# Finance and Productivity Growth: Firm-level Evidence \*

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#### Abstract

We examine the effect of financing frictions on productivity growth at the firm level. Using a model we show that a rise in financial frictions leads to increased sensitivity of productivity growth to the use of external finance. We test this prediction using a large dataset of mostly private European firms and find strong evidence supporting the prediction. 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 crises.

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

JEL classifications: D24, G30, O16

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# 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.<sup>1</sup> And yet, the effect of financial frictions on innovation and
productivity growth is not well understood. Given that productivity is 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.<sup>2</sup>

<sup>9</sup> Using a stylized model, we examine the effect of financial frictions on innovation activity <sup>10</sup> and productivity growth. The model implies that a rise in financial frictions leads to fewer <sup>11</sup> investments in innovation, resulting in an increased sensitivity of productivity growth to <sup>12</sup> the use of external finance. The latter prediction forms the basis for our empirical tests, <sup>13</sup> which we carry out using firm-level data on productivity and financing from three European <sup>14</sup> countries.

Our key finding is that an increase in financial frictions leads to increased sensitivity 15 of firm-level productivity growth to debt growth. Viewed through the lens of our model, 16 this suggests that financial frictions hamper productivity growth at the firm level. We 17 demonstrate this result using a variety of proxies for financial frictions. First, we focus 18 on firm-specific variation in financial frictions by examining the leverage, cash holdings and 19 interest expense ratios of firms relative to their industry peers. Next, we use the industry-level 20 measure of external finance dependency introduced by Rajan and Zingales (1998). And last, 21 we employ variations in sovereign bond spreads as a macro-level measure of financial frictions. 22 With each of these measures, we find that the link between financing and productivity growth 23 strengthens as financial frictions increase. 24

<sup>&</sup>lt;sup>1</sup>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)).

 $<sup>^{2}</sup>$ 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.

Our results help address a number of questions. First, studies such as Cerra and Saxena 25 (2008), Reinhart and Rogoff (2009a), and Reinhart and Rogoff (2009b) find that financial 26 crises have a persistent negative effect on output. This finding is in contrast to traditional 27 models that imply a sharp rebound following a recession (see Hall (2016) for a discussion). 28 A link between financial frictions and productivity growth can help to explain this persistent 29 negative effect, as lower productivity growth will not only directly lower output, but also 30 lower subsequent employment growth and investment, amplifying the effects of financial 31 crisis. Second, a significant literature has shown a positive relationship between financial 32 development and growth (see Goldstein (1969) and King and Levine (1993)).<sup>3</sup> However, 33 as noted in Levine (2005), the exact mechanisms by which finance influences economic 34 development remains uncertain. The link between financial frictions and productivity growth 35 that we investigate provides an additional channel by which finance can influence growth. 36

We carry out our analysis using firm-level data on a large sample of European firms 37 obtained from the Amadeus dataset. Bureau van Dijk constructs this dataset from regulatory 38 filings by firms in each European country. Relative to the standard Compustat sample of 39 public U.S. firms, this dataset has two characteristics that prove helpful for our tests. First, 40 it includes data on mid-sized, privately held firms that are likely to face financial frictions. 41 Second, it includes data on both value-added and wage costs that allow us to accurately 42 measure productivity at the firm level, in addition to data on external financing.<sup>4</sup> We 43 use data from three large European countries: France, Italy and Spain.<sup>5</sup> We carry out our 44 analysis for the full sample and for each of these countries separately, providing an additional 45 degree of robustness. 46

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

<sup>&</sup>lt;sup>3</sup>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.

<sup>&</sup>lt;sup>4</sup>In comparison, Census data sets that are typically used in productivity studies do not include measures of financing.

<sup>&</sup>lt;sup>5</sup>Germany and the UK are not included due to data limitations.

firms use equity financing infrequently. We use a variety of measures of financial frictions, including industry-adjusted leverage, cash, and interest expense ratios, 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 58 sensitivity of future productivity growth to debt growth. This finding supports the model 59 prediction that a rise in financial frictions constrains a firm's productivity growth. While we 60 find strong statistical support for this finding in our full sample, we also find strong support 61 for this relation when we examine each country in our sample separately. We carry out a 62 number of robustness checks on our main findings, and obtain similar results using different 63 measures of productivity. Furthermore, our results are robust to using a broader measure of 64 financing that includes both debt and equity finance. 65

One potential concern with our findings is that they may be a result of reverse causality. 66 Specifically, debt use may correlate with future productivity growth because firms may 67 borrow in anticipation of TFP growth, rather than borrowing to invest in productivity 68 enhancing projects. We address this concern by using Levinsohn and Petrin (2003) to 69 decompose productivity growth into a part that is potentially anticipated by the firm, and a 70 part that is not anticipated. This decomposition relies on the insight in Levinsohn and Petrin 71 (2003) that the use of fully flexible inputs, such as materials, provides information about the 72 portion of productivity that is potentially known to the firm, but not the econometrician. 73 Based on this decomposition, we find that our results arise only for the portion of productivity 74 growth that is unanticipated by the firm, providing evidence against a reverse causality 75 explanation. 76

The paper is organized as follows. Section 2 provides a brief literature review. Section 3 presents a stylized model that develops the testable hypotheses. Section 4 discusses the data used to test the model predictions. Section 5 presents the main findings of our results. Section 6 provides further tests and extensions. Section 7 concludes.

# <sup>81</sup> 2 Literature review

A growing literature examines the effect of financial frictions on firm-level productivity. 82 Chemmanur, Krishnan, and Nandy (2011) find that venture capital improves the produc-83 tivity of private firms. Gatti and Love (2008) use World Bank survey data from Bulgaria 84 and find that firms that lack access to credit have lower subsequent productivity growth. 85 Ferrando and Ruggieri (2015) show that Euro area firms with a higher synthetic financial 86 frictions measures have low productivity levels. Caggese (2019) finds that Italian firms that 87 are in industries with greater financial constraints exhibit less productivity growth over the 88 life cycle. And Manaresi and Pierri (2018) find that credit supply contractions during the 89 Great Recession led to reduced output and productivity at Italian firms. Compared to these 90 studies, we proposed a novel method of investigating whether financial frictions hamper 91 productivity growth at the firm-level, apply it to a broad data set of European firms and 92 find evidence in support of this mechanism. 93

Some closely related studies examine the role of aggregate financial conditions on firm-94 level productivity: Beck, Levine, and Loayza (2000) find that financial development impacts 95 growth mainly through increased productivity; Bertrand, Schoar, and Thesmar (2007) find 96 the French banking reforms of 1985 helped improve the allocative efficiency of firms; 97 Bakke (2009) shows that an aggregate reduction of credit in Venezuela led to reduced 98 productivity; Hsu, Tian, and Xu (2014) examine how better developed equity markets gg support innovations at the firm-level; Krishnan, Nandy, and Puri (2015) demonstrate that 100 bank deregulation leads to increased productivity at US manufacturing firms; and Franklin, 101 Rostom, and Thwaites (2015) find that firms reliant on lenders that were more adversely 102 affected during the financial crisis had lower subsequent productivity growth. Compared to 103 these studies, we focus on the effect of financial frictions at the firm level on their subsequent 104 productivity growth. 105

Studies that provide potential explanations for why economic activity remains persistently depressed following a financial crisis include the follow. Bassetto, Cagetti, and Nardi (2015) argue that increased financing costs for entrepreneurs lead to persistently lower output. Clementi and Palazzo (2015) show that reduced entry may lead to a persistent

output drop. Farmer (2014) finds that a decline in asset prices due to lower animal spirits 110 can lead to lasting declines in employments. Hall (2011) emphasizes the role of the zero lower 111 bound on holding down output following a crisis. Christiano, Eichenbaum, and Trabandt 112 (2015) argue that financial frictions played a key role in the evolution of the economy during 113 and immediately after the Great Recession. And Petrosky-Nadeau and Wasmer (2015) point 114 to frictions in goods market as important for understanding persistence in labor markets. By 115 contrast to these studies, we argue that the effect of financial frictions of productivity growth 116 at the firm-level helps explain the slow recovery of economies following financial crises. 117

# $_{118}$ 3 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.

### 123 3.1 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  $\alpha$  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,  $\delta$ . 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.<sup>6</sup>

<sup>&</sup>lt;sup>6</sup>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.

