financial development. We do the same comparison for physical-capital tangibility by comparing the industry at the 75th percentile of tangibility (rubber and plastics products) with the one at the 25th percentile of tangibility (chemicals and chemical products).

Table 3 provides a summary of the economic magnitudes for the financial measures that are significant in the baseline regressions, computing the implied percentage-point change in R&D intensity and relating that value to the average R&D intensity. It is evident that the estimated effects can be quite large, with a difference in R&D intensity of up to 45 percent of the mean R&D intensity for the interaction between the size of the private bond market and external financial dependence. Specifically, the industry at the 75th percentile of external dependence has an R&D intensity that is about one percentage point higher in France (the country at the 75th percentile of bond-market capitalization) than does the industry at the 25th percentile of external dependence in Canada (the country at the 25th percentile of bond-market capitalization). This difference makes up 45 percent of the average R&D intensity. The interpretation is that deeper bond-market capitalization would increase the R&D intensity of the high-dependence sector relative to the low-dependence sector by 45 percent of the mean industry value. For liquid

liabilities, private credit, and stock-market capitalization, the magnitudes are between 18 and 25 percent of the mean R&D intensity.

Tangibility also is a substantial determinant of the cross-industry variation in R&D as financial markets get deeper. An increase in the relative size of private credit and private bond markets from the 25th-percentile to the 75th-percentile nation are both estimated to reduce R&D intensity by around 22 to 23 percent in comparing the industry at the 75th percentile of tangibility to that at the 25th percentile. The effect of more developed financial markets as measured by liquid liabilities is 16.5 percent. Put differently, the data suggest that as these markets grow relative to GDP relatively more R&D occurs in sectors with lower stocks of physical capital. One interpretation is that improvements in credit markets (measured broadly as liquid liabilities or more specifically finance supplied through banks or the bond market) tend to benefit those industries with fewer tangible assets, thus loosening credit constraints for R&D investment.

It is interesting to note that there is not a significant effect via tangibility when financial development is measured by the size of the stock market. That is, R&D intensities are not different between levels of tangibility as stock markets grow. This may suggest that firms with fewer tangible assets tap into equity markets even in countries where those markets are relatively small, as we discuss in the following section.

<Table 3>

The coefficient on the industry share in GDP is negative and significant throughout in Table 2, with similar magnitudes across the different regressions. This indicates that R&D intensity is lower in larger industries, which is similar to the finding in Rajan and Zingales (1998) that larger industries grow more slowly than smaller industries.

4.2. International financial market development

While the link between domestic financial market development and R&D intensity turns out to be strong, there is evidence for just one influential channel of international capital. We interact four measures of international integration – total external assets and liabilities, portfolio equity, FDI equity, and foreign debt – with both the external financial dependence and tangibility variables. As Table 4 shows, FDI equity seems to be the crucial international financial development dimension that affects R&D intensity via the interaction terms. Total assets and liabilities also show a (weakly) significant effect when interacted with external dependence. Since foreign direct investment is one of the components of total assets and liabilities, it might be that this effect is driven by the FDI channel.

The coefficient on the interaction between FDI equity and external dependence is highly significant while that on the tangibility interaction is less precisely estimated, though still significant. Both coefficients are of comparable sizes to those on the domestic measures for liquid liabilities, private credit, and stock-market capitalization. Turning to the magnitudes of the effects of FDI and external dependence in Table 3, we find that they are similar to the liquid liabilities and private credit variables. Specifically, the industry at the 75^{th} percentile of external dependence has an R&D intensity that is 0.44 percentage points higher in France (the country at the 75^{th} percentile of FDI) than does the industry at the 25^{th} percentile of external dependence in Germany (the country at the 25^{th} percentile of FDI). This difference makes up 19.7 percent of the average R&D intensity. For tangibility, this thought experiment delivers a difference in R&D intensity of -0.38 percentage points or -17.4 percent of average R&D intensity. The interaction between tangibility and FDI shows a similar magnitude (both in percentage points and relative to mean R&D intensity) as the liquid liability measure, which can be taken as a general measure of

overall credit in the economy. Thus, greater stocks of FDI are associated with greater R&D investments for industries with lower proportions of tangible assets.

<Table 4>

4.3. Discussion

In this section we relate our empirical findings regarding R&D investments to established theories in the finance literature. We structure our discussion according to the main contributions of this paper: (i) the role of tangibility; (ii) national versus international measures of financial development; and (iii) market-based versus intermediated finance.

