Finance and Productivity Growth: Firm-level Evidence *

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Keywords: Financial crises, Financial frictions, Innovation, Total factor productivity (TFP)

JEL classifications: D24, G30, O16

February 4, 2016

*We thank Mitchell Berlin, Simon Gilchrist, Brent Glover, João Gomes, Michael Roberts, Toni Whited, and seminar participants at Peking University, Office of Financial Research, Federal Reserve Board, Bank of England, 2012 Money, Macro and Finance conference, 2013 IBEFA summer meetings, the 2013 Asia meetings of the Econometric Society and the 2015 Fall Midwest Macro Meetings for helpful comments. Levine: Patrick Thiele Fellow in Finance, Finance Department, Wisconsin School of Business, University of Wisconsin, 975 University Ave, Madison, WI 53706, (608)262-9810, oliver.levine@wisc.edu. Warusawitharana: Board of Governors of the Federal Reserve System, Division of Research and Statistics, Mail Stop 97, 20th Street and Constitution Avenue NW, Washington, DC 20551, (202)452-3461, m1mnw00@frb.gov.

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Abstract

We examine the effect of financing frictions on corporate innovation. Using a model we show that a rise in financial frictions leads to increased sensitivity of productivity growth, our measure of innovation, to the use of external finance. We test this prediction using a large dataset of mostly private European firms and find strong evidence that financial frictions inhibit firm-level productivity growth. Our findings demonstrate an important link between financial markets and the real economy, and help to explain why economic activity remains persistently depressed following financial crisis.

1 Introduction

We examine whether financial frictions impact innovation and productivity growth at firms. A large literature has shown that financial frictions reduce investment in physical capital and influence employment decisions.[1] And yet, the effect of financial frictions on innovation and productivity growth is not well understood. Given that productivity has been shown to be key to understanding differences in economic activity across countries and over time, evidence of such a link would demonstrate an important channel through which financial frictions can propogate to the real economy.[2]

Using a stylized model, we examine the effect of financial frictions on innovation activity and productivity growth. The model implies that a rise in financial frictions leads to fewer investments in innovation, resulting in an increased sensitivity of productivity growth to the use of external finance. The latter prediction forms the basis for our empirical tests, which we carry out using firm-level data on productivity and financing from four European countries.

Our key finding is that an increase in financial frictions leads to reduced firm-level productivity growth. The estimates show that the strength of the relation between the use of external finance, specifically debt, and productivity growth is increasing in the severity of financial frictions. We demonstrate this result using a variety of proxies for financial frictions. First, we focus on firm-specific variation in financial frictions by examining the leverage or cash holdings of firms relative to their industry peers. Next, we use the industry-level measure of external finance dependency introduced by Rajan and Zingales (1998). And last, we employ variations in sovereign bond spreads as a macro-level measure of financial frictions. With each of these measures, we find that the link between financing and productivity growth strengthens as financial frictions increase.

Our results help address a number of questions. First, recent studies such as Cerra and Saxena (2008), Reinhart and Rogoff (2009a), and Reinhart and Rogoff (2009b) find that financial crises have a persistent negative effect on output. This finding is in contrast to traditional models that imply a sharp rebound following a recession. A link between financial frictions and productivity growth can help to explain this persistent negative effect, as lower productivity growth will not only

[1] Following Fazzari, Hubbard, and Petersen (1988), a large literature examines the effect on financial frictions on capital expenditures, (see Rauh (2006), Whited (2006), Chava and Roberts (2008), and Campello, Graham, and Harvey (2010), among others). A more recent literature finds that financial frictions may impact employment decisions (see Jermann and Quadrini (2012) and Falato and Liang (2014)).

[2] Clark (2008) notes the role of productivity growth in driving long-run growth. Hall and Jones (1999) find that productivity differences are key to understanding differences in output across countries. And Kydland and Prescott (1982) and Long and Plosser (1983) argue that productivity shocks provide the basis for understanding economic fluctuations.

directly lower output, but also lower subsequent employment growth and investment, amplifying the effects of financial crisis. Second, a significant literature has shown a positive relationship between financial development and growth (see Goldstein (1969) and King and Levine (1993)).[3] However, as noted in Levine (2005), the exact mechanisms by which finance influences economic development remains uncertain. The link between financial frictions and productivity growth that we investigate provides an additional channel by which finance can influence growth.

We carry out our analysis using firm-level data for a large sample of European firms obtained from the Amadeus dataset. Bureau van Dijk constructs this dataset from regulatory filings by firms in each European country. Relative to the standard Compustat sample of public U.S. firms, this dataset has two characteristics that prove helpful for our tests. First, it includes data on mid-sized, privately held firms that are likely to face financial frictions. Second, it includes data on both value-added and wage costs that are necessary to carefully measure productivity at the firm level, in addition to data on external financing.[4] In order to ensure a robust calculation of productivity, we focus on four of the larger European countries: France, Italy, Spain and the UK.[5] We carry out our analysis for the full sample and for each of these countries separately, providing an additional degree of robustness.

Our base empirical specification consists of a panel regression of firm-level total factor productivity (TFP) growth on lagged TFP growth, debt growth, a measure of financial frictions, an interaction of financial frictions with debt growth, and various control variables. We use debt growth as the primary measure of financing in our study as the bulk of the firms use equity financing infrequently. We use a variety of measures of financial frictions, including industry-adjusted leverage and cash, the external finance dependency measure of Rajan and Zingales (1998), and the sovereign bond spread. Due to the presence of lagged dependent variables, we carry out our analysis using the dynamic panel approach of Arellano and Bond (1991), and use selected lag levels of the regressors as instruments in the differenced observation equation; this approach helps partially alleviate endogeneity concerns.

Using this approach, we find that firms facing higher financial frictions exhibit a higher sensitivity of future productivity growth to debt growth. This finding supports the key prediction

[3] The broader literature that examines the link between finance and output includes Jayarathne and Strahan (1996), Butler and Cornaggia (2011), and Guiso, Sapienza, and Zingales (2004), who examine this relationship across US states, counties in some US states, and Italian regions, respectively.

[4] In comparison, Census data sets that are typically used in productivity studies do not include measures of financing.

[5] We exclude Germany due to data limitations.

of the model that a rise in financial frictions constrains a firm's productivity growth. While we find strong statistical support for this finding in our full sample, we also find strong support for this relation when we examine each country in our sample separately. We carry out a number of robustness checks on our main findings, and obtain similar results using different measures of productivity. Furthermore, our results are robust to using a broader measure of financing that includes both debt and equity finance.

One potential concern with our findings is that they may be a result of reverse causality. Specifically, debt use may correlate with future productivity growth because firms may borrow in anticipation of TFP growth, rather than borrowing to invest in productivity enhancing projects. We address this concern by using Levinsohn and Petrin (2003) to decompose productivity growth into a part that is potentially anticipated by the firm, and a part that is not anticipated. This decomposition relies on the insight in Levinsohn and Petrin (2003) that the use of fully flexible inputs, such as materials, provides information about the portion of productivity that is potentially known to the firm, but not the econometrician. Based on this decomposition, we find that our results arise only for the portion of productivity growth that is unanticipated by the firm, providing evidence against a reverse causality explanation.

Somewhat surprisingly, there are only a small number of studies that examine the effect of financial frictions on firm-level productivity. Chemmanur, Krishnan, and Nandy (2011) find that venture capital improves the productivity of private firms. Gatti and Love (2008) use World Bank survey data from Bulgaria and find that firms that lack access to credit have lower subsequent productivity growth. Ferrando and Ruggieri (2015) show that Euro area firms with a higher synthetic financial frictions measures have low productivity levels. Some closely related studies examine the role of aggregate financial conditions on firm-level productivity: Beck, Levine, and Loayza (2000) find that financial development impacts growth mainly through increased productivity; Bakke (2009) shows that an aggregate reduction of credit in Venezuela led to reduced productivity; Hsu, Tian, and Xu (2014) examine how better developed equity markets support innovations at the firm-level; Krishnan, Nandy, and Puri (2015) demonstrate that bank deregulation leads to increased productivity at US manufacturing firms; and Franklin, Rostom, and Thwaites (2015) find that firms reliant on lenders that were more adversely affected during the financial crisis had lower subsequent productivity growth. Compared to these studies, we focus on the effect of financial frictions at the firm level on their subsequent productivity growth.

The paper is organized as follows. Section 2 presents a stylized model that develops the testable hypotheses. Section 3 discusses the data used to test the model predictions. Section 4 presents the main findings of our results. Section 5 provides further tests and extensions. Section 6 concludes.

2 Model

This section presents a model that shows that, under fairly general assumptions about innovative projects and financial frictions, one obtains the following testable hypothesis: a rise in financial frictions leads to a stronger relationship between the use of finance and productivity growth.