#### <sup>127</sup> 3.2 Financing projects that increase productivity

Our point of departure is that firms can invest in innovative projects that lead to increases in 128 productivity, z. Let S denote these expenditures on innovative projects. Recent studies such 129 as Bloom, Sadun, and van Reenen (2012) and Eisfeldt and Papanikolaou (2013) emphasize 130 the role of information technology investments and organizational capital in generating 131 productivity increases at the firm level. We allow for the outcome from such expenditures to 132 be stochastic (see Doraszelski and Jaumandreu (2013) and Warusawitharana (2015)). The 133 firm realizes an increase in productivity given by the function  $g(S/K, \epsilon)$ , where the increase 134 in productivity is influenced by expenditures on innovative projects scaled by firm size and an 135 exogenous i.i.d. random variable  $\epsilon$ . The random variable  $\epsilon$  is realized after the firm chooses 136 S. Scaling by K captures the notion that larger firms must spend greater resources to obtain 137 a similar increase in log productivity, and also maintains homotheticity. Log-productivity 138 next period, z', is a random variable given by 139

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

The stochastic function specifying the increase in productivity resulting from spending on innovative projects,  $g(S/K, \epsilon)$ , is strictly increasing and concave in its first term:

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

In addition, we assume that  $g(S/K, \epsilon)$  satisfies the standard Inada conditions with respect to the first term, S/K.

### <sup>142</sup> 3.3 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,  $\phi$ . For simplicity, we abstract from capital structure concerns and model the firm as making a single financing decision (e.g., Gomes (2001)).<sup>7</sup> We focus on the effect

<sup>&</sup>lt;sup>7</sup>We also abstract from financing labor costs, the intermediate input in the model. Incorporating this feature, as in Jermann and Quadrini (2012), will not affect the testable prediction of the model as the intraperiod financing choice will be separable from the inter-period choice of borrowing for innovative projects.

of changes in this financial friction on the sensitivity of productivity growth to externalfinancing.

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

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

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

where  $\beta$  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:

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

<sup>153</sup> This expression arises as the second-order condition for optimality of the expenditure on <sup>154</sup> 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  $g(S/K, \epsilon)$  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.

### **3.4** 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.<sup>8</sup> The model also implies that expenditures on innovative projects fall as financial frictions rise.<sup>9</sup>

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:

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

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

170 **Proof.** See Section A of the Supplementary Materials. ■

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

<sup>&</sup>lt;sup>8</sup>The connection between financial markets and innovation dates back to Schumpeter (1911).

<sup>&</sup>lt;sup>9</sup>Phillips and Sertsios (2013) find that the product quality of airlines falls when firms are in financial distress.

low, firms obtain additional external finance and invest more in innovative projects, moving 181 them farther to the right along the function  $E[g(S/K,\epsilon)]$  that determines the expected 182 increase in productivity. Conversely, when financial frictions are high, firms choose a lower 183 level of external finance, with a lower associated expected increase in productivity. Reflecting 184 the concavity of  $E[g(S/K,\epsilon)]$ , a given increase in financial frictions has a larger proportional 185 impact on external financing than on the expected increase in productivity gains. Put 186 differently, the slope of the lines connecting the origins to the points  $X_L$  and  $X_H$ —which we 187 denote by  $\theta_L$  and  $\theta_H$  for low and high financial friction firms, respectively—is higher for the 188 firm that faces high financial frictions, i.e.,  $\theta_H > \theta_L$ . As a regression of productivity increases 189 on external finance yields a coefficient equal to the tangent of this slope, one obtains the 190 prediction that the sensitivity of productivity growth to external finance rises with financial 191 frictions. 192

For simplicity, we assume that financing costs are linear in the amount of external financing. If financing costs are increasing and convex in the amount of external financing, Proposition 1 and the above intuition holds, as the convex financing costs only cause firms to further reduce investment in innovations, increasing the sensitivity of productivity growth to external finance.

One limitation of the model is that it does not consider investment in innovation whose return is only realized after many periods. This could open the possibility for additional distortions in the financing and investment trade off; for example, managers with short-term incentives may increase current profits at the expense of R&D spending (see Terry (2017)). While in many settings the relationship between financing and investment would be similar, long-term returns to innovation may change the model predictions.

The empirical analysis in Sections 5 and 6 tests Proposition 1 using firm-level data from three European countries.

### <sup>206</sup> 3.5 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 expendituresin 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.<sup>10</sup> 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 217 endogenous productivity growth in the economy (see Romer (1990)). Under the Alternate 218 Hypothesis, the financial system enables firms to reach the existing production frontier, not 219 expand it. As such, the model framework implies a greater impact of the financial system 220 on growth than the Alternate Hypothesis. This distinction also has implications for the 221 consequences of a financial crisis. A reduction in spending on innovative projects due to 222 a financial crisis would lower productivity growth in the economy, leading to a permanent 223 reduction in the future level of productivity and output. In comparison, under the Alternate 224 Hypothesis, the underlying productivity path would not be affected by a financial crisis, 225 implying no permanent adverse effects on output. Our empirical tests will attempt to 226 distinguish between Proposition 1 and the above Alternate Hypothesis. 227

Another alternate channel is that a rise in financial frictions may lead firms to reduce slack, resulting in higher productivity.<sup>11</sup> 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

<sup>233</sup> prediction.

 $<sup>^{10}</sup>$ 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.

<sup>&</sup>lt;sup>11</sup>We thank Nick Bloom for this suggestion.

# <sup>234</sup> 4 Data and Estimation

The data we use in our study are obtained from the Amadeus database maintained by 235 Bureau Van Dijk. Bureau Van Dijk constructs this database based on required filings of 236 annual reports for corporations in European countries. The level of detail and the degree 237 of coverage varies across countries, reflecting the reporting requirements of each country. 238 In particular, the filing requirements apply to both public and private firms. As such, the 239 bulk of the sample consists of medium-sized private firms. Thus, the sample is much more 240 comprehensive than those that focus only on publicly traded firms. The sample period 241 extends from 2000 to 2010 and varies slightly across countries, due to the fact that Amadeus 242 only reports 10 years of data for each country. As the data set includes many outliers, we 243 Winsorize appropriate variables at the 97.5/2.5 percent levels in order to reduce the impact 244 of outliers. 245

One key benefit of this database is that it includes the variables necessary to carefully 246 construct measures of productivity and the use of finance at the firm-year level. As Syverson 247 (2011) discusses, productivity is typically measured using either log regressions of value-248 added on labor and capital, or log regressions of revenue on materials input, labor and capital. 249 Amadeus includes information on value-added, capital, labor (both wages and the number 250 of employees) and, for some countries, materials usage. This enables a robust calculation of 251 productivity at the firm level. In addition, the balance sheet component of Amadeus includes 252 information on short-term and long-term debt as well as contributed capital, enabling us to 253 construct measures of financing at the firm level. In comparison, we would not have the 254 necessary detail to carry out this analysis using data sets on US firms. While Compustat 255 provides detailed financial data, it does not enable a careful calculation of productivity as it 256 reports only revenue, capital, and employees. One the other hand, the US Census data sets 257 used in some productivity studies do not include firms' financing information. 258

We restrict the sample to three of the five largest countries in the database: France, Italy and Spain. We do not include Germany as the Amadeus data is particularly sparse for this country.<sup>12</sup> The UK is also excluded because Amadeus does not provide data on materials

<sup>12</sup> 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

input needed for our productivity estimation. We focus on these countries to provide a large number of observations for our productivity estimation, which we carry out at the countryindustry level. In order to fully benefit from the scale of the database, we perform our analysis for the three 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.