Tangibility – debt versus equity

Generally, when a firm has few tangible assets, it is less able to take advantage of credit markets since it has little real capital and equipment on which to collateralize the debt. This is particularly true for R&D investment, where much of the expenditures are on wages and salaries for scientists and other researchers. We find that the results via the tangibility channel are particularly strong for the various forms of credit markets, with the largest effects for private credit and private bond-market capitalization. This is consistent with the idea that R&D expenditures face financing constraints based on the lack of tangible assets. Thus, development of such financial markets plays a particularly large role in loosening such constraints.

As noted above, the size of the stock market, interacted with tangibility, does not have a significant effect on R&D expenditures. This finding indicates that development of the stock market plays little role in relaxing credit constraints associated with low stocks of capital and equipment. This makes sense since industries with fewer tangible assets are more inclined to use equity financing, requiring no collateralization, for their R&D programs even at lower levels of

financial development. Firms in those sectors may therefore find little additional stimulus to R&D from the development of domestic stock markets.

In contrast, there is a negative impact of FDI equity interacted with tangibility. That is, FDI can allow for greater financing of R&D even for firms with few physical-capital assets. This finding is consistent with evidence that industries with high reliance on intellectual capital tend to be more multinational in scope (Markusen, 2002), indicating that FDI may loosen any capital constraints facing their R&D programs.

National versus international measures of financial development

The basic results show that financial development at the international level may be just as important as financial development at the domestic level. The significantly positive impacts of FDI (via the external finance channel) indicate that openness to international capital can increase R&D expenditures by amounts that are similar to the impacts of development of domestic credit markets. Further, the tangibility results indicate that FDI may by a useful form of financing for firms with less capital and equipment. Note that FDI offers greater potential to monitor local-affiliate R&D activities, which seems consistent with the notion that sectors with low tangibility (and higher intellectual capital) would resort to this form of international capital.

Indeed, it is not surprising that the magnitude of FDI in an economy is the primary international variable that provides significant results for relative R&D expenditures. There are a number of reasons to expect FDI to be more effective in supporting R&D activity than other forms of international finance, as discussed by Kose, et al. (2009). First, innovative activities often entail greater uncertainty than physical-capital investments (Hall, 2002, and Hall and Lerner, 2010). It thus takes a greater commitment to invest in firms with high R&D intensity. Foreign direct investment might serve this requirement quite well. Neither portfolio equity nor

foreign debt offers the monitoring activities that are embodied in FDI, and thus provide a poor alternative form of financing for those firms with fewer tangible assets.

Second, the close relationships that are often established between multinational firms and their subsidiaries may reduce the need for tangible assets as collateral to support R&D investments. Further, subsidiaries may be able to access the internal credit resources of the multinational parent.[19] Third, FDI is a considerably more stable source of funding than are short-term financial flows. In that regard, it is more likely to finance innovative activities with longer time horizons.

More fundamentally, our finding that FDI is a primary source of R&D finance complements prior studies of the growth effects of international capital liberalization. In that literature positive growth impacts are often found for FDI liberalization but not necessarily for openness to other forms of portfolio equity or debt flows (Kose, et al. 2009). For example, using country-level data Kose, et al. (2008) show that total factor productivity (TFP) growth is increased by openness to FDI and portfolio equity flows. However, growth is diminished by openness to external debt, a relationship that weakens as countries achieve higher levels of domestic financial development and better domestic institutions. They argue that FDI both provides a more stable source of funding and brings increased efficiency and potential technology spillovers. International debt flows, in contrast, are more volatile and may lead to an inefficient allocation of capital, particularly where domestic financial institutions are weak.[20] Our results add another layer to this analysis by showing that FDI can spur R&D investments,

[19] See Desai, et al. (2004) and Manova, et al. (2009).

[20] Similarly, Vlachos and Waldenström (2005) find a threshold effect in that countries above a certain level of domestic financial development see higher growth in industry output and the number of establishments when international capital markets are liberalized.

presumably because FDI supports more relationship-based finance and less arm's-length, lending.

External financial dependence – Market-based versus intermediated finance

While we present our results by the type of financing based on domestic or international sources, alternatively we can consider a division into direct or market-based finance (e.g., stock-market capitalization and bond-market capitalization) versus intermediated finance (e.g., liquid liabilities and private credit). In the literature on the financing of innovative activities, one primary argument is that once firms must access external funds, market-based financing may provide a preferred form of financing relative to bank-based financing. The notion is that banks are effective at monitoring specific firm activities where the outcomes are relatively well defined but are less able to monitor innovative activities with highly uncertain returns. Further, bank lending decisions are typically made by a single bank manager, who forms an opinion about the potential returns and may be less likely to finance highly uncertain projects.