2.1 Setup

The model builds on a standard investment model of the firm. Firms use capital, K, and labor, L, to produce output, Y, using the following Cobb-Douglas specification:

$$Y = e^z K^\alpha L^{1-\alpha}, \tag{1}$$

where α denotes the capital share and z denotes the log productivity of the firm. The price of output is normalized to 1. Firms hire labor at a fixed wage rate, w. The cash flows of the firm are given by

$$\Pi = \max_L \; Y - wL. \tag{2}$$

The capital stock depreciates at a rate, δ. We assume that firms face a quadratic adjustment cost of investment, $\lambda \frac{I^2}{2K}$; this adjustment cost is only necessary to ensure that investment is well-defined.[6]

2.2 Financing projects that increase productivity

Our point of departure is that firms can invest in innovative projects that lead to increases in productivity, z. Let S denote these expenditures on innovative projects. Recent studies such as Bloom, Sadun, and van Reenen (2012) and Eisfeldt and Papanikolaou (2013) emphasize the role of information technology investments and organizational capital in generating productivity increases at the firm level. We allow for the outcome from such expenditures to be stochastic (see Doraszelski and Jaumandreu (2013) and Warusawitharana (2015)). The firm realizes an increase

[6]It also implies that one obtains the standard Q-theoretic result for investment given by, $1 + \lambda \frac{I}{K} = q(z)$, where $q(z)$ equals firm value divided by its capital stock.

in productivity given by the stochastic function $g(S/K)$, where the increase in productivity is influenced by expenditures on innovative projects scaled by firm size. This captures the notion that larger firms must spend greater resources to obtain a similar increase in log productivity, and also maintains homotheticity. Log-productivity next period, z', is a random variable given by

$$z' = z + g(S/K). \tag{3}$$

The stochastic function specifying the increase in productivity resulting from spending on innovative projects, $g(S/K)$, is strictly increasing and concave, with $g(0) = 0$.

$$\frac{\partial g(S/K)}{\partial S} > 0, \frac{\partial^2 g(S/K)}{\partial S^2} < 0. \tag{4}$$

In addition, we assume that $g(S/K)$ satisfies the standard Inada conditions.

2.3 Financing

Firms finance physical investment and innovative projects first using free cash flow from operations, and then by accessing external finance for any remaining needs. We capture financial frictions by assuming that each unit of external finance incurs an additional proportional cost, ϕ. For simplicity, we abstract from capital structure concerns and model the firm as making a single financing decision (e.g., Gomes (2001)). We focus on the effect of changes in this financial friction on the sensitivity of productivity growth to external financing.

The amount of external finance used by the firm, F, is given by the sources and uses of funds equations:

$$F = I + \lambda \frac{I^2}{2K} + S - \Pi. \tag{5}$$

As such, an increase in expenditures on innovative projects will require firms to obtain additional financing.

The value of the firm, $V(K, z)$, is the solution to the following Bellman equation:

$$\begin{aligned} V(K, z) &= \max_{I, K', S} -F(1 + \phi \mathcal{I}(F > 0)) + \beta E[V(K', z')], \\ K' &= K(1 - \delta) + I, \end{aligned} \tag{6}$$

where β denotes the discount rate of the firm, and $\mathcal{I}(F > 0)$ denotes an indicator function that equals one when firms obtain external finance. If firms have surplus cash flow ($F < 0$), it is returned to shareholders as a dividend. The incorporation of the expenditures on innovative projects and the corresponding impact on the transition for productivity z requires an additional restriction on $g(S/K)$:

$$\frac{\partial^2}{\partial S^2} E[V(K', z')] < 0. \tag{7}$$

This expression arises as the second-order condition for optimality of the expenditure on innovative projects, S.

The presence of the financial friction implies that there exists an inactivity region where firms neither pay dividends nor obtain external financing, with physical investment and expenditures on innovative projects determined by the budget constraint. For the regions where investment decisions are determined by first order conditions, one can show that the optimal expenditures on innovative projects is given by

$$1 + \phi \mathcal{I}(F > 0) = \beta \frac{\partial}{\partial S} E\left[V(K', z')\right], \tag{8}$$

where the marginal cost of such expenditures equals $1 + \phi \mathcal{I}(F > 0)$, and the right-hand-side yields the marginal benefit. The Inada conditions on $g(S/K)$ combined with the above concavity restriction ensure an interior solution to the optimal expenditures on innovative projects, S. The above first order condition indicates how financial frictions affect the optimal expenditure on innovative projects by changing the relative cost of funds.

2.4 Model implications

The model yields a couple of implications that have been examined in the literature. It implies that an increase in the use of finance is associated with increased expenditures on innovative projects (see Brown, Fazzari, and Petersen (2009)). Related, Cornaggia, Mao, Tian, and Wolfe (2015) find that increased banking competition improves corporate innovation.[7] The model also implies that expenditures on innovative projects fall as financial frictions rise.[8]

We focus our analysis on an untested prediction that relates financial frictions to the sensitivity of productivity growth to the use of external finance. Specifically, we examine the following relationship:

[7]The connection between financial markets and innovation dates back to Schumpeter (1911).
[8]Phillips and Sertsios (2013) find that the product quality of airlines falls when firms are in financial distress.

Proposition 1 *An increase in financial frictions strengthens the relationship between financing and productivity growth. Specifically,*

$$\frac{\partial}{\partial \phi}\left(\frac{\partial g(S/K)}{\partial F}\right) > 0.$$

Proof. See Appendix. ■

Intuitively, an increase in financial frictions increases the cost of funds for financially dependent firms, resulting in lower expenditures on innovative projects. The decreasing expected returns to spending on innovation implies that productivity growth is more sensitive to spending on innovative projects when these expenditures are low. As such, the sensitivity of productivity growth to financing is increasing in the severity of financial frictions.

Figure 1 presents a graphical illustration of Proposition 1. This figure plots the expected increase in productivity arising from innovative projects as a function of the use of external finance. Panels A and B show the outcomes for a firm with low and high financial frictions, respectively. The expected increases in productivity corresponding to the optimal expenditures on innovation are labeled X_L and X_H, respectively. When financial frictions are low, firms obtain additional external finance and invest more in innovative projects, moving them farther to the right along the function $G(S/K)$ that determines the expected increase in productivity. Conversely, when financial frictions are high, firms choose a lower level of external finance, with a lower associated expected increase in productivity. Reflecting the concavity of $G(S/K)$, a given increase in financial frictions has a larger proportional impact on external financing than on the expected increase in productivity gains. Put differently, the slope of the lines connecting the origins to the points X_L and X_H—which we denote by θ_L and θ_H for low and high financial friction firms, respectively—is higher for the firm that faces high financial frictions, i.e., $\theta_H > \theta_L$. As a regression of productivity increases on external finance yields a coefficient equal to the tangent of this slope, one obtains the prediction that the sensitivity of productivity growth to external finance rises with financial frictions.

The subsequent empirical analysis in Sections 4 and 5 tests the above proposition on firm-level data from four European countries.

2.5 Alternate hypotheses

The model provides one mechanism that results in a link between financial frictions and future productivity growth at the firm level. An alternative mechanism that would give rise to such a link is that firms may obtain financing—possibly to fund capital expenditures—in expectation of future productivity increases. This alternate explanation is essentially a reverse-causality argument that would be consistent with Jeong and Townsend (2007) and Buera, Kaboski, and Shin (2011), who emphasize the importance of financing for the growth of the most productive firms in the economy.[9] Thus, our Alternate Hypothesis states that:

Alternate Hypothesis: The sensitivity of productivity growth to the use of finance rises with financial frictions because firms obtain financing in expectation of future productivity increases.

The distinction matters as, under our model, the financial system helps support endogenous productivity growth in the economy (see Romer (1990)). Under the Alternate Hypothesis, the financial system enables firms to reach the existing production frontier, not expand it. As such, the model framework implies a greater impact of the financial system on growth than the Alternate Hypothesis. This distinction also has implications for the consequences of a financial crisis. A reduction in spending on innovative projects due to a financial crisis would lower productivity growth in the economy, leading to a permanent reduction in the future level of productivity and output. In comparison, under the Alternate Hypothesis, the underlying productivity path would not be affected by a financial crisis, implying no permanent adverse effects on output. Our empirical tests will attempt to distinguish between Proposition 1 and the above Alternate Hypothesis.

Another alternate channel is that a rise in financial frictions may lead firms to reduce slack, resulting in higher productivity.[10] As most of our firms are medium-sized private firms, they are not likely to have much slack. In addition, while such a channel may explain a direct link between financial frictions and productivity, it would not explain why the sensitivity of productivity growth to the use of finance varies with financial frictions, our key testable prediction.

3 Data and Estimation

The data we use in our study are obtained from the Amadeus database maintained by Bureau Van Dijk. Bureau Van Dijk constructs this database based on required filings of annual reports for corporations in European countries. The level of detail and the degree of coverage varies across countries, reflecting the reporting requirements of each country. In particular, the filing requirements apply to both public and private firms. As such, the bulk of the sample consists of

[9] As we primarily use debt as a measure of financing, a related alternate hypothesis is that firms change their capital structure in anticipation of future productivity increases. Our tests will encompass this hypothesis as well.

[10] We thank Nick Bloom for this suggestion.

medium-sized private firms. Thus, the sample is much more comprehensive than those that focus only on publicly traded firms. The sample period extends from 2000 to 2010 and varies slightly across countries, due to the fact that Amadeus only reports 10 years of data for each country. As the data set includes many outliers, we Winsorize appropriate variables at the 97.5/2.5 percent levels in order to reduce the impact of outliers.

