Debt Overhang, Rollover Risk, and Corporate Investment: Evidence from the European Crisis[*]

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Abstract

We quantify the role of financial factors behind the sluggish post-crisis performance of European firms. We use a firm-bank-sovereign matched database to identify separate roles for firm and bank balance sheet weaknesses arising from changes in sovereign risk and aggregate demand conditions. We find that firms with higher debt levels and a higher share of short-term debt reduce their investment more after the crisis. This negative effect is stronger for firms linked to weak banks with exposures to sovereign risk, signifying increased rollover risk. These financial channels explain about 60% of the decline in aggregate corporate investment.

JEL-Codes: E22, E32, E44, F34, F36, G32

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1   Introduction

Investment expenditure in Europe collapsed in the aftermath of the 2008 global financial crisis. Figure 1 shows that, by the end of 2016, net corporate investment as a share of GDP across the euro area still has not fully recovered, with higher declines in the most affected periphery countries. By contrast, the US recovered much faster over the same period, reaching its 2008 peak by 2014, though there was a slowdown later on. This collapse in corporate investment in Europe followed a boom period during which corporate sector borrowed heavily. Figure 2 shows that indebtedness of euro area non-financial corporations, measured as debt liabilities to GDP, increased 30 percentage points since 1999 on average, and 90 percentage points for the periphery countries.

Thus far the literature has primarily focused on bank-sovereign linkages and the collapse in aggregate demand to explain the depth of the crisis in Europe. We focus instead on firm-specific financial conditions to explain the decline in firm-level and aggregate corporate investment. In a recent paper, Bernanke (2018) provides new evidence on the channels by which the recent financial crisis depressed economic activity in the United States. He shows that the deterioration in household balance sheets and the associated deleveraging played a smaller role in explaining the severe downturn relative to the panic in funding and securitization markets, which disrupted the supply of credit to the real economy. We also investigate the disruptive effect of a reduction in the supply of credit on the real economy, but in contrast to Bernanke (2018) we focus on the inter-linkages between the balance sheets of banks and *firms*. This exercise is not possible for the US given the limited data on bank-firm relationships due to the lack of regulatory financial reporting by private firms.[1]

Specifically, we investigate whether corporate debt accumulated during the boom years holds back investment in the aftermath of the crisis and how this effect interacts with weak credit supply from banks in a period of tightened lending conditions. We refer to a situation

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[1] In the US, even though private firms account for 74 percent of aggregate employment and 56 percent of aggregate gross output, they are not required to publicly disclose their financial data. In Europe, private firms also account for over 70 percent of aggregate employment and over 50 percent of aggregate output on average and in most European countries these (small) private firms are required to file their financial data. See Kalemli-Ozcan et al. (2015) for data coverage in Europe and Dinlersoz et al. (2018) for the US.
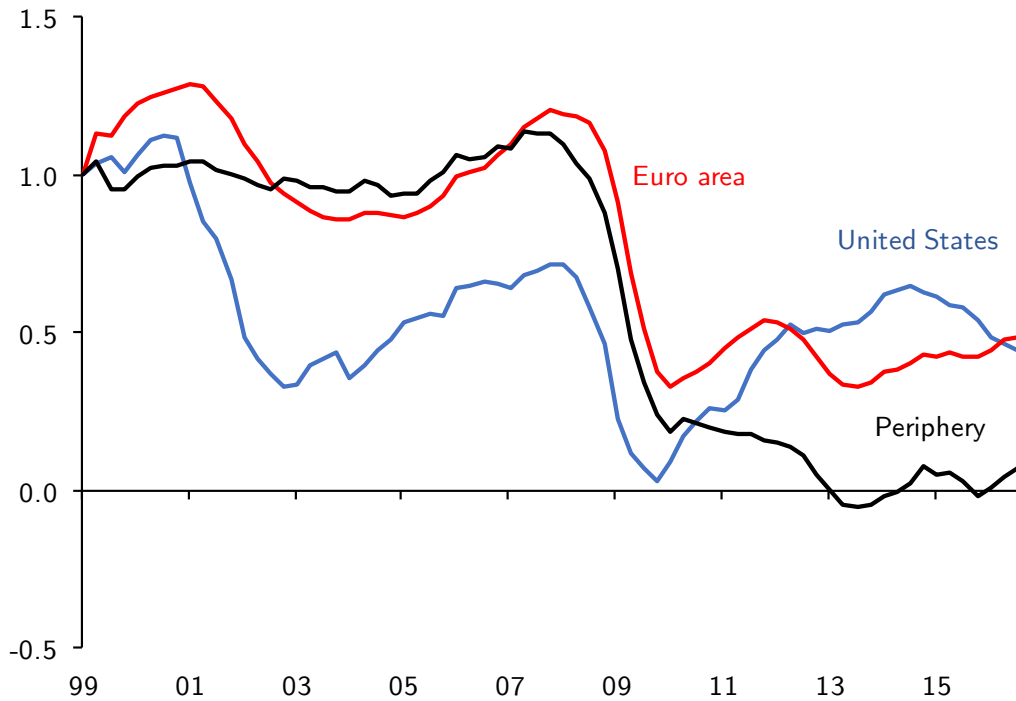
Figure 1: Evolution of Net Corporate Investment