Market-based financing, on the other hand, relies on a wide variety of opinions, with this diversity allowing for investment in uncertain activities. Allen and Gale (2000) point out that market-based systems may be particularly significant when opinions vary about the potential outcome of risky R&D investments. In this case, a diverse set of financiers obtain information and invest based on their individual priors, which may differ from other investors' expectations. Thus, development of market-based external finance is likely to be important for innovative enterprises. Conversely, bank-based systems may have a comparative advantage in monitoring borrower behavior and managing risk when there is greater agreement about the potential outcomes of investment.

This line of thinking is consistent with our results, which show that the positive impacts on R&D intensities are strongest for the stock-market capitalization and private bond-market capitalization variables (interacted with external dependence). Interestingly, we find that liquid liabilities and private credit have impacts on R&D intensity that are similar to those of stock-market capitalization. Thus, we may be picking up both the importance of market-based financing and the relative preference for debt over equity in terms of maintaining control rights. Of the international measures, FDI may incorporate aspects of both direct finance (through its equity component) and intermediated finance (since FDI entails some control over management).

Finally, note that Denis and Mihov (2003) find a negative relationship between R&D expenditures and the likelihood of issuing bonds. Those firms that do issue bonds (relative to private credit) tend to be larger, more profitable, have a higher proportion of fixed assets, and spend less on R&D. In contrast, Altunbaş et al. (2009) argue that bond markets may be particularly useful for financing activities that embody forward-looking expectations. In a study of large European firms, they find that firms with more growth opportunities (measured by higher and more visible capital investment spending, which they describe as R&D investment) prefer the bond market over syndicated loans. Thus, if large firms with higher credit ratings tend to undertake relatively more R&D investment, then this may explain the larger impacts of the private bond-market interaction terms in our regressions. Our data do not allow us to infer firm details such as size or credit ratings but this line of thought may be suggestive of the differential effects.

In summary, our findings on the determinants of relative R&D investments across industries and countries complement these various ideas. Development of domestic financial markets and openness to FDI clearly raise R&D intensities in sectors with higher degrees of

external dependence and lower proportions of physical assets. Since the latter are largely industries with much intellectual capital, these forms of market growth favor R&D expenditures in high-technology sectors. This finding may offer one clue about why growth and productivity are enhanced as found in the prior literature.

5. Sensitivity analysis and robustness

5.1 Combinations of financial development variables

An important issue is whether there is an omitted variable bias from only considering one financial development variable at a time. As can be seen in Table 1c, many of the measures of financial development are correlated with one another. Since we use those variables interacted with our measures for external financial dependence and tangibility, the correlations among the interaction terms are even higher. Thus, we are unable to include all of the financial development variables at once due to multicollinearity. Nevertheless, we consider specific combinations that measure different aspects of financial market development and hence are less correlated. Thereby, we clarify whether the development of different types of financial variables may substitute for one another. In particular, we examine combinations of the credit variables and the stock-market variables. Further, since the bond market appears to play a large role, we focus on combinations that include the private bond-market variable.

Table 5 shows the results of these combinations of financial development variables. Generally, the overall results are little changed. Domestic private credit appears to complement domestic stock-market development as the interactions with the stock-market variable remain significant when included along with interaction terms with liquid liabilities or bank credit (columns 1 and 2). The coefficients on the interactions with external dependence are somewhat smaller (and less precise for private credit and liquid liabilities). The stock-market interaction

with external dependence remains highly significant. The results on the tangibility interactions also remain largely the same, with R&D intensity responding to the two credit variables and not the stock-market size.

The stock-market capitalization interaction with external dependence is also robust to including FDI and private bonds. In each case the effects of the size of stock markets come through the external dependence channel and not through the tangibility channel.

The results on the private bond-market variable for both the interactions with external financial dependence and tangibility are quite robust, with little change in either the magnitude or significance of the interaction terms when it is included along with any of the other measures of domestic or international financial development. The coefficients on the interaction terms with liquid liabilities or private credit (columns 3 and 4) are both slightly smaller and somewhat less significant, while the coefficient on the stock-market variable (column 5) interacted with external financial dependence is somewhat larger and more significant. Thus, joint development of the private bond market and domestic credit or equity markets plays a role in facilitating higher R&D intensity.