One key benefit of this database is that it includes the variables necessary to carefully construct measures of productivity and the use of finance at the firm-year level. As Syverson (2011) discusses, productivity is typically measured using either log regressions of value-added on labor and capital, or log regressions of revenue on materials input, labor and capital. Amadeus includes information on value-added, capital, labor (both wages and the number of employees) and, for some countries, materials usage. This enables a robust calculation of productivity at the firm level. In addition, the balance sheet component of Amadeus includes information on short-term and long-term debt as well as contributed capital, enabling us to construct measures of financing at the firm level. In comparison, we would not have the necessary detail to carry out this analysis using data sets on US firms. While Compustat provides detailed financial data, it does not enable a careful calculation of productivity as it reports only revenue, capital, and employees. One the other hand, the US Census data sets used in some productivity studies do not include firms' financing information.

We restrict the sample to four of the five largest countries in the database: France, Italy, Spain and United Kingdom (UK). We exclude Germany, the other large European country, as the Amadeus data is particularly sparse for Germany.[11] We focus on these countries to provide a large number of observations for our productivity regression, which we carry out at the country-industry level. In order to fully benefit from the scale of the database, we perform our analysis for the four countries taken together, as well as for each country individually. The latter specification allows all the coefficients to vary freely across the countries and provides an additional degree of robustness to the analysis.

The analysis is done using real, rather than nominal, values in order to eliminate the impact of aggregate price changes. We use the price of fixed assets to deflate the capital stock, and the consumer price index for all items excluding food and energy to deflate other variables. The price indices are obtained at the individual country level. As such, we measure both productivity growth and external finance in real terms.

[11] This arises due to the fact that the German reporting requirements are less stringent than those in other European countries, and most firms choose to not file detailed annual reports and instead pay the small non-reporting fine.

3.1 Measurement of productivity

We estimate productivity using a regression of value added on capital and labor inputs. Specifically, productivity—which we will denote $TFP_{i,t}$—is estimated as the residual from the following regression:

$$\log va_{i,t} = c + \alpha \log K_{i,t} + \beta \log L_{i,t} + \epsilon_{i,t}, \tag{9}$$

where $va_{i,t}$ denotes value added by firm i in year t, and $K_{i,t}$ and $L_{i,t}$ denote capital and labor inputs, respectively. The specification assumes a Cobb-Douglas production function. We do not impose a constant returns-to-scale restriction and instead allow both the capital and labor elasticities to be estimated. We estimate this regression at a 2-digit SIC code equivalent level for each country, thereby allowing the regression coefficients to vary across industries within a country. Taking differences in the residual yields the log growth rate of productivity, $\Delta TFP_{i,t+1} \equiv TFP_{i,t+1} - TFP_{i,t}$, which we use as the dependent variable in our subsequent analysis.

We measure capital using the replacement value of capital and measure labor as the staff cost of employees. We calculate the replacement value of capital following the double declining balance method employed by Summers and Salinger (1983). Using the replacement value of capital enables us to incorporate potential differences in the quality of the capital stock by vintage.[12] We measure the labor input by the staff cost, rather than the number of employees, to capture potential differences in productivity across employees. We carry out robustness checks using alternative measures of productivity, detailed in Section 5.2, to tackle concerns regarding the measurement of productivity.

In economic terms, the TFP measure we use reflects the amount of value added by the firm beyond what can be explained by its capital and labor inputs. An increase in TFP implies that, holding factor inputs constant, the firm contributes a higher amount of value added to the economy. There are many reasons for such an increase, for example the firm may improve the efficiency with which it uses its capital or workers, or the firm may increase the quality of its products, enabling it to charge higher prices. Importantly, such increases in productivity are in part likely to be driven by investments made by the firm.

[12] Effectively, this method gives a higher weight to capital that was more recently installed compared to that given by accounting measures.

3.2 Summary statistics

Table 1 presents the summary statistics from the data. The table reports means for each variable, with medians in brackets and standard deviations in parentheses. The summary statistics are reported for each country individually, as well as for the pooled sample.

For all countries, productivity growth is slightly negative on average. In particular, TFP declined notably in the years following the recent financial crisis. We also find that productivity growth is quite volatile, with significant variation within and across firms. Debt growth, adjusted for inflation, exhibits similar properties with the exception of firms in France, where firms realized substantial debt growth, on average. As most of our sample consists of mid-sized privately held firms, we use debt growth as the primary measure of financing. In order to verify that debt is indeed the marginal source of financing for these firms, we report the fraction of firms that exhibit positive debt and equity growth in the last two lines of the table. The results indicate that while nearly half of the firm-year observations report positive debt growth, only between 5 to 10 percent of firms report an increase in contributed capital, thereby confirming the importance of debt as a source of financing.[13]

The summary statistics also reveal notable differences across countries for some variables in the sample. For instance, while firms in the UK are bigger on average, firms in France have smaller leverage and higher cash holdings. As all our results are obtained from within-firm variation only, such cross-country differences are unlikely to have much impact on our findings.

3.3 Correlations

One concern with any empirical analysis is the presence of multi-collinearity in the regressors. Table 2 presents the cross-correlations for the variables used in the regression for each country in the sample. As the table indicates, there is little cross-correlation in the regressors indicating that multi-collinearity is not a serious concern in our setting.[14]

We use industry-adjusted book leverage and cash holdings as our firm-level measures of financial frictions.[15] Table 2 shows that there is a modest negative correlation between the two variables, ranging from -0.2 to -0.25 across the samples. As such, these two variables provide correlated but

[13]Computing these fractions in terms of debt or equity scaled by total assets also shows the primary role of debt finance.

[14]The largest correlation arises between log age and log assets.

[15]We adjust for industry-level effects by subtracting the industry median for a given year from the corresponding leverage and cash variables.

distinct measures of financial frictions at the firm level.

The results also indicate a small negative correlation between sales growth and TFP growth. This reflects the fact that while TFP growth quantifies growth in output per unit of factor inputs, capital and labor, sales growth incorporates growth in both TFP and the factor inputs. This negative correlation indicates that our results are not merely capturing a relationship between financial frictions and the overall growth of the firm.

3.4 Estimation approach

Proposition 1 states that the sensitivity of future productivity growth to debt growth is increasing in the severity of financial frictions. We test this proposition using the following regression:

$$\begin{aligned} \Delta TFP_{i,t+1} &= \rho_1 \Delta TFP_{i,t} + \rho_2 \Delta TFP_{i,t-1} + \gamma \Delta \text{Debt}_{i,t} + \nu \, \text{Financial friction}_{i,t} \\ &\quad + \phi \, \text{Financial friction}_{i,t} \times \Delta \text{Debt}_{i,t} + \delta X_{i,t} + a_i + b_t + \epsilon_{i,t+1}, \end{aligned} \tag{10}$$

where $\Delta TFP_{i,t+1}$ denotes real productivity growth from year t to $t+1$; $\Delta\text{Debt}_{i,t}$ denotes the log difference in real debt financing from year $t-1$ to t; $\text{Financial friction}_{i,t}$ denotes a measure of financial frictions; $X_{i,t}$ denotes control variables; and a_i and b_t denote firm and year fixed effects, respectively. The control variables include firm age, measured from the date of incorporation, firm size, measured as the log assets of the firm, sales growth from the prior year, and physical investment during year t. The key regression coefficient of interest is ϕ, with Proposition 1 implying that $\phi > 0$.

As Holtz-Eakin, Newey, and Rosen (1988) note, the presence of lagged dependent variables lead to biased estimates from traditional panel regressions. As such, we employ the dynamic panel estimator developed by Holtz-Eakin, Newey, and Rosen (1988) and Arellano and Bond (1991). This estimator uses first differences of the observation equation, with the lagged dependent variable in levels as instruments for the differenced equation. The resulting system of equations is estimated via GMM. The use of lag variables as instruments in this GMM-based estimation approach helps alleviate endogeneity concerns. The dynamic panel estimator yields two diagnostic tests: a specification test of whether the error terms in the differenced equation are serially correlated of order one, and only of order one, and a GMM-style J-test of overidentification restrictions.[16] We test these condition in all our specifications.

[16] The serial correlation of order one in the error term arises from the first differencing of the observation equation.

One concern is that the dynamic panel estimator suffers from a potential weak instruments problem. As such, we do not use the full set of lagged variables as instruments, but instead use only two lags of each of the dependent variables as instruments in our GMM specification (see Cummins, Hassett, and Oliner (2006)). This approach helps limit the number of instruments to those that may be most informative.

As the estimator begins by first-differencing the observation equation, it sweeps away any firm (or industry) fixed effect and focuses only on within-firm variation. This ensures that any effect we observe does not arise from unobserved firm-specific heterogeneity, reducing the concern of an omitted variable bias.

4 Financial frictions and productivity growth

This section presents the key results of our empirical analysis.