### **4.1** Measurement of productivity

We assume that the production function is Cobb-Douglas and takes the form

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

where  $va_{i,t}$  denotes value added by firm i in year t, and  $K_{i,t}$  and  $L_{i,t}$  denote capital and 274 labor inputs, respectively. Productivity—which we will denote  $TFP_{i,t}$ —is given by the 275 residual  $\epsilon_{i,t}$ . We do not impose a constant returns-to-scale restriction and instead allow 276 both the capital and labor elasticities to be estimated. We estimate productivity using 277 the approach of Wooldridge (2009), a generalized method of moments implementation of 278 Levinsohn and Petrin (2003). The approach decomposes productivity into observed and 279 unobserved components and uses the firm's materials input as the intermediate input to 280 serve as a proxy for unobserved productivity. See Section 6.1 for further discussion of the 281 Levinsohn and Petrin (2003) approach. 282

We estimate this model 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.

non-reporting fine.

We measure capital using the replacement value of capital and measure labor as the 287 staff cost of employees. We calculate the replacement value of capital following the double 288 declining balance method employed by Summers and Salinger (1983). Using the replacement 289 value of capital enables us to incorporate potential differences in the quality of the capital 290 stock by vintage.<sup>13</sup> We measure the labor input by the staff cost, rather than the number 291 of employees, to capture potential differences in productivity across employees. We carry 292 out robustness checks using alternative measures of productivity, detailed in Section B.2, to 293 tackle concerns regarding the measurement of productivity. 294

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.

#### 302 4.2 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. This reflects the overall low productivity growth of these countries over this period, as well as the notable decline in TFP in the immediate aftermath of the financial crisis.<sup>14</sup> 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

 $<sup>^{13}</sup>$ Effectively, this method gives a higher weight to capital that was more recently installed compared to that given by accounting measures.

<sup>&</sup>lt;sup>14</sup>Petrin, White, and Reiter (2011) show that within-firm productivity growth is noticeably weaker than aggregate productivity for U.S. firms.

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 the marginal source of financing.<sup>15</sup>

The summary statistics also reveal differences across countries for some variables in the sample. These cross country differences are unlikely to have much direct effect on the results because our estimation approach uses only within-firm variation.

Finally, we report the correlation matrix for the variables of interest in Section B.1 of the Supplementary Materials. We find little cross-correlation in the regressors indicating that multi-collinearity is not a serious concern in our setting.

#### 326 4.3 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:

$$\Delta TFP_{i,t+1} = \rho_1 \Delta TFP_{i,t} + \rho_2 \Delta TFP_{i,t-1} + \gamma \Delta \text{Debt}_{i,t} + \nu \text{ Financial friction}_{i,t} + \psi \text{ Financial friction}_{i,t} \times \Delta \text{Debt}_{i,t} + \delta X_{i,t} + a_i + b_t + \epsilon_{i,t+1}, \quad (10)$$

where  $\Delta TFP_{i,t+1}$  denotes real productivity growth from year t to t+1;  $\Delta Debt_{i,t}$  denotes 330 the log difference in real debt financing from year t - 1 to t; Financial friction<sub>i,t</sub> denotes a 331 measure of financial frictions;  $X_{i,t}$  denotes control variables; and  $a_i$  and  $b_t$  denote firm and 332 year fixed effects, respectively. The control variables include firm age, measured from the 333 date of incorporation, firm size, measured as the log assets of the firm, sales growth from 334 the prior year, and physical investment during year t. Standard errors are heteroskedasticity 335 robust and adjust for clustering at the firm level. The key regression coefficient of interest 336 is  $\psi$ , with Proposition 1 implying that  $\psi > 0$ . 337

 $<sup>^{15}\</sup>mathrm{Computing}$  these fractions in terms of debt or equity scaled by total assets also shows the primary role of debt finance.

As Holtz-Eakin, Newey, and Rosen (1988) note, the presence of lagged dependent 338 variables lead to biased estimates from traditional panel regressions. As such, we employ the 339 dynamic panel estimator developed by Holtz-Eakin, Newey, and Rosen (1988) and Arellano 340 and Bond (1991). This estimator uses first differences of the observation equation, with 341 the lagged dependent variable in levels as instruments for the differenced equation. The 342 resulting system of equations is estimated via GMM. The use of lag variables as instruments 343 in this GMM-based estimation approach helps alleviate endogeneity concerns. The dynamic 344 panel estimator yields two diagnostic tests: a specification test of whether the error terms 345 in the differenced equation are serially correlated of order one, and only of order one, and 346 a GMM-style J-test of overidentification restrictions.<sup>16</sup> We test these condition in all our 347 specifications. 348

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.

# <sup>358</sup> 5 Financial Frictions and Productivity Growth

<sup>359</sup> This section presents the key results of our empirical analysis.

### <sup>360</sup> 5.1 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

<sup>&</sup>lt;sup>16</sup>The serial correlation of order one in the error term arises from the first differencing of the observation equation.

that yield productivity increases. We examine this relation using the regression specification in Eq. (10), but excluding the financial friction term and its interaction with debt growth, i.e., setting  $\nu = \psi = 0$ .

Table 2 reports the results of this analysis for each of the three countries in our sample individually as well as for the full sample. The results show that debt growth at the firm level has a highly statistically significant effect on future TFP growth, with the exception of Spain. The results imply that a one standard deviation increase in debt growth is associated with between a 0.036 to 0.064 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 2.2% to 2.6% 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, while larger firms exhibit slower productivity growth, firm age does not have a clear relationship with productivity growth.

### **5.2** 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 country levels. At the firm level, we use three proxies for financial frictions: book leverage, cash holdings, and interest expense ratio. These are measured as book debt divided by total assets, cash divided by total assets, and the interest expense divided by lagged book debt. These firm-level

measures of financial frictions have the benefit of providing significant cross-sectional and 393 firm-level variation for identification. At the same time, these variables reflect endogenous 394 choices of the firm. To mitigate this concern, each of these firm-level measures are taken 395 relative to the industry median. This adjustment controls for heterogeneity in firms across 396 industries. For example, firms in capital-intensive industries may use more debt because they 397 have greater access to collateral. In addition, we lag all financial frictions proxies by one 398 period to mitigate simultaneity bias, and include control variables in all specifications in order 390 to account for observable heterogeneity. Finally, as an alternative approach to addressing 400 the potential endogeneity issues of these measures, we also use financial frictions proxies that 401 are constructed at the country and industry levels. Specifically, we use the country-specific 402 sovereign debt spread and the industry-specific external financing dependency measure of 403 Rajan and Zingales (1998). 404

#### 405 **5.2.1** Leverage

We use the leverage of a firm, relative to its industry median, as our first measure of financial frictions. 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. Empirically, both Kaplan and Zingales (1997) and Whited and Wu (2006) find that financial constraints are increasing in leverage.