We next consider whether domestic and international financial development measures interact with one another. Columns 6-9 of Table 5 show that the impacts of the international-equity variable (FDI) via the external dependence channel remain significant and are only slightly smaller in magnitude when included with any of the domestic credit or stock-market variables. Further, the FDI interactions have little effect on the size of the external dependence interactions with the credit variables but attenuate the size of the external dependence interactions with stock-market capitalization. One interesting finding is that the tangibility interaction with FDI generally loses significance except where stock-market capitalization is

included, in which case it takes on a larger magnitude and is more significant. Thus, with respect to financing R&D investment there appears to be a notable complementarity between development of the stock market and growth in FDI for sectors with low levels of physical assets.

<Table 5>

5.2 Institutional quality

In a recent paper, Eichengreen, et al. (2009) show that capital liberalization has positive growth effects on financially dependent industries only in countries with well developed financial systems and institutions. To rule out that overall development or institutional quality are the silent drivers behind our financial development interaction terms, we control for real GDP per capita (in logs) and a "quality of governance" index interacted with external dependence and asset tangibility.[21]

To summarize the findings, when these two controls are included the estimates of the coefficients on interactions between financial development and external dependence and tangibility are little changed. Thus, our conclusions regarding the impacts of financial market development on R&D investments remain robust. Among the interaction terms that include GDP per capita, only tangibility exerts a statistically significant effect. Specifically, we find that higher income has a positive effect on R&D investments in industries with more tangible assets. The coefficient on institutional quality by itself is positive and significant, suggesting a

[21] We do not report regression tables for this and subsequent robustness checks for the sake of brevity. However, they may be obtained from the authors upon request. Data on GDP per capita are taken from the World Bank's World Development Indicators while the institutional index is provided by the PRS Group's International Country Risk Guide (ICRG). This index reports the mean value of the sub-indicators "corruption", "law and order", and "bureaucracy quality". This measure is widely used as an indicator for institutional quality (see, for example, Kose, et al., 2008).

stimulative direct effect on R&D intensity. In this case, both interaction terms between institutional quality and industry characteristics are significant and have the expected sign as well. These results indicate that institutional development plays both direct and indirect roles in encouraging investments in research and development. The main point, however, is that including domestic institutions does not alter the importance of the different types of financial development we have already discussed.

5.3 Comparative advantage

Systematic differences among economies in economic environments or relative factor endowments generate distinct comparative advantages in industries across countries. In the regressions above we controlled for this factor by including relative industry size. However, this basic variable may not capture all the national and sectoral components of specialization. Thus, as an additional robustness check we control first for national characteristics, including country size (as measured by real GDP) and three factor endowments (labor force, real capital stock and the share of the labor force with tertiary education).[22] Real capital stock is computed from gross fixed capital formation using the perpetual inventory method. In these regressions these time-varying country variables do not exert a statistically significant effect on R&D intensity at the industry level and, more importantly, leave unaffected the estimates of the interaction terms.

To account for comparative advantage at the industry level, we compute sector-level capital-labor ratios across all countries, using data from the UNIDO Indstat 4 Database, and interact these ratios with both the real capital stock and the labor force. It is notable that our basic results are robust to controlling for both the direct and interacted effects of these additional variables. Compared to our baseline results displayed in Tables 2 and 4, estimates of the interaction terms between financial development and external dependence remain positive and

[22] All data are taken from the World Bank's World Development Indicators.

highly significant. The coefficients on tangibility retain their signs but are somewhat less significant. Overall, however, the main pattern of the effects of financial development on R&D investments remains undisturbed.

5.4 Additional robustness checks

We also consider a variety of alternative financial development variables, with similar results in most cases. These alternative measures are all taken from the World Bank's *Financial Structure Database 2007*. A somewhat broader measure, private credit by deposit money banks and other financial institutions, provides similar results to those for private credit by deposit money banks. We also consider capitalization of the public-bond market, which is found to have smaller effects and is less significant than private bond-market capitalization. Further, we compare two alternative measures of stock-market capitalization: total market value traded relative to GDP (also called market liquidity) and the market turnover ratio. The stock-market total value traded interacted with external dependence has a positive and significant coefficient of 0.015, which is somewhat smaller than the effect of market capitalization. The turnover ratio is not significant. Further, as with stock-market capitalization, neither of these alternatives is significant when interacted with tangibility. These results suggest that both stock-market size and liquidity may be relevant for R&D expenditures for those industries that rely more on external financing.

Further, note that with the exception of the Czech Republic and Poland, our sample covers advanced OECD countries. To ensure that the results are not driven by these two economies, we exclude them from the regressions and rerun each specification. We find very similar effects overall to the baseline cases. None of the previously insignificant channels becomes significant.