4.1 Use of finance and productivity growth

Before exploring the effect of financial frictions on productivity growth, we examine whether the use of finance is related to productivity growth at the firm level. Such a finding arises from our modeling assumptions that firms use external finance to invest in innovative projects that yield productivity increases. We examine this relation using the regression specification in (10), but excluding the financial friction term and it's interaction with debt growth, i.e., setting $\nu = \phi = 0$.

Table 3 reports the results of this analysis for each of the four countries in our sample individually as well as for the full sample. The results show that debt growth at the firm level has a statistically significant effect on future TFP growth. The results imply that a one standard deviation increase in debt growth is associated with between a 0.033 to 0.059 standard deviations increase in TFP over the next period. Thus, keeping factor (capital and labor) inputs constant, a rise in debt leads to a rise in value added at firms.

The results also demonstrate the persistence of TFP. The coefficient on $\Delta TFP_{i,t}$ implies that following a 10% increase in TFP we will observe a subsequent decline in TFP of between 2.0% to 2.7% next period. Thus, much of the initial increase in TFP persists. The dynamic panel estimation method performs well in the presence of this persistence, while a fixed effects panel regression would be biased due to the inclusion of the lagged dependent variable.

The coefficient estimates for the control variables indicate that firms with high sales growth have subsequently lower TFP growth, similar to the negative coefficient on lagged productivity growth. In addition, investment is positively related to future productivity growth. This could either reflect firms investing in expectation of future TFP increases, or technical progress embodied in new capital that is not fully captured by our replacement value of capital measure. Finally, firm age and size do not appear to have any clear directional impact on productivity growth.

4.2 Financial frictions

We next examine the key prediction of our model that increased financial frictions are associated with a higher sensitivity of productivity growth to the use of external finance. We use various measures of financial frictions, at the firm, industry, and aggregate levels. At the firm level, we use the deviation in book leverage from the industry median to proxy for the cost of debt. In addition, we use a similar measure based on cash holdings. These firm-level measures provide the benefit of providing significant cross-sectional and firm-level variation for identification. However, given that cash and leverage are endogenous choices of the firm, these variables are confounded with other information. For this reason we examine our prediction using an economy-wide measure of financial frictions, the sovereign debt spread. Finally, we use the external financing dependency measure of Rajan and Zingales (1998) as an industry-specific measure of financial frictions.

4.2.1 Industry-adjusted leverage

We use the leverage of a firm, relative to its industry median, as our first measure of financial frictions. Using the deviation from the industry median controls for heterogeneity in assets and processes across industries that may be lead to different leverage choices. The deviation relative to the industry is likely due to the financial condition of the firm, with higher leverage firms having higher costs of additional debt financing.

The choice of leverage as a financial frictions measure is motivated in part by models of default, such as Leland (1994) and Hennessy and Whited (2007), which imply that firms with higher leverage would have higher probability of default, and as such, face a higher cost of debt. An alternate motivation is provided by models with collateral constraints, such as Kiyotaki and Moore (1997), which imply that firms face higher shadow costs of funds as they get closer to their borrowing limit.

Table 4 presents the results obtained from estimating Equation (10), using the firm's deviation in book leverage from its industry median as of $t-1$ for our measure of financial frictions. We find a statistically significant effect for the interaction of firm-level debt growth with industry adjusted leverage for our full sample, as well as for each of the four countries in our sample taken separately. These results indicate that the sensitivity of future productivity growth to debt growth is increasing in the degree of financial frictions, supporting Proposition 1.

To interpret the economic impact implied by the coefficient estimate on the interaction term, we explore the differential effect of a change in debt for firms with varying levels of financial frictions. Specifically, given a one standard deviation increase in debt, we measure the implied future change in productivity for a firm at the 75th percentile of financial frictions minus that of a firm at the 25th percentile. Using the coefficient estimate from Table 4 for the full sample, the differential effect on productivity growth for firms with high versus low financial frictions is 7.3 percentage points. This differential effect is economically significant, revealing that the returns to additional investment in innovation are much higher for financially constrained firms.

We examine the various specification tests discussed in Arellano and Bond (1991). We find serial correlation of order one as expected. We find no evidence of serial correlation of order two for the UK, France and Spain, as well as the combined sample, indicating that these samples satisfy this test. We also examine the Hansen/Sargan J-test of the overidentification restrictions, and find no evidence to reject the model specification when we consider each country separately.[17]

4.2.2 Industry-adjusted cash holdings

We next use lagged cash holdings of the firm as a measure of financial frictions. A firm with higher cash holdings could potentially either require less external financing to invest in innovative projects or, if they were to access external debt markets, would face a lower likelihood of default. As with leverage, we use the deviation in cash holdings relative to the industry median to account for variation in cash holdings due to heterogeneity in real assets across industries. As financial frictions ease as cash holdings rise, Proposition 1 would imply a negative coefficient on the interaction term.

Table 5 presents the results from estimating Equation (10), with the deviation of the firm's cash holdings from its industry median as of $t-1$ as our measure of financial frictions. The coefficient on the interaction of cash holdings and debt growth is negative and statistically significant for the full sample, as well as for three of the four countries in our sample. In economic magnitudes, the impact of cash holdings on the sensitivity of TFP growth to debt growth is significantly smaller than the corresponding results using leverage, but still economically meaningful. Using the same

[17] The J-test rejects at the 5 percent level for the full sample, potentially due to the fact that imposing the restriction that the regression parameters are identical across the four countries leads to slightly larger model errors. However, these model errors are not large enough to reject the model at the 1 percent level.

approach as in the previous subsection, the differential effect on productivity growth for firms with high versus low financial frictions is 0.86 percentage points.

For the most part, our findings satisfy the specification tests for dynamic panel models. We find evidence of no serial correlation of order two for the full sample and each of the countries except Italy. The specifications for each of the countries taken separately also satisfy the J-test for over-identifying conditions.

4.2.3 Sovereign bond spreads

Given that leverage and cash holdings are to some extent chosen by the firm, there is a potential concern that the industry deviations we use may not fully reflect the firm's financing frictions. To address this concern, we next examine variation in aggregate financing costs over time, where we proxy for aggregate financing costs using the cost of sovereign debt. A rise in sovereign financing costs will likely directly impact the funding costs of banks, given the role of the sovereign in providing support for banks and other financial institutions (for instance, sovereigns provide an implicit guarantee for the debt of major banks). Indeed, the recent sovereign debt crisis in Europe has highlighted the degree to which the health of the banking sector is intertwined with the health of the sovereign. As a rise in financing costs for banks and other financial institutions will directly impact the availability of finance for the firms in that country—especially for the mid-sized firms that comprise the bulk of our sample—a rise in sovereign financing costs will increase financial frictions faced by firms.

We measure sovereign financing costs using the spread between each country's 10-year sovereign bond and the 10-year German bond. Taking the spread relative to the German bond eliminates potential variation in interest rates arising from changes in inflation expectations, and provides a measure of the riskiness of the sovereign. For each firm-year observation, we construct this variable as the average of the spread for the 12 month period over which the firm reports financial results. As such, firms with different fiscal year ends will have different measures of average sovereign bond spreads even within the same year.

Table 6 presents the results using the 10-year sovereign bond spread as the measure of financial frictions. Consistent with our firm-level measures of financial frictions, we find that the relationship between firm-level debt growth and subsequent TFP growth strengthens as the bond spread increases. This finding holds for the full sample, as well as for France, Spain and Italy, supporting Proposition 1. We find no significant result for the UK, possibly reflecting the fact that there is less time series variation between the bond spreads on UK and German bonds than for the other countries in the sample. The results are also economically significant, with a one percentage point rise in sovereign spreads leading to marked increase in the coefficient on debt growth: the differential effect on productivity growth for firms with high versus low financial frictions is 1.6 percentage points. Our results generally satisfy the specification test for serial correlation of order redtwo and the J-test of over-identifying restrictions.

4.2.4 External finance dependency

The next measure of financial frictions we examine is the external finance dependency of the firm's industry. One would possibly expect that firms in industries that are more dependent on external finance would face greater financial frictions than firms in less financially dependent industries (see Dell'ariccia, Detragiache, and Rajan (2008) and Buera, Kaboski, and Shin (2011)). Following Rajan and Zingales (1998), we measure the external finance dependency of firms as the median ratio of fixed assets to sales for US firms in the same 2-digit industry.

Table 7 reports the results of estimating Equation (10) using the industry external finance dependency as the measure of financial frictions. As the industry finance dependency does not vary over time, it's regression coefficient, ν, is not identified. However, the interaction of this variable with firm-level debt growth does vary over time, enabling us to estimate the coefficient of interest, ϕ.

Using this specification, we find that firms in industries that are more dependent on external finance have a greater sensitivity of productivity growth to lagged debt growth in our full sample, as well as in France and Italy; the coefficient for the U.K. is significant at the 10% level. Our findings are economically smaller than with the other proxies for financial frictions, with the differential effect on productivity growth for firms with high versus low financial frictions being 0.11 percentage points. The estimations satisfy the various specification tests for some, but not all, of the samples.