Note: Net fixed capital formation of non-financial corporations, scaled by total economy GDP. Index 1999q1=1. Periphery group of economies comprises Greece, Ireland, Italy, Spain, and Portugal.

Sources: Eurostat and BEA.

where debt holds back investment as "debt overhang". The finance literature defines debt overhang as high levels of debt that are curtailing investments because the benefits from additional investment in firms financed with risky debt accrue largely to existing debt holders rather than shareholders (Myers, 1977). The macro literature, on the other hand, focuses on high levels of public debt that are crowding out private investment in general equilibrium via higher borrowing costs (e.g. Krugman (1988), Bulow and Rogoff (1991), and Aguiar et al. (2009)). In the European context, both channels are likely to be at work, and they will be reinforced by sovereign-bank linkages that weaken bank balance sheets on account of exposures to risky sovereign debt. As a consequence, firms that are already highly leveraged may not want to take on additional debt to finance investment, as in Myers (1977), or they might not be able to take on additional debt because banks do not want to lend to them. Either way, the
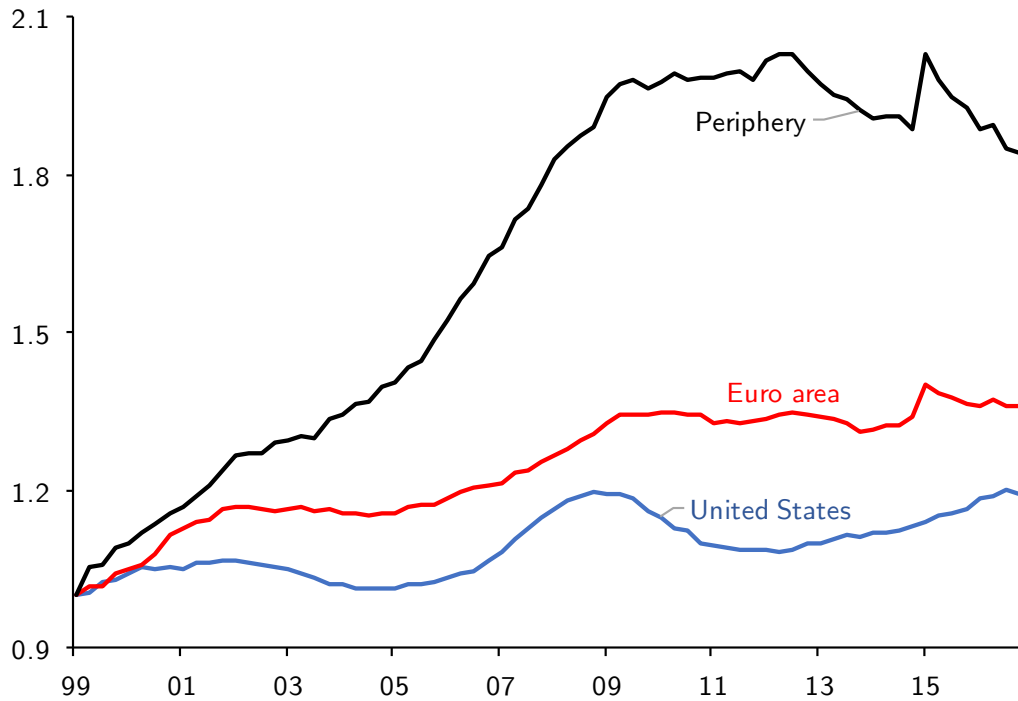
2

Figure 2: Evolution of Non-Financial Corporate Debt to GDP

Note: Credit to non financial corporations granted by banks and non-banks, scaled by total economy GDP. Index 1999q1=1. Periphery group of economies comprises Greece, Ireland, Italy, Spain, and Portugal.