Recall that our industry characteristics, external dependence and asset tangibility, were calculated from data for the years 1990-99. Thus, we conduct another robustness check by restricting our regression sample to these years. The tangibility interaction term remains significant only for private bond-market capitalization and the estimate exceeds the value of the benchmark coefficient. The results on external financial dependence remain robust in this subsample. We also look at the period 1995-1999 separately since stock markets and FDI boomed during that period. The coefficients for the interaction terms on external financial dependence are generally comparable to those for the whole sample. For the tangibility interaction, the coefficients are nearly double for liquid liabilities, private credit and foreign direct investment.

6. Conclusions

In this paper we examine the impacts of financial market development on R&D intensity in 22 manufacturing industries in 18 OECD countries for the period 1990-2003. We include a range of variables capturing domestic financial market development, encompassing liquid liabilities, private credit by banks, and both stock and bond markets. Financing constraints for R&D may be particularly tight due to the intangible nature of R&D assets. Thus we ask whether expenditures on R&D in industries with greater levels of intangible assets respond more to financial development. Further, because prior literature based on firm-level analysis points to cash flow (internal funds) as important for the direct financing of R&D, we ask whether expenditures on R&D in industries that rely more on external funds respond more to financial development. Overall, we expect to see varying responses to the different types of financial development. By interacting these measures with tangibility and external financial dependence,

we identify sectoral effects of relaxations of specific financing constraints that may be detrimental to financing R&D.

We find statistically and economically strong effects for most domestic indicators of financial market development. In particular, the largest impacts arise from the development of the bond market for firms relying more on external finance. The other measures of domestic financial market development are smaller and similar to each other.

For international capital flows, foreign direct investment has by far the strongest impacts on R&D, operating both through sectoral financial dependence and asset tangibility. It is remarkable that neither portfolio investments nor foreign debt (which is a combination of portfolio debt and other investment) seem to be related to R&D intensity at the industry level. We interpret these results as suggesting that it requires strong monitoring and managerial commitment (which is present with FDI but not with more short-term and volatile portfolio investment) to support more risky investments in research and development.

The largest impacts occur in response to private bond-market growth. This outcome may be related to the size and credit ratings of firms that undertake R&D investment, although we cannot examine this question specifically due to data limitations. Alternatively, it may be that the development of private bond markets has larger effects for firms relying more on external finance because those markets allow for a greater diversity of opinion among financiers, while maintaining some control rights (in the event of bankruptcy) that stock markets do not permit.

In terms of asset tangibility, we find similar magnitudes of both credit markets and FDI, with insignificant results for stock markets. This may indicate an important role of monitoring through relationship lending for those firms with limited tangible assets, which generally correspond to a high degree of intellectual capital established through R&D spending.

In summary, we find that development of different forms of financing may stimulate R&D investment to different degrees. Policymakers in both advanced and emerging economies are keen to promote domestic private R&D spending, which is a direct input into innovation and growth. Thus, they offer tax advantages, direct subsidies and infrastructural support for R&D programs. Our results suggest that a key factor in encouraging R&D investments is access to finance of various forms. Thus, authorities may wish to remove impediments to the growth of domestic financial markets, which seem to promote higher R&D intensities in sectors with high external dependence or low asset tangibility. It also seems important to relax restrictions on FDI flows, which have similar effects and seem particularly significant for building R&D in sectors with high intellectual capital. Of course, these findings do not necessarily imply that these policies will maximize overall welfare. Rather, they underscore the need to ensure access to financial resources if R&D investments are an important policy concern.

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

Average R&D intensity is the industry average over all years (1990-2003) and countries, where R&D intensity is calculated as R&D expenditures as a share of industry output by country *j* in industry *k* in year *t* for the years 1990 to 2003. We take R&D expenditures from OECD, ANBERD database, ISIC Rev. 3, with manufacturing industries defined at the two-digit level. Columns 4 and 5 record two industry variables, calculated using Compustat data over 1990-1999. External dependence is the 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. The variable comes from Klapper, Laeven, and Rajan (2006). Tangibility is the industry-level median of the ratio of net property, plant, and equipment relative to the total book value of assets, where the numerator and denominator are summed over all years (1990-1999) for each firm before dividing.