Table 3 presents the results obtained from estimating Eq. (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 industryadjusted leverage for our full sample, as well as for each of the three 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, as indicated by Proposition 1.

To interpret the economic impact implied by the coefficient estimate on the interaction 422 term, we explore the differential effect of a change in debt for firms with varying levels of 423 financial frictions. Specifically, given a one standard deviation increase in debt, we measure 424 the future change in productivity for a firm at the 75th percentile of financial frictions minus 425 that of a firm at the 25th percentile implied by the interaction term. Using the coefficient 426 estimate from Table 3 for the full sample, the differential effect on productivity growth for 427 firms with high versus low financial frictions is 6.6 percentage points. This differential effect 428 is economically significant, revealing that the returns to additional investment in innovation 429 are higher for financially constrained firms. 430

Although the key regression coefficient of interest for testing Proposition 1 in Eq. (10)431 is the interaction term,  $\psi$ , the coefficient on the financial frictions measure,  $\nu$ , may also be 432 of interest. If our proxy captured only financial frictions, we would expect the coefficient  $\nu$ 433 to be negative. Perhaps surprisingly, we find that the coefficient on leverage is positive and 434 significant. One possible explanation for this is that it is capturing the effect of longer lags 435 in the returns to innovations financed with debt, with firms that had higher debt growth 436 before t-1 exhibiting both higher leverage and higher productivity growth from t to t+1. 437 This does not necessarily indicate that leverage is a poor proxy for financial frictions but 438 simply that past borrowing is also informative about future growth. 439

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 France, Italy 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.<sup>17</sup>

#### 446 5.2.2 Cash holdings

<sup>447</sup> We next use lagged cash holdings of the firm as a measure of financial frictions. A firm <sup>448</sup> with higher cash holdings could potentially either require less external financing to invest

<sup>&</sup>lt;sup>17</sup>The *J*-test rejects at the 1 percent level for the full sample, potentially due to the fact that imposing the restriction that the regression parameters are identical across the three countries leads to slightly larger model errors.

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 across industries. Because financial frictions ease as cash holdings rise, Proposition 1 would imply a negative coefficient on the interaction term,  $\psi$ .

Table 4 presents the results from estimating Eq. (10) using adjusted cash holding as of 454 t-1 as our measure of financial frictions. The coefficient on the interaction of cash holdings 455 and debt growth is negative and statistically significant for the full sample, as well as for 456 all three countries in our sample. In economic magnitudes, the impact of cash holdings on 457 the sensitivity of TFP growth to debt growth is significantly smaller than the corresponding 458 results using leverage, but still economically meaningful. Using the same approach as in the 459 previous subsection, the differential effect on productivity growth for firms with high versus 460 low financial frictions is 0.42 percentage points. In addition, the coefficient on adjusted cash 461 holdings,  $\nu$ , is positive and significant, suggesting that firms with more cash have higher 462 future growth. This could be because lower financial frictions allow for greater growth. 463

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

#### 468 5.2.3 Interest expense

As an additional firm-level approach, we use the ratio of interest expense to lagged debt as a measure of financial frictions faced by firms. Interest expense captures both the price of debt finance and the extent of current borrowing by firms, and firms with higher interest expenses likely face a higher marginal cost of further borrowing. As with our other firm-level financial friction measures, we use deviations in interest expenses relative to the industry median to control for heterogeneity across industries.

Table 5 presents the results from estimating Eq. (10) using the firm's adjusted interest expense ratio as of t - 1 as our measure of financial frictions. We find that, for the combined sample, the sensitivity of productivity growth to lagged debt growth increases with interest expenses, consistent with Proposition 1. In economic magnitudes, the results for the combined sample indicate that the differential impact of a one standard deviation increase in debt growth for a firm that faces high financial constraints equals 0.91 percentage points. At the individual country level, the results are not as strong as with the leverage and cash measures, with much of the significance driven by firms in Italy.

In contrast to the leverage proxy for financial frictions, the direct effect of the interest expense ratio on future growth,  $\nu$ , is mostly negative. This suggests that firms with the highest cost of debt, independent of the amount of borrowing, are likely to experience lower growth going forward.

#### <sup>487</sup> 5.2.4 Sovereign bond spreads

Given that leverage, cash holdings, and interest expense are, to some extent, chosen by the 488 firm, there is a potential concern that they may not fully reflect the firm's financing frictions. 489 To help address this concern, we next examine variation in aggregate financing costs over 490 time, where we proxy for aggregate financing costs using the cost of sovereign debt. A rise 491 in sovereign financing costs will likely directly impact the funding costs of banks, given the 492 role of the sovereign in providing support for banks and other financial institutions (see 493 Bofondi, Carpinelli, and Sette (2013)). Indeed, the recent sovereign debt crisis in Europe 494 has highlighted the degree to which the health of the banking sector is intertwined with the 495 health of the sovereign. As a rise in financing costs for banks and other financial institutions 496 will directly impact the availability of finance for the firms in that country—especially for 497 the mid-sized firms that comprise the bulk of our sample—a rise in sovereign financing costs 498 will increase financial frictions faced by firms. 499

We measure sovereign financing costs using the spread between each country's 10year 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 507 financial frictions. Consistent with our firm-level measures of financial frictions, we find that 508 the relationship between firm-level debt growth and subsequent TFP growth strengthens as 509 the bond spread increases. This finding holds for the full sample, as well as for France and 510 Italy, supporting Proposition 1. The coefficient implies a differential effect on productivity 511 growth for firms with high versus low financial frictions of 0.49 percentage points. Our results 512 generally satisfy the specification test for serial correlation of order two and the J-test of 513 over-identifying restrictions. 514

#### 515 5.2.5 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 Eq. (10) using the industry external finance dependency as the measure of financial frictions. As the industry finance dependency does not vary over time, its regression coefficient,  $\nu$ , 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,  $\psi$ .

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 Spain; the coefficient for Italy 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 0.14 percentage points. The estimations satisfy the various specification tests for some, but not all, of the samples.

# <sup>535</sup> 6 Alternate Explanations and Robustness

This section examines the possibility of reverse causality and provides additional robustness tests.

### 538 6.1 Testing for reverse causality

<sup>539</sup> Our previous results demonstrated that a rise in financial frictions lead to an increased <sup>540</sup> sensitivity of productivity growth to debt growth, consistent with Proposition 1. This <sup>541</sup> finding is also consistent with the Alternate Hypothesis that firms obtain financing in <sup>542</sup> expectation of future productivity increases, possibly to finance physical investment. This <sup>543</sup> Alternate Hypothesis is essentially a form of reverse causality. This section provides a test <sup>544</sup> to differentiate between these two competing explanations.

<sup>545</sup> We address reverse causality by decomposing TFP growth into two components: one <sup>546</sup> that is potentially anticipated by the firm and another that is not anticipated.<sup>18</sup> Under the <sup>547</sup> Alternate Hypothesis, the relationship between productivity growth and financial frictions <sup>548</sup> arises mainly from the component of TFP growth that is potentially anticipated by the <sup>549</sup> firm but unknown to the econometrician. Conversely, evidence that this relationship arises <sup>550</sup> mainly from the component unanticipated by the firm (and unknown to the econometrician) <sup>551</sup> would be supportive of Proposition 1.<sup>19</sup>

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,

 $<sup>^{18}</sup>$ 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.