Source: Bank of International Settlements.

result will be a firm de-leveraging process, where firms that overborrowed during the boom period will de-lever as they face an increased debt burden.

This debt overhang effect might be reinforced by an increase in rollover risk, depending on the maturity structure of the debt. If the debt accumulated during the boom period is mostly short-term, rollover risk will increase because lenders are often unwilling to renew expiring credit lines during a crisis when collateral values drop (e.g. Diamond (1991) and Acharya et al. (2011)). Debt maturity may also affect the debt overhang by altering incentives to invest. According to Myers (1977), short-term debt reduces the debt overhang problem because the value of shorter debt is less sensitive to the value of the firm and thus receives a much smaller benefit from new investment. However, Diamond and He (2014) show that reducing maturity can increase debt overhang. For firms with future investment opportunities, shorter-term debt

may impose stronger debt overhang in bad times since less risk is shared by shorter-term debt.

A special dataset is required to be able to distinguish between these different financial channels that may affect firm-level investment. First, we need a firm-bank matched dataset since the deterioration in firm and bank balance sheets have to be measured simultaneously to separate shifts in bank weakness and firm weakness. Second, we need detailed data on the financial position of firms including on the total amount of debt oustanding and on the maturity of this debt to capture the effects of debt overhang and rollover risk. Third, we need to have a comprehensive dataset of firm-level balance sheets with a broad coverage of small and large firms to gauge the aggregate implications of financial factors. Small firms tend to be informationally opaque and dependent on banks for their external financing, and therefore more likely to be affected by debt overhang (e.g. Kashyap et al. (1993, 1994a,b)) and they make up a large part of aggregate economic activity in Europe. Finally, we need firm-level data from multiple countries with varying degrees of sovereign risk to isolate bank-sovereign linkages.

We use the Orbis-Bureau Van Dijk/Moody's database, where the European country coverage is also known as the AMADEUS database. The database has detailed firm-level balance sheet information on investment, indebtedness, debt service, and debt maturity across a large number of European countries. The database also incorporates information on each firm's main relationship bank(s), including the names and address of the bank, which we use to match firms and banks. For each bank, we obtain bank balance sheet information, including data on total sovereign bond holdings, from BANKSCOPE. In order to distinguish between banks' exposure to their *own* sovereign as opposed to other sovereigns, we use confidential ECB data which has nationality information on the sovereign exposure.

We measure weakness in bank balance sheets using the bank's holdings of risky sovereign bonds. In Europe, where banks hold sovereign bonds and firms depend on banks for their lending, sovereign risk can affect firm investment through bank-sovereign linkages. Following an increase in sovereign risk, banks with large exposures to risky sovereigns will experience a deterioration in their balance sheets, reducing the supply of loans to firms via a traditional bank lending channel (as in Gennaioli et al. (2014) and Acharya et al. (2014b)). This will lead to an increase in debt overhang and rollover risk, especially for firms that financed themselves

4

primarily with short-term debt during the boom years. It is also possible that weak banks continue to lend to risky borrowers in an effort to preserve relationships, consistent with loan evergreening and resulting in a reduction in rollover risk (e.g. Hoshi et al. (1990), Peek and Rosengren (2000, 2005) and Caballero et al. (2008)). Our empirical strategy will be able to evaluate the relative importance of bank lending channel versus evergreening channel.

We use a difference-in-difference approach to identify the effect of corporate debt overhang and rollover risk on investment, assessing the differential (relative) impact on investment of different levels of leverage and debt maturity between the pre-crisis and post-crisis periods. Consistent with the literature, we consider the year 2008 as the start of the financial crisis. We limit the analysis to firms in the euro area. The advantage of this setup is that we limit the analysis to firms that were subject to the same monetary policy but experienced diverging sovereign risk and banking conditions during the crisis. We measure leverage as the ratio of debt to total assets and debt maturity as the ratio of long-term debt to total debt. The analysis controls for the usual determinants of investment and also for debt service since the debt to assets ratio may not fully capture the effects of lingering debt overhang when debt is measured at book value. We condition on aggregate demand shocks since it is possible that firms decreased investment due to negative demand (or productivity) shocks rather than the debt overhang and rollover risk channels we focus on.