Industry	ISIC	Average R&D intensity	External dependence	Tangibility
Food products and beverages	15	0.0024	0.1809	0.3467
Tobacco products	16	0.0060	0.9445	0.1881
Textiles	17	0.0050	0.2615	0.3433
Wearing apparel, dressing and dyeing of fur	18	0.0028	0.1743	0.1261
Leather, leather products and footwear	19	0.0036	0.0981	0.1231
Wood and products of wood and cork (except furniture)	20	0.0021	0.1560	0.4472
Pulp, paper and paper products	21	0.0050	0.1233	0.5039
Publishing, printing and reproduction of recorded media	22	0.0012	0.0959	0.2141
Coke, refined petroleum products and nuclear fuel	23	0.0048	-0.0439	0.6112
Chemicals and chemical products	24	0.0397	0.7905	0.1778
Rubber and plastics products	25	0.0135	0.2995	0.3641
Other non-metallic mineral products	26	0.0063	-0.1205	0.3887
Basic metals	27	0.0070	0.1468	0.4095
Fabricated metal products, except machinery and equipment	28	0.0050	0.1664	0.2757
Machinery and equipment, n.e.c.	29	0.0191	0.0765	0.2088
Office, accounting and computing machinery	30	0.0662	0.5015	0.1135
Electrical machinery and apparatus, n.e.c.	31	0.0292	0.1373	0.2090
Radio, television and communication equipment	32	0.0900	0.3276	0.1594
Medical, precision and optical instruments, watches and clocks	33	0.0503	0.6425	0.1452
Motor vehicles, trailers and semi-trailers	34	0.0239	0.3943	0.2728
Other transport equipment	35	0.0415	0.1235	0.2419
Furniture; manufacturing n.e.c.	36	0.0054	0.3761	0.1844

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

The table provides summary statistics over the 22 industries and 18 countries for the sample period from 1990-2003. R&D intensity is calculated as R&D expenditures as a share of industry output by country *j* in industry *k* in year *t* for the years 1990 to 2003. The R&D intensity summary statistics are taken over all industries, years, and countries. R&D expenditures are from OECD, ANBERD database, ISIC Rev. 3. Industry production (gross output at current prices) is from OECD, STAN database, ISIC Rev. 3. Industry share in GDP is defined as industry production relative to GDP. GDP data (in current local currency units) are from the World Bank's World Development Indicators 2007. External dependence is the 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 for each firm before dividing. The variable is calculated by Klapper, Laeven, and Rajan (2006), using Compustat data over 1990-1999. Tangibility is the industry-level median of the ratio of net property, plant, and equipment relative to the total book value of assets, where the numerator and denominator are summed over all years for each firm before dividing. We calculate this variable using Compustat data over 1990-1999. The second block of figures provides summary statistics (over countries and years) for the domestic financial development variables, taken from the World Bank Financial Structure Database 2007 (Beck, Demirgüç-Kunt, and Levine, 2000). The third block of figures provides summary statistics (over countries and years) for the international financial development variables, taken from Lane and Milesi-Ferretti (2006). The financial development variables are all calculated relative to GDP.

	Mean	Std. Dev.	Min	Max	Observations
R&D intensity	0.0221	0.0382	0.0000	0.7007	3802
Industry share in GDP	0.0269	0.0281	0.0003	0.2730	4662
External dependence	0.2660	0.2535	-0.1205	0.9445	22
Tangibility	0.2752	0.1321	0.1135	0.6112	22
Liquid liabilities	0.7313	0.4045	0.2733	2.4222	240
Private credit	0.7918	0.3942	0.0867	2.1785	240
Stock market capitalization	0.5816	0.4104	0.0022	2.6877	239
Private bond market capitalization	0.3398	0.2336	0.0006	1.1882	238
Total external assets and liabilities	2.5581	2.4130	0.3452	17.9457	249
Portfolio equity	0.4032	0.6116	0.0027	4.6202	246
FDI equity	0.4966	0.4405	0.0117	2.2009	249
Foreign debt	1.5649	1.5279	0.2499	11.2992	249

Table 1c: Correlations among financial development variables

The table provides correlations among the domestic and financial development variables for the 18 countries for the sample period from 1990-2003. The domestic financial development variables (the first four variables) come from the World Bank Financial Structure Database 2007 (Beck, Demirgüç-Kunt, and Levine, 2000). The international financial development variables (the last four variables) are taken from Lane and Milesi-Ferretti (2006). The financial development variables are all calculated relative to GDP.