<sup>&</sup>lt;sup>19</sup>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). As such, managers are not able to fully anticipate such TFP increases.

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  $\eta_{i,t}$ .

<sup>557</sup> Our insight is that any information a firm had about its  $TFP_{i,t+1}$  as of time t would <sup>558</sup> be a subset of its information about its  $TFP_{i,t+1}$  as of t + 1, which would be captured by <sup>559</sup>  $\omega_{i,t+1}$ . Therefore, evidence that the relationship between debt growth and TFP growth arises <sup>560</sup> mainly from the  $\omega$  component would be supportive of the Alternate Hypothesis. Conversely, <sup>561</sup> evidence that the relationship arises mainly from the  $\eta$  component would be supportive of <sup>562</sup> Proposition 1. To the best of our knowledge, we are the first to use this decomposition of <sup>563</sup> TFP to address potential reverse-causality concerns in TFP growth regressions.

We estimate Eq. (10) separately using the two components of TFP,  $\omega_{i,t}$  and  $\eta_{i,t}$ , as the 564 dependent variable and report the results in Table 8. Panel A shows the results from this 565 regression using the unanticipated component of TFP growth,  $\eta_{i,t}$ . The analysis is carried 566 out for each of our five measures on financial frictions, with each of the first three columns 567 showing the results for an individual country, and the fourth column reporting the results 568 for the combined sample. For brevity, only the coefficient and t-statistic of the interaction 569 between debt growth and the financial friction measure are reported. Consistent with our 570 model and our baseline results in Tables 3–7, we find evidence that the sensitivity of the 571 unanticipated component of TFP to debt growth is increasing in the severity of financial 572 frictions. The significance of the estimates, both statistically and economically, are similar 573 to our baseline results, suggesting that our previous conclusions are not due to reverse 574 causality. 575

Panel B of Table 8 presents the corresponding results using the potentially anticipated 577 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 firms 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 (2003) confirms this intuition.

While this analysis helps address reverse causality concerns, mechanisms other than that 585 presented in Proposition 1 may generate the observed results. In particular, keeping financial 586 frictions constant, unobserved firm-level shocks to opportunities to innovate could lead firms 587 to borrow more and invest in innovation, potentially generating a similar relationship between 588 debt growth, financial frictions and productivity growth. However, the robustness of the 589 results to using industry- and country-level measures of financial frictions suggests this is 590 not the case. Another possible explanation is if, as in Gilchrist, Schoenle, Sim, and Zakrajšek 591 (2017), financially constrained firms reduce their need for debt finance by keeping prices high, 592 thus reducing the future customer base and productivity. 593

### <sup>594</sup> 6.2 Additional robustness checks

We perform additional robustness checks. Specifically, estimating our interaction regressions using labor productivity or the productivity measured using a simple OLS estimation of Eq. (9) reveals that, in most specifications, the sensitivity of productivity growth to debt growth increases as financial frictions increase. Estimating our models using the sum of debt and equity to capture external finance, we obtain similar results with four of our financial constraints measures. These results are presented in Sections B.2 and B.3 of the Supplementary Materials.

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. In unreported results, we find no clear relationship between financial constraint indices and the sensitivity of future TFP growth to debt growth by firms. One possible explanation is that these financial constraint indices—developed for publicly traded US corporations—may not be applicable for measuring financial constraints for the mostly privately-held medium-sized firms in our sample.

# 612 7 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 decomposition of TFP into a component 620 that is potentially inside the information set of the firm and a component that is not. TFP 621 growth measured using the former component would potentially be anticipated by the firm, 622 whereas TFP growth measured using the latter component would be unanticipated. Using 623 this decomposition, we find that the sensitivity of productivity growth to debt growth rises 624 with financial frictions in the component of TFP that is unanticipated by the firm, while no 625 such result obtains for the anticipated component. These findings provide evidence that our 626 results do not arise from firms increasing borrowing in anticipation of future TFP increases, 627 a form of reverse causality. 628

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 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.

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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	All
$\Delta \text{TFP}$	-0.004	-0.027	-0.008	-0.012
	[0.000]	[-0.006]	[0.000]	[0.000]
	(0.176)	(0.260)	(0.229)	(0.226)
Age	24.074	25.208	17.334	20.690
2	[ 19.750]	[23.000]	[ 15.000]	[ 17.000]
	(17.048)	(15.715)	(11.083)	(14.251)
Assets, mil. USD	19.978	46.349	28.610	30.788
,	[2.317]	[11.746]	[ 1.982]	[ 3.204]
	(272.310)	(309.078)	(649.454)	(517.055)
Asset turnover	2.175	1.319	1.646	1.690
	[ 1.963]	[ 1.188]	[ 1.425]	[ 1.473]
	(1.050)	(0.711)	(1.013)	(1.004)
Investment	0.039	0.067	0.077	0.066
	[-0.028]	[-0.012]	[-0.005]	[-0.010]
	(0.363)	(0.350)	(0.381)	(0.370)
Sales growth	0.027	0.003	0.032	0.024
0	[ 0.021]	[ 0.011]	[ 0.027]	[ 0.022]
	(0.138)	(0.193)	(0.212)	(0.194)
Book leverage	0.122	0.276	0.220	0.211
8	[ 0.081]	[0.270]	[0.172]	[0.165]
	(0.123)	(0.173)	(0.188)	(0.180)
Cash	0.137	0.052	0.106	0.100
	[ 0.086]	[ 0.020]	[ 0.059]	[ 0.051]
	(0.144)	(0.076)	(0.124)	(0.123)
Interest expense ratio	0.161	0.088	0.137	0.130
I I I I I I I I I I I I I I I I I I I	[ 0.097]	[ 0.062]	[ 0.071]	[0.072]
	(0.176)	(0.097)	(0.169)	(0.158)
Debt growth	0.085	0.010	0.009	0.026
	[0.015]	[-0.003]	[-0.089]	[-0.040]
	(0.940)	(0.621)	(0.768)	(0.781)
Sovereign bond spread	0.068	0.376	0.038	0.123
Sovereign sona spread	[ 0.031]	[0.256]	[0.022]	[0.032]
	(0.090)	(0.278)	(0.080)	(0.207)
Ext Fin Dependency	0.222	0.245	0.232	0.233
Life This Dependency	[ 0 139]	$\begin{bmatrix} 0.154 \end{bmatrix}$	[ 0 139]	$\begin{bmatrix} 0.147 \end{bmatrix}$
	(0.294)	(0.313)	(0.313)	(0.309)
Debt growth $> 0$ ratio	0.504	0 499	0.384	0.445
Equity growth $> 0$ , ratio	0.053	0.094	0.054	0.069
	0.000	0.00 <b>-</b>		0.000

Table 2: No financial frictions 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  $\Delta \text{TFP}_{t+1}$ . 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. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