To control for aggregate demand shocks we use four-digit industry×country×year fixed effects. These effects will absorb the impact of changes in credit demand for the four-digit sector that our firms operate in as well as any changes in country-level demand conditions, including those arising from changes in sovereign risk and general uncertainty conditions. We also control for bank fixed effects to capture the role of pre-existing bank relationships. We assume that most of the fluctuations in aggregate demand derive from country and narrowly defined industry-specific factors, not idiosyncratic firm-specific factors. To the best of our knowledge we are the first to allow these demand effects to vary at a very granular level (four-digit) of industry classification and also across countries and over time.

We run two sets of regressions: First, a cross sectional regression of differences in average investment rates between the crisis period (2008-2012) and the pre-crisis period (2000-2007)

5

on differences in our explanatory variables. Second, a panel regression of triple interactions, where we interact a crisis dummy that takes the value of one starting in 2008, with the interaction variables of our measure of weak banks with the leverage, debt service, and maturity variables. The advantage of the cross sectional regression is that it averages out any lumpiness in investment within periods. The advantage of the panel regression setup is that it allows to capture granular dynamic effects as opposed to one-time change in the cross-section regressions. To mitigate concerns about reverse causality, we measure leverage, debt service, maturity, and bank-firm relationships prior to the crisis. Because some firms deleveraged during the crisis, our conservative approach, if anything, underestimates the effect of high leverage on investment.

Our findings are as follows. First, high *ex ante* debt levels depress investment during crisis times, consistent with debt overhang, with both high leverage and high debt service affecting investment negatively. This result is due to a combination of increased debt service that is associated with de-leveraging and a negative balance sheet shock to firms that enter the crisis with high leverage. These firms have low net worth due to their high leverage and are financially constrained. Second, firms with a shorter maturity of debt reduce investment more during the crisis, consistent with an increase in rollover risk. An increase in default risk during the crisis raises borrowing costs, making it more difficult to refinance maturing debt. This result is in striking contrast to the pre-crisis period when firms, who financed themselves with a shorter maturity of debt invested more. Third, the debt overhang and rollover effects are influenced by sovereign-bank linkages. Firms whose main bank's balance sheet deteriorated because of large exposure to sovereign risk have significantly lower investment rates, and experience more debt overhang during the crisis. Among these firms the ones with higher shares of long-term debt experience less rollover risk during the crisis and increased investment more. The latter result indicates that firms that have borrowed more long term can mitigate the adverse effects of their banks' weakness as they do not need to rollover loans. This result also suggests that if there were any loan evergreening by weak banks to firms facing higher rollover risk (i.e., firms with a higher share of short-term debt), such evergreening did not contribute to improving real outcomes since these firms decreased investment more.

Our contribution to the literature is twofold. First, we consider the role of financial frictions at the firm-level and show how these frictions interact with banks' financial shocks, while the existing literature mostly focuses on the role of banks on firms' investment directly or through their sovereign exposures. Moreover we conduct this analysis for a nationally representative set of firms in each country, while existing literature mostly focuses on syndicated loans to large firms (e.g. Acharya et al. (2014b), Becker and Ivashina (2018), Popov and Van Horen (2015) for Europe and Amiti and Weinstein (2018), Correa et al. (2013) for the US). Using firm-bank matched data to separate bank lending from firm risk/credit demand channel, we show that firms' financial positions have an important *independent* effect on investment in addition to the role of weak bank balance sheets that led to a reduction in credit supply. Second, we simultaneously consider the role of firm-level leverage and debt maturity, while existing empirical literature abstracts from the maturity structure of debt, in spite of the important role of maturity in the theoretical literature on debt and investment. For example, although papers such as Giroud and Mueller (2017) and Ottonello and Winberry (2018) also focus on firm-level leverage as we do, they do not consider the role of maturity. As we show, the role of maturity is key to have a full understanding of firm-level leverage on sluggish investment.

Our contributions are made possible by the uniqueness of our firm-bank-sovereign matched dataset, which features an extensive coverage of small firms including their debt levels, maturity structure, and banks. Using a similar firm-level dataset encompassing small firms but without matching it to firms' banks' balance sheets, Gopinath et al. (2017) show the importance of firm leverage on misallocation and aggregate productivity dynamics during the boom period in the Southern European countries, whereas our focus is on the investment dynamics in the Euro Area countries during the bust period.