	Liquid liabilities	Private credit	Stock market capitalization	Private bond market capitalization	Total external assets and liabilities	Portfolio equity	FDI equity	Foreign debt
Liquid liabilities	1							
Private credit	0.8327	1						
Stock market capitalization	0.2576	0.3788	1					
Private bond market capitalization	0.0312	0.0554	-0.12	1				
Total external assets and liabilities	0.0553	0.2159	0.4072	-0.0844	1			
Portfolio equity	0.0405	0.1786	0.4684	-0.1807	0.9123	1		
FDI equity	-0.0049	0.169	0.4859	0.0297	0.8127	0.6701	1	
Foreign debt	0.0786	0.2232	0.3141	-0.0792	0.9756	0.8437	0.7108	1

Table 2: Regression of R&D intensity on domestic financial development interacted with external financial dependence and tangibility

The table illustrates OLS panel regression results for 22 manufacturing industries in 18 OECD countries for the years 1990-2003. Each column represents a separate regression using a different measure of domestic financial market development (as indicated in the first row) interacted with both external financial dependence and asset tangibility. The dependent variable is R&D intensity calculated as R&D expenditures as a share of industry output. Industry share in GDP is defined as industry production relative to GDP. Robust standard errors are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%.

	Liquid liabilities	Private credit	Stock market capitalization	Private bond market capitalization
Industry share in GDP	-0.1347	-0.1386	-0.138	-0.1331
	(0.0189)***	(0.0193)***	(0.0210)***	(0.0183)***
Liquid liabilities	0.0039			
	(0.0086)			
External dependence * Liquid liabilities	0.0175			
	(0.0049)***			
Tangibility * Liquid liabilities	-0.0193			
	(0.0111)*			
Private credit		0.0025		
		(0.0059)		
External dependence * Private credit		0.0183		
		(0.0052)***		
Tangibility * Private credit		-0.0243		
		(0.0127)*		
Stock market capitalization			-0.0044	
			(0.0046)	
External dependence * Stock market capitalization			0.0233	
			(0.0057)***	
Tangibility * Stock market capitalization			-0.0047	
			(0.0119)	
Private bond market capitalization				0.0088
				(0.013)
External dependence * Private bond market cap.				0.0674
				(0.0069)***
Tangibility * Private bond market cap.				-0.0375
				(0.0112)***
Constant	0.0172	0.0195	0.0155	0.0147
	(0.0051)***	(0.0041)***	(0.0034)***	(0.0034)***
Country-, Industry- and Year-Dummies	YES	YES	YES	YES
Observations	3643	3643	3667	3626
R-squared	0.5	0.5	0.48	0.49

Table 3: Magnitudes of estimates

The first line reports the difference in R&D intensity in percentage points between an industry at the 75th percentile of external financial dependence in a country at the 75th percentile of the respective financial development and an industry at the 25th percentile of external financial dependence in a country at the 25th percentile of financial development. The second line relates the percentage point difference to the mean R&D intensity. Lines 3 and 4 show magnitudes for the same thought experiment undertaken for asset tangibility.

Differential in R&D intensity	Liquid liabilities	Private credit	Stock market capitalization	Private bond market capitalization	FDI Equity
External financial dependence	0.40	0.46	0.56	0.99	0.44
as percentage of R&D intensity	18.1	20.9	25.2	45.0	19.7
Tangibility	-0.37	-0.51	-	-0.49	-0.38
as percentage of R&D intensity	-16.5	-22.9	-	-22.3	-17.4

Table 4: Regression of R&D intensity on international financial development interacted with external financial dependence and tangibility

The table illustrates OLS panel regression results for 22 manufacturing industries in 18 OECD countries for the years 1990-2003. Each column represents a separate regression using a different measure of international financial market development (as indicated in the first row) interacted with both external financial dependence and asset tangibility. The dependent variable is R&D intensity calculated as R&D expenditures as a share of industry output. Industry share in GDP is defined as industry production relative to GDP. Robust standard errors are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%.

	Total external assets and liabilities	Portfolio equity	FDI equity	Foreign debt
Industry share in GDP	-0.1401	-0.1378	-0.1496	-0.1302
	(0.0232)***	(0.0241)***	(0.0223)***	(0.0214)***
Total external assets and liabilities	-0.0004			
	(0.0006)			
External dependence * Total external assets and liab.	0.0012			
	(0.0007)*			
Tangibility * Total external assets and liab.	-0.0008			
	(0.0019)			
Portfolio equity		-0.0002		
		(0.0025)		
External dependence * Portfolio equity		0.0037		
		(0.003)		
Tangibility * Portfolio equity		-0.003		
		(0.0087)		
FDI equity			-0.0023	
			(0.0046)	
External dependence * FDI equity			0.0194	
			(0.0052)***	
Tangibility * FDI equity			-0.0191	
			(0.0115)*	
Foreign debt				-0.0009
				(0.0008)
External dependence * Foreign debt				0.0006
				(0.0009)
Tangibility * Foreign debt				0.0011
				(0.0022)
Constant	0.0174	0.0168	0.02	0.0158
	(0.0035)***	(0.0035)***	(0.0034)***	(0.0033)***
Country-, Industry- and Year-Dummies	YES	YES	YES	YES
Observations	3795	3795	3795	3795
R-squared	0.47	0.47	0.48	0.47