5 Alternate Explanations and Robustness

5.1 Testing for reverse causality

Our previous results demonstrated that a rise in financial frictions lead to an increased sensitivity of productivity growth to debt growth, consistent with Proposition 1. This finding is also consistent with the Alternate Hypothesis that firms obtain financing in expectation of future productivity increases, possibly to finance physical investment. This Alternate Hypothesis is essentially a form of reverse causality. This section provides a test to differentiate between these two competing explanations.

We address reverse causality by decomposing TFP growth into two components: one that is potentially anticipated by the firm and another that is not anticipated.[18] Under the Alternate Hypothesis, the relationship between productivity growth and financial frictions arises mainly from the component of TFP growth that is potentially anticipated by the firm but unknown to the econometrician. Conversely, evidence that this relationship arises mainly from the component unanticipated by the firm (and unknown to the econometrician) would be supportive of Proposition 1.[19]

The basis of our decomposition builds on the insight of Levinsohn and Petrin (2003) that the use of fully flexible inputs, such as materials, reflects expectations of TFP by the firm's management. That is, if management anticipates that TFP is going to increase, they will increase the use of flexible inputs so as to fully benefit from the higher TFP. Levinsohn and Petrin (2003) use this insight to control for the endogeneity of a firm's labor choice each period in the estimation of TFP. As a side product of their approach, one obtains a decomposition of TFP into a part that is potentially inside the information set of the firm, and thus potentially anticipated, and a part that is not. Formally, Levinsohn and Petrin (2003) employ the following specification:

$$\log va_{i,t} = c + \alpha \log K_{i,t} + \beta \log L_{i,t} + \omega_{i,t} + \eta_{i,t}, \tag{11}$$

where $\omega_{i,t}$ and $\eta_{i,t}$, respectively, denote the components of TFP that are known and unknown to the firm at time t. The known component, $\omega_{i,t}$, impacts the materials input decision of the firm in that period. Conversely, $\eta_{i,t}$ has no impact on a firm's materials input, as it is not known to the firm. Thus, one can use data on materials input as a proxy for $\omega_{i,t}$ and separately identify $\omega_{i,t}$ and $\eta_{i,t}$. As data on materials input is not available for the UK, we carry out this decomposition for the other three countries in the sample: France, Italy and Spain.

Our insight is that any information a firm had about its $TFP_{i,t+1}$ as of time t would be a subset of its information about its $TFP_{i,t+1}$ as of $t+1$, which would be captured by $\omega_{i,t+1}$. Therefore, evidence

[18] One could also describe the former as potentially inside the information set of the firm, and the latter as outside the information set of the firm. Both components are outside the information set of the econometrician.

[19] One question the reader may pose is whether our modeling framework implies that firms would have knowledge of TFP increases obtained from financing innovation. In the model, firms face uncertainty about the outcome of these TFP increasing projects, as emphasized by Doraszelski and Jaumandreu (2013), such that increases in TFP are stochastic. As such, managers are not able to fully anticipate such TFP increases.

that the relationship between debt growth and TFP growth arises mainly from the ω component would be supportive of the Alternate Hypothesis. Conversely, evidence that the relationship arises mainly from the η component would be supportive of Proposition 1. To the best of our knowledge, we are the first to use this decomposition of TFP to address potential reverse-causality concerns in TFP growth regressions.

We estimate Equation (10) separately using the two components of TFP, $\omega_{i,t}$ and $\eta_{i,t}$, as the dependent variable and report the results in Table 8. Panel A shows the results from this regression using the unanticipated component of TFP growth, $\eta_{i,t}$. The analysis is carried out for each of our four measures on financial frictions, with each of the first three columns showing the results for an individual country, and the fourth column reporting the results for the combined sample. For brevity, only the coefficient and t-statistic of the interaction between debt growth and the financial friction measure are reported. Consistent with our model and our baseline results in Tables 4–7, we find evidence that the sensitivity of the unanticipated component of TFP to debt growth is increasing in the severity of financial frictions. The significance of the estimates, both statistically and economically, are similar to our baseline results, suggesting that our previous conclusions are not due to reverse causality.

Panel B of Table 8 presents the corresponding results using the potentially anticipated component of TFP, $\omega_{i,t}$, as the dependent variable. Strikingly, we find no evidence that the sensitivity of TFP growth varies with financial frictions when we focus only on this component of TFP. This indicates that the sensitivity of TFP growth to debt growth is unlikely to arise primarily due to firm's borrowing in anticipation of future TFP growth.

Taken together, the above findings provide evidence against the Alternative Hypothesis. Some may argue that this is not surprising, as firms are not particularly likely to know, a year ahead, how much output they will produce per unit of factor inputs. The above analysis using the decomposition provided by Levinsohn and Petrin confirms this intuition.

5.2 Measurement of productivity

There are a number of related methods one can use to measure TFP at the firm level. As Syverson (2011) discusses, in many contexts, one obtains similar conclusions from these different measures of TFP. Nonetheless, it is helpful to examine whether our finding of an increase in financial frictions leading to increased sensitivity of TFP growth to debt growth is robust to different measures of TFP.

The TFP measure obtained in Equation (9) measures productivity relative to all factor inputs. Output per worker provides a simpler measure of productivity that is often used in the literature. Panel A of Table 9 presents the results from estimating the regressions of Tables 4 to 7 using value added per worker as the measure of productivity. Each row reports the results from a separate regression. For brevity, only the coefficient and t-statistic of the interaction between debt growth and the financial friction measure are reported. We find that the results are similar to those in our baseline specifications, suggesting that our findings are not sensitive to the measure of productivity.

In Panel B of Table 9 we repeat the analysis using an alternative measure of productivity commonly used in the literature, one obtained using the approach of Levinsohn and Petrin (2003).[20] While this estimation method provides some econometric advantages—it accounts for the endogeneity of the labor choice in the production function—we do not use this approach for the baseline analysis as this requires data on the materials input, a variable that is not available for UK firms. However, the results in Panel B reveal that the estimates are quite similar using this alternative measure of productivity. Taken together, these findings indicate that our results are robust to alternative measures of productivity.

5.3 Broader measure of financing

The previous results were obtained using debt as the marginal source of financing. This reflects the view that, for our sample comprised mostly of private firms, equity financing would be quite costly. In this section, we examine the robustness of our results to using the sum of debt and equity to provide a broader measure of the use of external finance.

Table 10 presents the results from estimating the regressions of Tables 4 to 7 using the sum of debt and equity as the measure of external financing. Each row reports the results from a separate regression. For brevity, only the coefficient and t-statistic of the interaction between financing growth and the financial friction measure are reported. The coefficient estimates for the full sample support Proposition 1, i.e., the sensitivity of productivity growth to the use of external finance rises with industry-adjusted leverage, sovereign bond spreads and industry external finance depdendency, and falls with industry-adjusted cash holdings. For the most part, the results are similar when we examine each of the four countries in our sample separately. In economic magnitudes, the findings using the total financing measure are close to those obtained using debt financing only.

[20]The Levinsohn-Petrin measure of productivity is the sum of $\eta_{i,t}$ and $\omega_{i,t}$ from Equation (11).

5.4 Alternate measures of financing frictions

We next investigate the robustness of our findings to measures of financial constraint indices developed in the literature. We examine the financial constraint indices developed by Cleary (1999), Whited and Wu (2006) and Hadlock and Pierce (2010). The first two methods were developed based on firm-level income and balance sheet information obtained from the Compustat data set. The latter method focused on the discussion of financing conditions in the 10-K filings of firms. Using these measures, we find no clear relationship between financial constraint indices and the sensitivity of future TFP growth to debt growth by firms.[21] One possible explanation is that these financial constraint indices—developed for publicly traded US corporations—may not necessarily be applicable for measuring financial constraints for the mostly privately-held medium-sized firms in our sample.

6 Conclusion

The recent financial crisis has shown that failures in the financial system can adversely affect real economic growth. In this paper, we expand on the existing literature by exploring the effect of financial frictions on firm-level innovation and productivity growth. We show that, in a setting where firms can invest in innovative projects, the connection between financing and productivity growth strengthens as the severity of financial frictions increases. Using firm-level European data, we find strong empirical support for this hypothesis. This findings is robust to various measures of financial frictions and productivity.

We address reverse-causality concerns using a novel decomposition of TFP into a component that is potentially inside the information set of the firm and a component that is not. TFP growth measured using the former component would potentially be anticipated by the firm, whereas TFP growth measured using the latter component would be unanticipated. Using this decomposition, we find that the sensitivity of productivity growth to debt growth rises with financial frictions in the component of TFP that is unanticipated by the firm, while no such result obtains for the anticipated component. These findings provide evidence that our results do not arise from firms increasing borrowing in anticipation of future TFP increases, a form of reverse causality.

Overall, our findings indicate that, in addition to the well-studied relationship between financial frictions and physical investment, financial frictions also lower firms' investments in innovative

[21]Results available from authors.

projects, thereby inhibiting future productivity growth. As a lower rate of productivity growth translates to lower output growth, *ceteris paribus*, our results may help explain why financial crises lead to persistently lower economic activity.