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	France	Italy	Spain	All
$\Delta \text{TFP}_{i,t}$	-0.22**	-0.24**	-0.26**	-0.24**
	(-14.85)	(-17.01)	(-4.92)	(-14.98)
$\Delta \mathrm{TFP}_{i,t-1}$	-0.07**	-0.07**	-0.06	-0.06**
	(-7.64)	(-7.25)	(-1.60)	(-4.93)
$\text{Log age}_{i,t}$	-0.94	0.72	0.29	0.74
	(-1.02)	(1.25)	(0.09)	(0.82)
$\text{Log assets}_{i,t}$	-0.17**	-0.04	-0.09	-0.07**
	(-4.22)	(-1.32)	(-0.98)	(-3.46)
Sales $\operatorname{growth}_{i,t}$	-0.16**	-0.14**	-0.11**	-0.12**
	(-13.86)	(-9.64)	(-6.06)	(-20.77)
$Investment_{i,t}$	$0.05^{**}$	$0.08^{**}$	$0.04^{**}$	$0.05^{**}$
	(15.29)	(15.98)	(2.84)	(9.99)
Debt $\operatorname{growth}_{i,t}$	0.012**	0.015**	0.010	0.008**
	(3.98)	(8.13)	(1.62)	(3.95)
Obs.	$118,\!397$	121,918	$283,\!446$	523,761
Serial corr. test, order 1 (p-val)	< 0.001	< 0.001	< 0.001	< 0.001
Serial corr. test, order 2 (p-val)	0.656	0.723	0.994	0.319
Hansen J-Test (p-val)	0.231	0.214	0.048	< 0.001

Table 3: 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  $\Delta \text{TFP}_{t+1}$ . 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. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
$\Delta \text{TFP}_{i,t}$	-0.26**	-0.32**	-0.31**	-0.29**
	(-16.31)	(-7.56)	(-5.65)	(-10.24)
$\Delta \mathrm{TFP}_{i,t-1}$	-0.08**	-0.08**	-0.08*	-0.08**
,	(-8.75)	(-6.08)	(-2.01)	(-5.14)
$\text{Log age}_{i,t}$	-0.69	0.88	-0.10	0.09
	(-0.78)	(1.60)	(-0.03)	(0.09)
$\text{Log assets}_{i,t}$	-0.20**	-0.15*	-0.20*	-0.17**
	(-5.45)	(-2.41)	(-2.16)	(-3.89)
Sales $\operatorname{growth}_{i,t}$	-0.14**	-0.12**	-0.10**	-0.11**
-,-	(-14.13)	(-7.40)	(-5.25)	(-16.49)
$Investment_{i,t}$	0.06**	0.07**	0.04**	0.05**
	(16.47)	(12.42)	(3.07)	(9.89)
Debt $\operatorname{growth}_{i,t}$	0.039**	0.102**	$0.059^{**}$	0.046**
,	(23.36)	(2.80)	(3.89)	(3.15)
Adj. book leverage <sub><i>i</i>,<math>t-1</math></sub>	$1.106^{**}$	$1.755^{*}$	$0.944^{**}$	$0.922^{**}$
1.	(11.78)	(2.41)	(3.59)	(2.84)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. book leverage <sub><i>i</i>,<i>t</i>-1</sub>	$0.338^{**}$	$0.384^{**}$	$0.317^{**}$	$0.324^{**}$
	(13.21)	(2.76)	(4.79)	(3.63)
Obs.	$118,\!396$	$121,\!918$	$283,\!446$	523,760
Serial corr. test, order 1 (p-val)	< 0.001	< 0.001	< 0.001	< 0.001
Serial corr. test, order 2 (p-val)	0.827	0.765	0.997	0.244
Hansen J-Test (p-val)	0.653	0.146	0.132	< 0.001

Table 4: 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  $\Delta \text{TFP}_{t+1}$ . 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. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
$\Delta \text{TFP}_{i,t}$	-0.14**	-0.23**	-0.21**	-0.18**
	(-7.70)	(-15.33)	(-4.17)	(-6.75)
$\Delta \mathrm{TFP}_{i,t-1}$	-0.07**	-0.07**	-0.05	-0.04**
,	(-7.03)	(-7.15)	(-1.47)	(-2.97)
$\log age_{i,t}$	-0.49	0.74	0.45	1.84
,-	(-0.45)	(1.27)	(0.14)	(1.70)
$\text{Log assets}_{i,t}$	-0.15**	-0.02	-0.07	-0.04
	(-2.88)	(-0.89)	(-0.84)	(-1.51)
Sales $\operatorname{growth}_{i,t}$	-0.14**	-0.14**	-0.09**	-0.11**
	(-10.26)	(-9.52)	(-4.74)	(-15.95)
$\text{Investment}_{i,t}$	0.04**	$0.07^{**}$	0.02*	0.04**
	(8.82)	(14.86)	(2.40)	(13.29)
Debt $\operatorname{growth}_{i,t}$	0.009**	0.016**	0.010	$0.007^{**}$
	(2.61)	(7.82)	(1.83)	(2.65)
Adj. cash holdings <sub><i>i</i>,<math>t-1</math></sub>	$1.326^{**}$	$1.027^{**}$	$1.105^{**}$	1.281**
,	(23.09)	(10.84)	(22.12)	(5.45)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. cash holdings <sub><i>i</i>,<i>t</i>-1</sub>	-0.025**	-0.066**	-0.051**	-0.048**
, , , , , , , , , , , , , , , , , , , ,	(-4.12)	(-4.03)	(-5.87)	(-8.15)
Obs.	$107,\!916$	$121,\!551$	$261,\!100$	490,567
Serial corr. test, order 1 (p-val)	< 0.001	< 0.001	< 0.001	< 0.001
Serial corr. test, order 2 (p-val)	0.544	0.442	0.532	0.679
Hansen J-Test (p-val)	0.051	0.156	0.276	0.019

Table 5: Industry-adjusted interest expense ratio. 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  $\Delta \text{TFP}_{t+1}$ . 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. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
$\Delta \text{TFP}_{i,t}$	-0.21**	-0.27**	-0.25**	-0.24**
	(-13.50)	(-17.09)	(-3.60)	(-18.66)
$\Delta \mathrm{TFP}_{i,t-1}$	-0.07**	-0.06**	-0.05	-0.05**
	(-6.56)	(-5.72)	(-1.08)	(-4.68)
$\log age_{i,t}$	-1.83	0.75	0.72	0.89
- )-	(-1.78)	(1.20)	(0.18)	(1.18)
$\text{Log assets}_{i,t}$	-0.23**	-0.10**	-0.14	-0.10**
	(-4.88)	(-2.76)	(-0.88)	(-4.59)
Sales $\operatorname{growth}_{i,t}$	-0.14**	-0.15**	-0.14**	-0.13**
- ,-	(-10.29)	(-10.08)	(-3.74)	(-17.98)
$\text{Investment}_{i,t}$	0.06**	0.08**	0.03	0.05**
	(13.04)	(15.24)	(0.99)	(13.09)
Debt $\operatorname{growth}_{i,t}$	$0.019^{**}$	$0.070^{**}$	0.041	$0.034^{**}$
	(5.52)	(6.57)	(1.43)	(13.81)
Adj. interest exp. $ratio_{i,t-1}$	0.127	-1.707**	-0.664	-0.540**
,	(0.93)	(-4.22)	(-1.26)	(-5.40)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. interest exp. ratio <sub><i>i</i>,<i>t</i>-1</sub>	-0.061	$0.545^{**}$	0.162	$0.128^{**}$
	(-1.52)	(3.84)	(1.08)	(4.08)
Obs.	$102,\!320$	$114,\!832$	$249,\!027$	$466,\!179$
Serial corr. test, order 1 (p-val)	< 0.001	< 0.001	0.166	< 0.001
Serial corr. test, order 2 (p-val)	0.115	0.004	0.643	0.510
Hansen J-Test (p-val)	0.122	0.220	0.123	0.004