Table 5: Combinations of financial development variables

The table illustrates OLS panel regression results for 22 manufacturing industries in 18 OECD countries for the years 1990-2003. Each column represents a different combination of various measures of financial development. The financial development variables are each interacted with external financial dependence and tangibility. The dependent variable is R&D intensity calculated as R&D expenditures as a share of industry output. Industry share in GDP is defined as industry production relative to GDP. Robust standard errors are in parentheses: * significant at 10 %; ** significant at 5%; *** significant at 1%.

	Liquid liabilities and stock market capitalization	Private credit and stock market capitalization	Liquid liabilities and private bond market capitalization	Private credit and private bond market capitalization	Stock market cap and private bond market cap	Liquid liabilities and FDI	Private credit and FDI	Stock market capitalization and FDI	Private bond market capitalization and FDI
Industry share in GDP	-0.1422	-0.1462	-0.1354	-0.1372	-0.1486	-0.1539	-0.1539	-0.1526	-0.1515
	(0.0206)***	(0.0211)***	(0.0181)***	(0.0185)***	(0.0201)***	(0.0226)***	(0.0226)***	(0.0233)***	(0.0210)***
Liquid liabilities	0.0046		0.0014			0.0034			
	(0.0091)		(0.0092)			(0.0085)			
Private credit		0.0041		-0.001			0.0029		
		(0.0062)		(0.0068)			(0.006)		
Stock market capitalization	-0.0058	-0.0066			-0.0059			-0.0055	
	(0.0043)	(0.0043)			(0.0052)			(0.0042)	
Private bond market capitalization			0.01	0.012	0.0066				0.0077
			(0.0151)	(0.0166)	(0.0148)				(0.0136)
FDI equity						-0.0021	-0.0029	-0.0001	-0.0034
						(0.0045)	(0.0048)	(0.0046)	(0.005)
External dependence*	0.0126		0.0147			0.0175			
Liquid liabilities	(0.0051)**		(0.0050)***			(0.0049)***			
Tangibility *	-0.0193		-0.0122			-0.0211			
Liquid liabilities	(0.0111)*		(0.0115)			(0.0113)*			

External dependence*		0.0121		0.0142			0.016		
Private credit		(0.0055)**		(0.0053)***			(0.0052)***		
Tangibility *		-0.0251		-0.0138			-0.0231		
Private credit		(0.0121)**		(0.0138)			(0.0122)*		
External dependence*	0.0172	0.0161			0.0282			0.0173	
Stock market capitalization	(0.0058)***	(0.0057)***			(0.0063)***			(0.0052)***	
Tangibility *	0.0036	0.0068			0.0007			0.0072	
Stock market capitalization	(0.011)	(0.0103)			(0.0125)			(0.0098)	
External dependence*			0.0661	0.0655	0.0757				0.0671
Private bond market capitalization			(0.0072)***	(0.0070)***	(0.0076)***				(0.0067)***
Tangibility *			-0.0385	-0.0377	-0.0329				-0.0362
Private bond market capitalization			(0.0112)***	(0.0114)***	(0.0128)**				(0.0111)***
External dependence*						0.0185	0.0164	0.0108	0.0186
FDI equity						(0.0057)***	(0.0055)***	(0.0048)**	(0.0054)***
Tangibility *						-0.0182	-0.0144	-0.022	-0.0126
FDI equity						(0.012)	(0.0113)	(0.0097)**	(0.0115)
Constant	0.0166	0.0186	0.016	0.0178	0.0143	0.0217	0.0226	0.0181	0.0184
	(0.0056)***	(0.0044)***	(0.0045)***	(0.0036)***	(0.0039)***	(0.0056)***	(0.0044)***	(0.0035)***	(0.0035)***
Country-, Industry- and Year-Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3522	3522	3467	3467	3491	3643	3643	3667	3619
R-squared	0.5	0.5	0.52	0.52	0.5	0.5	0.5	0.48	0.5