Appendix

A Proofs

Proposition 1 *An increase in financial frictions strengthens the relationship between financing and productivity growth. I.e.,*

$$\frac{\partial}{\partial \phi}\left(\frac{\partial g(S/K)}{\partial F}\right) > 0$$

Proof. Decompose the above derivative as follows:

$$\frac{\partial}{\partial \phi}\left(\frac{\partial g(S/K)}{\partial F}\right) = \frac{\partial S}{\partial \phi}\frac{\partial}{\partial S}\left(\frac{\partial g(S/K)}{\partial F}\right). \tag{A.1}$$

We first establish that the relationship between financial frictions and expenditures on innovative projects is negative. Write the optimal expenditures in innovative projects for external finance dependent firms as

$$1 + \phi = \frac{\partial}{\partial S}\beta E\left[V(K', z')\right].$$

Differentiate the above with respect to S to obtain

$$\frac{\partial \phi}{\partial S} = \frac{\partial^2}{\partial S^2}\beta E\left[V(K', z')\right].$$

By the second-order condition for an interior solution to S given in equation (7), one obtains that

$$\frac{\partial \phi}{\partial S} < 0 \quad \Rightarrow \quad \frac{\partial S}{\partial \phi} < 0. \tag{A.2}$$

Effectively, this states that an increase in financial frictions lowers optimal expenditures in innovative projects.

We establish negativity of the second expression as follows:

$$\frac{\partial}{\partial S}\left(\frac{\partial g(S/K)}{\partial F}\right) = \left(\frac{\partial^2 g(S/K)}{\partial S^2}\right)\frac{\partial S}{\partial F}.$$

One can show that an increase in expenditures on innovative projects requires an increase in financing. I.e.,

$$\frac{\partial F}{\partial S} > 0 \Rightarrow \frac{\partial S}{\partial F} > 0.$$

Combined with the concavity of $g(S/K)$, one obtains that

$$\frac{\partial}{\partial S}\left(\frac{\partial g(S/K)}{\partial F}\right) < 0 \tag{A.3}$$

Substituting equations (A.2) and (A.3) into (A.1), one obtains the desired result. ■

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Table 1: **Summary statistics.** Reports means, [medians], and (standard deviations). Sample period is 2000-2010, with two exceptions: due to data availability, sample period begins in 2001 for France and ends in 2009 for Spain. Ratios and estimates are Winsorized at the 2.5/97.5 percent levels.

	France	Italy	Spain	UK	All
ΔTFP	-0.004	-0.025	-0.008	-0.006	-0.011
	[0.000]	[-0.010]	[-0.000]	[0.000]	[-0.001]
	(0.158)	(0.224)	(0.208)	(0.260)	(0.207)
Age	23.637	25.144	17.240	28.761	21.203
	[19.000]	[23.000]	[15.000]	[21.500]	[17.250]
	(16.853)	(15.706)	(11.037)	(23.078)	(15.275)
Assets, mil. USD	27.068	49.354	31.080	385.044	62.917
	[2.289]	[11.637]	[1.971]	[23.209]	[3.746]
	(733.924)	(565.914)	(757.153)	(4524.196)	(1465.951)
Asset turnover	2.139	1.320	1.625	1.926	1.698
	[1.936]	[1.187]	[1.407]	[1.684]	[1.478]
	(1.046)	(0.715)	(1.017)	(1.277)	(1.033)
Investment	0.038	0.066	0.077	0.045	0.064
	[-0.028]	[-0.012]	[-0.005]	[0.015]	[-0.009]
	(0.369)	(0.351)	(0.383)	(0.306)	(0.368)
Sales growth	0.028	0.003	0.032	0.029	0.025
	[0.022]	[0.011]	[0.027]	[0.028]	[0.023]
	(0.140)	(0.194)	(0.220)	(0.197)	(0.198)
Book leverage	0.122	0.275	0.223	0.309	0.219
	[0.080]	[0.269]	[0.174]	[0.258]	[0.171]
	(0.123)	(0.173)	(0.190)	(0.252)	(0.190)
Cash	0.138	0.052	0.107	0.093	0.101
	[0.087]	[0.020]	[0.059]	[0.043]	[0.051]
	(0.145)	(0.077)	(0.125)	(0.127)	(0.125)
Debt growth	0.082	0.009	0.009	-0.010	0.024
	[0.013]	[-0.003]	[-0.088]	[-0.018]	[-0.037]
	(0.946)	(0.625)	(0.769)	(0.727)	(0.782)
Sovereign bond spread	0.068	0.376	0.038	0.699	0.168
	[0.031]	[0.256]	[0.022]	[0.737]	[0.032]
	(0.090)	(0.279)	(0.079)	(0.216)	(0.259)
Ext. Fin. Dependency	0.222	0.246	0.233	0.250	0.235
	[0.139]	[0.154]	[0.139]	[0.133]	[0.145]
	(0.295)	(0.315)	(0.315)	(0.391)	(0.318)
Debt growth> 0, ratio	0.504	0.499	0.384	0.474	0.448
Equity growth> 0, ratio	0.053	0.094	0.054	0.065	0.068

Table 2: **Correlations.** Reports correlation tables of variables used in the baseline regression. Book leverage and cash are industry-adjusted.

	ΔTFP	Log age	Log assets	Sales growth	Debt growth	Book leverage	Cash
France							
ΔTFP	1.00						
Log age	-0.00	1.00					
Log assets	-0.02	0.30	1.00				
Sales growth	-0.08	-0.06	0.08	1.00			
Debt growth	0.06	0.00	0.04	0.05	1.00		
Book leverage	0.07	-0.08	-0.01	-0.03	0.27	1.00	
Cash	-0.05	0.03	-0.11	0.01	-0.02	-0.22	1.00
Italy							
ΔTFP	1.00						
Log age	-0.01	1.00					
Log assets	-0.01	0.20	1.00				
Sales growth	-0.08	-0.05	0.09	1.00			
Debt growth	0.04	-0.02	0.04	0.09	1.00		
Book leverage	0.05	-0.06	0.02	-0.04	0.22	1.00	
Cash	-0.03	0.01	-0.07	0.02	-0.07	-0.26	1.00
Spain							
ΔTFP	1.00						
Log age	-0.02	1.00					
Log assets	-0.05	0.41	1.00				
Sales growth	-0.08	-0.08	0.03	1.00			
Debt growth	0.04	-0.01	0.09	0.06	1.00		
Book leverage	0.04	-0.07	0.14	0.01	0.29	1.00	
Cash	-0.05	0.01	-0.11	0.01	-0.08	-0.25	1.00
UK							
ΔTFP	1.00						
Log age	0.00	1.00					
Log assets	0.01	0.16	1.00				
Sales growth	-0.08	-0.06	0.06	1.00			
Debt growth	0.03	0.00	0.07	0.11	1.00		
Book leverage	0.06	-0.12	0.07	-0.01	0.21	1.00	
Cash	-0.04	-0.00	-0.08	-0.00	-0.05	-0.23	1.00
All							
ΔTFP	1.00						
Log age	-0.01	1.00					
Log assets	-0.04	0.36	1.00				
Sales growth	-0.08	-0.08	0.03	1.00			
Debt growth	0.04	-0.00	0.05	0.06	1.00		
Book leverage	0.03	-0.07	0.14	-0.00	0.23	1.00	
Cash	-0.04	0.00	-0.14	0.01	-0.05	-0.26	1.00

Table 3: **Baseline specification.** Reports coefficients (t-stats) for an Arellano-Bond dynamic panel data regression using the first two lags of the dependent variable as regressors. The dependent variable is ΔTFP_{t+1}. The last three lines report the p-values of a test for first and second order auto-correlation in the error term, and the p-value for the Hansen J-test. Year fixed effects were included but not reported. Statistical significance at the 1 and 5 percent level is indicated by ** and *.

	France	Italy	Spain	UK	All
$\Delta\text{TFP}_{i,t}$	-0.20**	-0.21**	-0.20**	-0.27**	-0.23**
	(-17.18)	(-17.42)	(-6.24)	(-18.13)	(-44.41)
$\Delta\text{TFP}_{i,t-1}$	-0.06**	-0.07**	-0.04	-0.08**	-0.06**
	(-8.03)	(-8.26)	(-1.91)	(-5.34)	(-16.00)
Log $\text{age}_{i,t}$	-1.11	0.75	2.88	0.22	1.09*
	(-1.49)	(1.89)	(1.51)	(0.09)	(2.31)
Log $\text{assets}_{i,t}$	-0.16**	-0.02	0.00	-0.13	-0.04**
	(-4.78)	(-1.03)	(0.07)	(-0.90)	(-2.61)
Sales $\text{growth}_{i,t}$	-0.14**	-0.15**	-0.14**	-0.15**	-0.14**
	(-15.30)	(-15.54)	(-30.11)	(-6.03)	(-29.04)
$\text{Investment}_{i,t}$	0.05**	0.08**	0.04**	0.05	0.05**
	(18.89)	(20.05)	(9.75)	(1.83)	(39.77)
Debt $\text{growth}_{i,t}$	0.013**	0.016**	0.006*	0.021**	0.008**
	(4.52)	(10.91)	(2.14)	(2.82)	(10.66)
Obs.	130,437	124,142	297,325	49,129	601,033
Serial corr. test, order 1 (p-val)	<0.001	<0.001	0.016	<0.001	<0.001
Serial corr. test, order 2 (p-val)	0.316	0.042	0.061	0.818	0.492
Hansen J-Test (p-val)	0.170	0.187	0.089	0.402	0.009

Table 4: **Industry-adjusted book leverage.** Reports coefficients (t-stats) for an Arellano-Bond dynamic panel data regression using the first two lags of the dependent variable as regressors. The dependent variable is ΔTFP_{t+1}. The last three lines report the p-values of a test for first and second order auto-correlation in the error term, and the p-value for the Hansen J-test. Year fixed effects were included but not reported. Statistical significance at the 1 and 5 percent level is indicated by ** and *.