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  $\Delta \text{TFP}_{t+1}$ . 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. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
$\Delta \text{TFP}_{i,t}$	-0.22**	-0.25**	-0.27**	-0.24**
	(-17.66)	(-17.28)	(-4.63)	(-14.74)
$\Delta \text{TFP}_{i,t-1}$	-0.07**	-0.07**	-0.08	-0.05**
	(-8.10)	(-7.18)	(-1.80)	(-3.93)
$\log age_{i,t}$	-1.12**	0.67	-1.46	1.93
-,-	(-2.61)	(1.20)	(-0.41)	(1.93)
$\text{Log assets}_{i,t}$	-0.18**	-0.04	-0.15	-0.06**
-,-	(-7.78)	(-1.59)	(-1.54)	(-2.74)
Sales $\operatorname{growth}_{i,t}$	-0.15**	-0.13**	-0.13**	-0.14**
-,-	(-15.82)	(-8.05)	(-9.07)	(-17.93)
$Investment_{i,t}$	$0.05^{**}$	$0.07^{**}$	0.02	0.05**
	(15.53)	(12.46)	(1.53)	(8.47)
Debt $\operatorname{growth}_{i,t}$	0.009**	0.006	$0.019^{*}$	0.004
- ) - -	(3.90)	(1.78)	(2.28)	(1.48)
10-yr spread <sub>t</sub>	-2.258	2.710	6.843	2.293**
	(-0.93)	(1.04)	(0.45)	(3.16)
Debt growth <sub><i>i</i>,<i>t</i></sub> × 10-yr spread <sub><i>t</i></sub>	$0.052^{**}$	$0.032^{**}$	-0.043	$0.038^{**}$
,	(2.75)	(3.87)	(-1.18)	(8.14)
Obs.	$118,\!397$	$121,\!918$	$283,\!446$	523,761
Serial corr. test, order 1 (p-val)	< 0.001	< 0.001	< 0.001	< 0.001
Serial corr. test, order 2 (p-val)	0.035	0.972	0.060	0.707
Hansen J-Test (p-val)	0.241	0.236	0.035	0.015

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  $\Delta \text{TFP}_{t+1}$ . 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). Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
$\Delta \text{TFP}_{i,t}$	-0.22**	-0.24**	-0.26**	-0.24**
	(-14.86)	(-17.01)	(-5.12)	(-15.25)
$\Delta \mathrm{TFP}_{i.t-1}$	-0.07**	-0.07**	-0.06	-0.06**
,	(-7.64)	(-7.25)	(-1.72)	(-5.00)
$\text{Log age}_{i,t}$	-0.92	0.71	0.04	0.75
	(-1.00)	(1.23)	(0.01)	(0.85)
$\text{Log assets}_{i,t}$	-0.17**	-0.04	-0.09	-0.07**
	(-4.18)	(-1.33)	(-1.10)	(-3.50)
Sales $\operatorname{growth}_{i,t}$	-0.16**	-0.14**	-0.11**	-0.12**
-,-	(-13.86)	(-9.64)	(-6.04)	(-20.92)
$\text{Investment}_{i,t}$	$0.05^{**}$	$0.08^{**}$	$0.04^{**}$	0.05**
	(15.27)	(15.93)	(2.85)	(10.19)
Debt $\operatorname{growth}_{i,t}$	0.009**	0.014**	0.009	$0.007^{**}$
	(3.40)	(6.52)	(1.48)	(3.01)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Ext. fin. dependency	0.010**	0.007	0.009**	$0.009^{**}$
	(3.69)	(1.92)	(2.81)	(5.16)
Obs.	$118,\!349$	$121,\!485$	$283,\!040$	$522,\!874$
Serial corr. test, order 1 (p-val)	< 0.001	< 0.001	< 0.001	< 0.001
Serial corr. test, order 2 (p-val)	0.670	0.692	0.952	0.333
Hansen J-Test (p-val)	0.230	0.201	0.045	< 0.001

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. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. book leverage <sub><i>i</i>,<i>t</i>-1</sub>	0.268**	$0.337^{**}$	0.377**	0.415**
	(4.44)	(2.64)	(4.55)	(5.51)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. cash holdings <sub><i>i</i>,<i>t</i>-1</sub>	-0.020*	-0.063**	-0.048**	-0.044**
	(-2.12)	(-4.35)	(-7.06)	(-9.68)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. interest exp. ratio <sub><i>i</i>,<i>t</i>-1</sub>	-0.081	$0.588^{**}$	-0.040	0.172**
	(-1.17)	(4.69)	(-0.59)	(6.45)
Debt growth <sub><i>i</i>,<i>t</i></sub> × 10-yr spread <sub><i>t</i></sub>	0.024	$0.030^{**}$	$0.075^{**}$	$0.038^{**}$
·	(1.05)	(4.63)	(2.83)	(8.48)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Ext. fin. dependency	0.015**	$0.009^{*}$	0.005	0.011**
	(3.98)	(2.50)	(1.60)	(5.61)

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

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

	France	Italy	Spain	All
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. book leverage <sub><i>i</i>,<i>t</i>-1</sub>	0.020	-0.283	0.031	0.015
	(1.24)	(-1.05)	(0.74)	(0.27)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. cash holdings <sub><i>i</i>,<i>t</i>-1</sub>	0.003	-0.002	-0.010*	-0.003
	(1.30)	(-0.31)	(-2.39)	(-1.46)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. interest exp. ratio <sub><i>i</i>,<i>t</i>-1</sub>	0.011	0.031	0.012	0.024
	(0.59)	(0.44)	(0.33)	(1.59)
Debt growth <sub><i>i</i>,<i>t</i></sub> × 10-yr spread <sub><i>t</i></sub>	0.007	-0.019	-0.033	-0.008*
	(0.62)	(-0.96)	(-1.71)	(-2.04)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Ext. fin. dependency	-0.003*	-0.001	0.000	-0.001
	(-2.18)	(-0.23)	(0.16)	(-0.76)

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.  $\theta$  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



# 786 Supplementary Materials

### 787 A Proofs

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

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

**Proof.** Decompose the above derivative as follows:

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

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

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

788 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

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

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

<sup>791</sup> We establish negativity of the second expression as follows:

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

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  $g(S/K, \epsilon)$ , one obtains that

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

<sup>792</sup> Substituting equations (A.2) and (A.3) into (A.1), one obtains the desired result.  $\blacksquare$ 

### 793 **B** Additional empirical analysis

#### 794 B.1 Correlations

One concern with any empirical analysis is the presence of multi-collinearity in the regressors. Table A.1 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.<sup>20</sup>

We use industry-adjusted book leverage and cash holdings as two of our firm-level 799 measures of financial frictions.<sup>21</sup> Table 2 shows that there is a modest negative correlation 800 between the two variables, ranging from -0.22 to -0.27 across the samples. As such, these 801 two variables provide correlated but distinct measures of financial frictions at the firm level. 802 The results also indicate a small negative correlation between sales growth and TFP 803 growth. This reflects the fact that while TFP growth quantifies growth in output per unit 804 of factor inputs, capital and labor, sales growth incorporates growth in both TFP and the 805 factor inputs. This negative correlation indicates that our results are not merely capturing 806 a relationship between financial frictions and the overall growth of the firm. 807

<sup>&</sup>lt;sup>20</sup>The largest correlation arises between log age and log assets.

<sup>&</sup>lt;sup>21</sup>We adjust for industry-level effects by subtracting the industry median for a given year from the corresponding leverage and cash variables.