	France	Italy	Spain	UK	All
$\Delta\text{TFP}_{i,t}$	-0.25**	-0.32**	-0.26**	-0.39**	-0.28**
	(-17.99)	(-9.17)	(-7.62)	(-21.66)	(-22.14)
$\Delta\text{TFP}_{i,t-1}$	-0.07**	-0.08**	-0.06**	-0.11**	-0.07**
	(-9.43)	(-7.54)	(-2.89)	(-7.44)	(-16.03)
Log age$_{i,t}$	-0.81	0.68	2.01	-0.61	1.08*
	(-1.09)	(1.68)	(1.10)	(-0.23)	(2.29)
Log assets$_{i,t}$	-0.19**	-0.18**	-0.13*	-0.32*	-0.14**
	(-6.06)	(-3.88)	(-2.47)	(-2.07)	(-5.57)
Sales growth$_{i,t}$	-0.13**	-0.13**	-0.13**	-0.13**	-0.12**
	(-15.60)	(-11.22)	(-22.38)	(-5.32)	(-23.38)
Investment$_{i,t}$	0.05**	0.07**	0.04**	0.03	0.05**
	(20.13)	(14.53)	(10.06)	(1.20)	(40.38)
Debt growth$_{i,t}$	0.038**	0.124**	0.058**	0.122**	0.050**
	(27.55)	(5.01)	(4.09)	(13.18)	(6.17)
Adj. book leverage$_{i,t-1}$	1.057**	2.211**	0.982**	1.302**	1.081**
	(10.62)	(4.40)	(3.69)	(14.01)	(5.23)
Debt growth$_{i,t}$ $\times$ Adj. book leverage$_{i,t-1}$	0.321**	0.474**	0.325**	0.369**	0.351**
	(12.17)	(5.01)	(5.16)	(12.05)	(6.94)
Obs.	130,436	124,142	297,325	49,129	601,032
Serial corr. test, order 1 (p-val)	<0.001	<0.001	<0.001	0.001	<0.001
Serial corr. test, order 2 (p-val)	0.971	0.002	0.221	0.667	0.909
Hansen J-Test (p-val)	0.484	0.767	0.105	0.282	0.045

Table 5: **Industry-adjusted cash holdings.** Reports coefficients (t-stats) for an Arellano-Bond dynamic panel data regression using the first two lags of the dependent variable as regressors. The dependent variable is ΔTFP_{t+1}. The last three lines report the p-values of a test for first and second order auto-correlation in the error term, and the p-value for the Hansen J-test. Year fixed effects were included but not reported. Statistical significance at the 1 and 5 percent level is indicated by ** and *.

	France	Italy	Spain	UK	All
$\Delta\text{TFP}_{i,t}$	-0.09**	-0.19**	-0.17**	-0.25**	-0.18**
	(-5.68)	(-15.05)	(-5.18)	(-12.99)	(-27.10)
$\Delta\text{TFP}_{i,t-1}$	-0.06**	-0.07**	-0.05*	-0.08**	-0.06**
	(-6.64)	(-8.06)	(-2.38)	(-4.63)	(-12.55)
Log $\text{age}_{i,t}$	-1.34	0.79	0.89	-0.63	1.28*
	(-1.43)	(1.96)	(0.42)	(-0.23)	(2.42)
Log $\text{assets}_{i,t}$	-0.17**	-0.01	-0.04	-0.16	-0.03
	(-3.74)	(-0.38)	(-0.71)	(-1.03)	(-1.51)
Sales $\text{growth}_{i,t}$	-0.13**	-0.15**	-0.12**	-0.14**	-0.13**
	(-10.44)	(-15.35)	(-23.19)	(-5.20)	(-22.73)
$\text{Investment}_{i,t}$	0.04**	0.07**	0.02**	0.02	0.04**
	(11.61)	(18.61)	(4.11)	(0.97)	(26.41)
Debt $\text{growth}_{i,t}$	0.012**	0.017**	0.011**	0.024**	0.009**
	(3.26)	(10.42)	(3.39)	(3.20)	(10.36)
Adj. cash $\text{holdings}_{i,t-1}$	1.387**	1.043**	1.179**	1.116**	1.128**
	(25.97)	(12.98)	(25.10)	(7.70)	(24.86)
Debt $\text{growth}_{i,t} \times$ Adj. cash $\text{holdings}_{i,t-1}$	-0.025**	-0.071**	-0.056**	-0.026	-0.045**
	(-4.14)	(-4.84)	(-8.39)	(-1.51)	(-12.39)
Obs.	118,143	123,762	273,712	42,465	558,082
Serial corr. test, order 1 (p-val)	<0.001	<0.001	<0.001	<0.001	<0.001
Serial corr. test, order 2 (p-val)	0.251	0.010	0.945	0.646	0.155
Hansen J-Test (p-val)	0.140	0.057	0.154	0.648	0.008

Table 6: **Financial conditions: 10-year bond spread to Germany.** Reports coefficients (t-stats) for an Arellano-Bond dynamic panel data regression using the first two lags of the dependent variable as regressors. The dependent variable is ΔTFP_{t+1}. The last three lines report the p-values of a test for first and second order auto-correlation in the error term, and the p-value for the Hansen J-test. Year fixed effects were included but not reported. The 10-yr spread is the spread between the ten-year soveriegn debt yield for the home country and the ten-year German debt yield. Statistical significance at the 1 and 5 percent level is indicated by ** and *.

	France	Italy	Spain	UK	All
$\Delta\text{TFP}_{i,t}$	-0.21**	-0.21**	-0.16**	-0.27**	-0.23**
	(-20.06)	(-17.39)	(-6.08)	(-20.02)	(-44.39)
$\Delta\text{TFP}_{i,t-1}$	-0.06**	-0.07**	-0.01	-0.07**	-0.06**
	(-8.87)	(-8.34)	(-0.84)	(-6.19)	(-16.01)
Log $\text{age}_{i,t}$	-0.76*	0.74	5.22**	0.80	1.26**
	(-2.29)	(1.90)	(3.08)	(0.33)	(2.61)
Log $\text{assets}_{i,t}$	-0.15**	-0.02	0.06	-0.10	-0.04*
	(-8.34)	(-1.15)	(1.53)	(-0.69)	(-2.48)
Sales $\text{growth}_{i,t}$	-0.14**	-0.15**	-0.14**	-0.15**	-0.14**
	(-20.75)	(-14.53)	(-25.88)	(-5.62)	(-29.05)
$\text{Investment}_{i,t}$	0.05**	0.07**	0.05**	0.05	0.05**
	(20.13)	(18.86)	(11.87)	(1.75)	(39.90)
Debt $\text{growth}_{i,t}$	0.009**	0.008**	0.001	0.027**	0.005**
	(4.28)	(3.34)	(0.30)	(2.83)	(5.67)
10-yr spread_t	-1.846	2.024	7.602	-0.325	0.234**
	(-1.18)	(1.01)	(0.69)	(-0.31)	(4.77)
Debt $\text{growth}_{i,t} \times$ 10-yr spread_t	0.048**	0.025**	0.048*	-0.011	0.021**
	(3.10)	(3.86)	(2.18)	(-0.99)	(7.52)
Obs.	130,437	124,142	297,325	49,129	601,033
Serial corr. test, order 1 (p-val)	<0.001	<0.001	0.403	0.001	<0.001
Serial corr. test, order 2 (p-val)	0.316	0.063	0.003	0.967	0.213
Hansen J-Test (p-val)	0.185	0.239	0.118	0.327	0.077

Table 7: **Dependence on external financing.** Reports coefficients (t-stats) for an Arellano-Bond dynamic panel data regression using the first two lags of the dependent variable as regressors. The dependent variable is ΔTFP_{t+1}. The last three lines report the p-values of a test for first and second order auto-correlation in the error term, and the p-value for the Hansen J-test. Year fixed effects were included but not reported. Dependence on external financing is measured as the median ratio of PP&E to sales for the corresponding U.S. industry, following Rajan and Zingales (1998). Statistical significance at the 1 and 5 percent level is indicated by ** and *.

	France	Italy	Spain	UK	All
$\Delta\text{TFP}_{i,t}$	-0.20**	-0.21**	-0.20**	-0.28**	-0.23**
	(-17.18)	(-17.37)	(-6.24)	(-17.88)	(-44.41)
$\Delta\text{TFP}_{i,t-1}$	-0.06**	-0.07**	-0.04	-0.08**	-0.06**
	(-8.02)	(-8.27)	(-1.89)	(-5.13)	(-15.90)
Log $\text{age}_{i,t}$	-1.10	0.74	2.91	-0.07	1.10*
	(-1.48)	(1.85)	(1.53)	(-0.03)	(2.33)
Log $\text{assets}_{i,t}$	-0.16**	-0.02	0.00	-0.14	-0.04*
	(-4.74)	(-1.06)	(0.08)	(-1.00)	(-2.57)
Sales $\text{growth}_{i,t}$	-0.14**	-0.15**	-0.14**	-0.15**	-0.14**
	(-15.27)	(-15.56)	(-30.09)	(-6.07)	(-29.16)
$\text{Investment}_{i,t}$	0.05**	0.08**	0.04**	0.05	0.05**
	(18.87)	(20.00)	(9.79)	(1.74)	(39.67)
Debt $\text{growth}_{i,t}$	0.010**	0.014**	0.006*	0.019*	0.007**
	(3.78)	(8.21)	(2.13)	(2.55)	(8.42)
Debt $\text{growth}_{i,t}$ $\times$ Ext. fin. dependency	0.012**	0.008*	0.002	0.013	0.007**
	(5.08)	(2.32)	(0.71)	(1.74)	(4.81)
Obs.	130,363	123,683	296,853	48,542	599,441
Serial corr. test, order 1 (p-val)	<0.001	<0.001	0.019	<0.001	<0.001
Serial corr. test, order 2 (p-val)	0.320	0.032	0.060	0.743	0.523
Hansen J-Test (p-val)	0.168	0.179	0.093	0.340	0.011

Table 8: **Testing for reverse causality using Levinsohn-Petrin decomposition.** For each of the four measures of financial frictions, Equation (10) is estimated using an Arellano-Bond dynamic panel data regression. For brevity, only the coefficient estimate on the interaction between debt growth and the financial frictions measure is reported, with t-statistic in parentheses. TFP growth is decomposed into two components: one that is not anticipated by the firm ($\eta_{i,t}$), and one that is potentially anticipated ($\omega_{i,t}$). The unanticipated and anticipated components are used as the dependent variable in Panels A and B, respectively. Statistical significance at the 1 and 5 percent level is indicated by ** and *.

A. Unanticipated component of TFP ($\eta_{i,t}$)

	France	Italy	Spain	All
Debt growth$_{i,t}$ × Adj. book leverage$_{i,t-1}$	0.268**	0.337**	0.377**	0.415**
	(4.44)	(2.64)	(4.55)	(5.51)
Debt growth$_{i,t}$ × Adj. cash holdings$_{i,t-1}$	-0.020*	-0.063**	-0.048**	-0.044**
	(-2.12)	(-4.35)	(-7.06)	(-9.68)
Debt growth$_{i,t}$ × 10-yr spread$_t$	0.024	0.030**	0.075**	0.038**
	(1.05)	(4.63)	(2.83)	(8.48)
Debt growth$_{i,t}$ × Ext. fin. dependency	0.015**	0.009*	0.005	0.011**
	(3.98)	(2.50)	(1.60)	(5.61)

B. Anticipated component of TFP ($\omega_{i,t}$)

	France	Italy	Spain	All
Debt growth$_{i,t}$ × Adj. book leverage$_{i,t-1}$	0.020	-0.283	0.031	0.015
	(1.24)	(-1.05)	(0.74)	(0.27)
Debt growth$_{i,t}$ × Adj. cash holdings$_{i,t-1}$	0.003	-0.002	-0.010*	-0.003
	(1.30)	(-0.31)	(-2.39)	(-1.46)
Debt growth$_{i,t}$ × 10-yr spread$_t$	0.007	-0.019	-0.033	-0.008*
	(0.62)	(-0.96)	(-1.71)	(-2.04)
Debt growth$_{i,t}$ × Ext. fin. dependency	-0.003*	-0.001	0.000	-0.001
	(-2.18)	(-0.23)	(0.16)	(-0.76)

Table 9: **Alternate measures of productivity.** For each of the four measures of financial frictions, Equation (10) is estimated using an Arellano-Bond dynamic panel data regression. For brevity, only the coefficient estimate on the interaction between debt growth and the financial frictions measure is reported, with t-statistic in parentheses. We use two approaches to estimate productivity growth, the dependent variable. Panel A uses labor productivity, measured as value added per worker. Panel B uses the Levinsohn-Petrin method to estimate productivity. Statistical significance at the 1 and 5 percent level is indicated by ** and *.

A. Labor productivity

	France	Italy	Spain	UK	All
Debt growth$_{i,t}$ × Adj. book leverage$_{i,t-1}$	0.252**	-0.063	0.250**	0.373**	0.397**
	(8.62)	(-1.10)	(4.46)	(15.50)	(8.40)
Debt growth$_{i,t}$ × Adj. cash holdings$_{i,t-1}$	-0.015*	-0.084**	-0.047**	-0.008	-0.036**
	(-2.43)	(-4.37)	(-6.98)	(-0.42)	(-8.07)
Debt growth$_{i,t}$ × 10-yr spread$_t$	0.047*	0.027	-0.013	-0.002	0.015**
	(2.31)	(1.90)	(-0.63)	(-0.17)	(4.72)
Debt growth$_{i,t}$ × Ext. fin. dependency	0.011**	0.022**	0.003	0.006	0.008**
	(3.69)	(3.76)	(1.03)	(0.71)	(4.13)

B. Levinsohn-Petrin method

	France	Italy	Spain	All
Debt growth$_{i,t}$ × Adj. book leverage$_{i,t-1}$	0.327**	0.377*	0.323**	0.283**
	(11.27)	(2.50)	(4.39)	(4.03)
Debt growth$_{i,t}$ × Adj. cash holdings$_{i,t-1}$	-0.023**	-0.064**	-0.052**	-0.047**
	(-3.63)	(-3.90)	(-6.06)	(-10.06)
Debt growth$_{i,t}$ × 10-yr spread$_t$	0.047*	0.032**	-0.017	0.038**
	(2.26)	(3.80)	(-0.45)	(8.04)
Debt growth$_{i,t}$ × Ext. fin. dependency	0.011**	0.007	0.009**	0.009**
	(3.76)	(1.75)	(2.59)	(5.35)

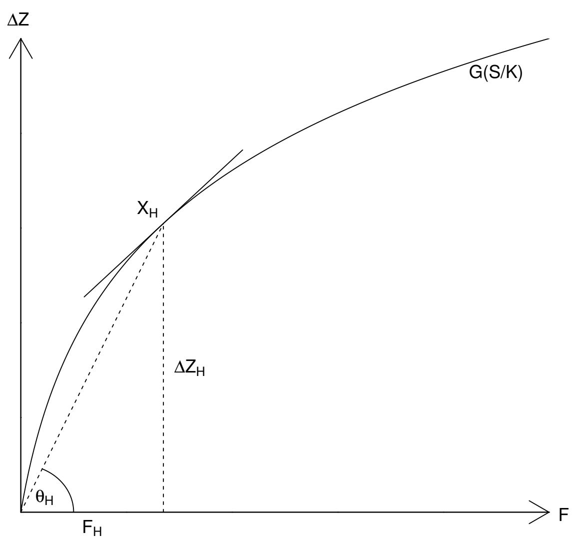
Table 10: **Total financing.** For each of the four measures of financial frictions, Equation (10) is estimated where debt growth has been replaced by growth in the sum of debt and equity financing. For brevity, only the coefficient estimate on the interaction between debt growth and the financial frictions measure is reported, with t-statistic in parentheses. Statistical significance at the 1 and 5 percent level is indicated by ** and *.

	France	Italy	Spain	UK	All
Financing growth$_{i,t}$ × Adj. book leverage$_{i,t-1}$	0.364**	0.276**	0.160**	0.438**	0.206**
	(12.32)	(7.50)	(2.62)	(9.38)	(6.60)
Financing growth$_{i,t}$ × Adj. cash holdings$_{i,t-1}$	-0.085**	-0.097**	-0.009**	-0.038*	-0.017**
	(-8.03)	(-7.44)	(-2.89)	(-2.09)	(-5.53)
Financing growth$_{i,t}$ × 10-yr spread$_t$	0.120**	0.022**	-0.146*	-0.014	0.032**
	(4.46)	(3.21)	(-2.25)	(-1.13)	(3.47)
Financing growth$_{i,t}$ × Ext. fin. dependency	0.020**	0.003	0.006**	0.017*	0.007**
	(4.71)	(0.97)	(4.39)	(2.09)	(6.32)

Figure 1: Productivity increases from innovative projects

The figure compares expected increases in productivity arising from investment in innovative projects. Panel A presents the increase in productivity as a function of external finance under low financial frictions, while Panel B presents the corresponding figure under high financial frictions. θ denotes the slope of the line connecting the origin to the point (labeled as X) that marks the expected increase in productivity from the optimal investment in innovative projects. Subscripts L and H denote optimal choices under low and high financial frictions, respectively.

Panel A: Low financial frictions



Panel B: High financial frictions