#### 808 B.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 Eq. (A.4) measures productivity relative to all factor 814 inputs. Output per worker provides a simpler measure of productivity that is often used in 815 the literature. Panel A of Table A.2 presents the results from estimating the regressions of 816 Tables 3 to 7 using value added per worker as the measure of productivity. Each row reports 817 the results from a separate regression. For brevity, only the coefficient and t-statistic of the 818 interaction between debt growth and the financial friction measure are reported. We find 819 that the results are broadly similar to those in our baseline specifications, suggesting that 820 our findings are not sensitive to the measure of productivity. 821

In Panel B of Table A.2 we repeat the analysis using a simple OLS estimate of productivity. Specifically, we estimate productivity as the residual from the following regression:

$$\log va_{i,t} = c + \alpha \log K_{i,t} + \beta \log L_{i,t} + \epsilon_{i,t}, \tag{A.4}$$

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. 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. The results in Panel B reveal that the estimates are similar using this alternative measure of productivity. Taken together, these findings indicate that our results are robust to alternative measures of productivity.

#### 828 B.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 of mostly 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 A.3 presents the results from estimating the regressions of Tables 3 to 7 using the 833 sum of debt and equity as the measure of external financing. Each row reports the results 834 from a separate regression. For brevity, only the coefficient and t-statistic of the interaction 835 between financing growth and the financial friction measure are reported. The coefficient 836 estimates for the full sample support Proposition 1, i.e., the sensitivity of productivity growth 837 to the use of external finance rises with industry-adjusted leverage, sovereign bond spreads 838 and industry external finance dependency, and falls with industry-adjusted cash holdings. 839 For the most part, the results are similar when we examine each of the four countries in our 840 sample separately. In economic magnitudes, the findings using the total financing measure 841 are close to those obtained using debt financing only. 842

	$\Delta \text{TFP}$	Log age	Log assets	Sales growth	Debt growth	Book leverage	$\operatorname{Cash}$
France							
$\Delta TFP$	1.00						
Log age	-0.00	1.00					
Log assets	-0.02	0.30	1.00				
Sales growth	-0.06	-0.06	0.08	1.00			
Debt growth	0.05	0.00	0.04	0.05	1.00		
Book leverage	0.06	-0.08	-0.01	-0.03	0.27	1.00	
Cash	-0.04	0.03	-0.11	0.01	-0.02	-0.22	1.00
Italy							
$\Delta \text{TFP}$	1.00						
Log age	-0.01	1.00					
Log assets	-0.01	0.20	1.00				
Sales growth	-0.06	-0.05	0.09	1.00			
Debt growth	0.03	-0.02	0.04	0.09	1.00		
Book leverage	0.04	-0.06	0.02	-0.04	0.22	1.00	
$\operatorname{Cash}$	-0.03	0.01	-0.07	0.02	-0.07	-0.26	1.00
Spain							
$\Delta TFP$	1.00						
Log age	-0.03	1.00					
Log assets	-0.05	0.41	1.00				
Sales growth	-0.04	-0.09	0.03	1.00			
Debt growth	0.04	-0.01	0.09	0.07	1.00		
Book leverage	0.03	-0.07	0.14	0.01	0.29	1.00	
Cash	-0.04	0.01	-0.11	0.01	-0.08	-0.25	1.00
All							
$\Delta TFP$	1.00						
Log age	-0.02	1.00					
Log assets	-0.05	0.37	1.00				
Sales growth	-0.04	-0.08	0.03	1.00			
Debt growth	0.04	-0.00	0.06	0.07	1.00		
Book leverage	0.02	-0.08	0.12	-0.01	0.24	1.00	
Cash	-0.03	0.01	-0.15	0.01	-0.05	-0.27	1.00

Table A.1: **Correlations.** Reports correlation tables of variables used in the baseline regression. Book leverage and cash are industry-adjusted.

Table A.2: Alternate measures of productivity. For each of the five 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 a simple OLS method to estimate productivity by regressing value added on labor and capital within each industry. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. book leverage <sub><i>i</i>,<i>t</i>-1</sub>	0.252**	-0.063	0.250**	0.397**
	(8.62)	(-1.10)	(4.46)	(8.40)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. cash holdings <sub><i>i</i>,<i>t</i>-1</sub>	-0.015*	-0.084**	-0.047**	-0.036**
	(-2.43)	(-4.37)	(-6.98)	(-8.07)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. interest exp. ratio <sub><i>i</i>,<i>t</i>-1</sub>	-0.007	0.902**	$0.072^{*}$	0.057**
· /·	(-0.17)	(4.93)	(2.03)	(3.28)
Debt growth <sub><i>i</i>,<i>t</i></sub> × 10-yr spread <sub><i>t</i></sub>	$0.047^{*}$	0.027	-0.013	0.015**
	(2.31)	(1.90)	(-0.63)	(4.72)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Ext. fin. dependency	0.011**	0.022**	0.003	0.008**
	(3.69)	(3.76)	(1.03)	(4.13)

#### A. Labor productivity

#### B. OLS

	France	Italy	Spain	All
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. book leverage <sub><i>i</i>,<i>t</i>-1</sub>	0.321**	0.474**	0.325**	0.351**
	(12.17)	(5.01)	(5.16)	(6.94)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. cash holdings <sub><i>i</i>,<i>t</i>-1</sub>	-0.025**	-0.071**	-0.056**	-0.045**
, , , , , , , , , , , , , , , , , , , ,	(-4.14)	(-4.84)	(-8.39)	(-12.39)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Adj. interest exp. ratio <sub><i>i</i>,<i>t</i>-1</sub>	-0.111	0.606**	0.044	0.153**
	(-1.87)	(4.86)	(0.80)	(5.38)
Debt growth <sub><i>i</i>,<i>t</i></sub> × 10-yr spread <sub><i>t</i></sub>	0.048**	0.025**	0.048*	0.021**
	(3.10)	(3.86)	(2.18)	(7.52)
Debt growth <sub><i>i</i>,<i>t</i></sub> × Ext. fin. dependency	0.012**	0.008*	0.002	0.007**
· ) ·	(5.08)	(2.32)	(0.71)	(4.81)

Table A.3: **Total financing.** For each of the five 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. Standard errors are heteroskedasticity robust and adjust for clustering at the firm level. Statistical significance at the 1 and 5 percent level is indicated by \*\* and \*.

	France	Italy	Spain	All
Total financing growth <sub><i>i</i>,<i>t</i></sub> × Adj. book leverage <sub><i>i</i>,<i>t</i>-1</sub>	0.382**	0.331**	0.159**	0.138**
	(11.92)	(5.74)	(3.46)	(4.85)
Total financing $\operatorname{growth}_{i,t} \times \operatorname{Adj.} \operatorname{cash} \operatorname{holdings}_{i,t-1}$	-0.086**	-0.093**	-0.004	-0.013**
	(-7.52)	(-6.22)	(-1.16)	(-2.89)
Total financing $\operatorname{growth}_{i,t} \times \operatorname{Adj}$ . interest exp. $\operatorname{ratio}_{i,t-1}$	-0.320*	-1.130**	-0.603	$-1.076^{**}$
· · · · · · · · · · · · · · · · · · ·	(-2.16)	(-5.40)	(-1.07)	(-6.31)
Total financing $\operatorname{growth}_{i,t} \times 10$ -yr $\operatorname{spread}_t$	$0.139^{**}$	$0.025^{*}$	-0.118*	$0.048^{**}$
, 	(3.76)	(2.48)	(-2.10)	(3.77)
Total financing $\operatorname{growth}_{i,t} \times \operatorname{Ext.}$ fin. dependency	$0.016^{**}$	0.004	$0.007^{**}$	$0.007^{**}$
·	(3.26)	(1.34)	(4.90)	(6.59)