Our paper proceeds as follows. Section 2 presents the broader literature that our paper relates to. Section 3 presents a stylized model to motivate our empirical exercise. Section 4 presents the data used in the paper and reports descriptive statistics. Section 5 introduces the empirical framework and identification methodology. Section 6 presents our empirical results. Section 7 concludes.

2   Related Literature

Our work builds on an extensive empirical literature on corporate debt and firm investment that predates the crisis. For instance, Whited (1992) shows that adding debt capacity variables to a standard investment model improves the model fit. Similarly, Bond and Meghir (1994) finds an empirical role for debt in standard investment models. For listed firms in the US, Lang et al. (1996) document a negative relationship between debt and investment for firms without valuable growth opportunities.

Our work also relates to more recent empirical literature on the sovereign-bank nexus. Sovereign-bank linkages can arise through different channels. One direct channel, which we focus on, arises from banks holding significant amounts of sovereign debt. As sovereign default risk increases and sovereign ratings get downgraded, the net worth of banks holding such sovereign debt will be negatively affected (Gennaioli et al., 2014). A more indirect linkage can arise when the government (explicitly or implicitly) backstops the financial system, through guarantees or bank bailouts (Laeven and Valencia, 2013). Such bailouts can add significantly to sovereign debt, increasing sovereign risk (Acharya et al., 2014a). Weaknesses in the banking sector can reinforce these sovereign-bank linkages as in Acharya and Steffen (2015) and Gennaioli et al. (2013). Another possible linkage is through moral suasion, when governments force banks to hold risky government bonds as in Becker and Ivashina (2018), Altavilla et al. (2017) and Ongena et al. (2017). We use the bank-sovereign channel as one specific channel through which rollover risk can materialize to sharpen the identification of the effect of rollover risk on corporate investment during the crisis. We focus on the channel that arises from bank holdings of sovereign debt since it is the one that is most straightforward to measure.

There exists a large theoretical literature on corporate investment and debt, starting with Hart and Moore (1994), Hart and Moore (1995), and Hart and Moore (1998) who show that debt is an optimal contract to resolve agency problems and prevent inefficient investment. These models either only examine long-term debt or short-term debt but not a combination of the two. Darst and Refayet (2017) develop a model where a combination of short-term and long-

term debt is optimal. In their model, long-term debt insulates the firm from a potential fall in credit spreads while short-term debt exposes the firm to credit spread fluctuations. However, short-term debt comes at the advantage of risk-free financing. Firms optimally choose the maturity structure of debt to inter-temporally manage how much risky debt to issue. The sovereign debt literature has developed models of debt contracts with bankruptcy costs and agency costs for debtholders, where short-term debt will generally be preferred because it is cheaper, except when self-fulfilling rollover crises are probable (Chaterjee and Eyigungor, 2012).

In related work on the implications of debt overhang, Lamont (1995) shows that the effect of debt overhang varies with economic conditions. Debt overhang binds when the economy is in a downturn since investment returns are low. As a result, high levels of debt can create multiple equilibria in which the profitability of investment varies with economic conditions. Hennessy (2004) shows that debt overhang distorts the level and composition of investment, with a severe problem of underinvestment for long-lived assets. A significant debt overhang effect is found, regardless of firms' ability to issue additional secured debt. Hennessy et al. (2007) corroborate large debt overhang effects of long-term debt on investment, especially for firms with high default risk.

We build on this literature, by incorporating a concept of debt maturity into the competitive equilibrium model of capital structure developed by Miao (2005) to motivate our empirical setup, and by providing new empirical evidence on the relevance of leverage and debt maturity for firm investment, exploiting the unique data and crisis setting in Europe to identify the effects.

3 Theoretical Background

Our stylized model of firm investment, leverage and debt maturity builds on Miao (2005). We depart from this model of firm investment by incorporating a notion of debt maturity. In this setting, there is a large number of identical firms. Information is perfect and investors are risk-neutral. They discount future cash flows at a constant risk-free rate $r > 0$. Time $t \in [0, 1]$

is continuous, and uncertainty is represented by a probability space $(\Omega, \mathcal{F}, \mathbb{P})$ over which all stochastic processes will be defined.

Firms operate under perfect competition and all firms are price takers. The price of the product of firms is denoted p. Firms use capital in order to produce output using a production function $F \colon \mathbb{R}_+ \to \mathbb{R}_+$, $F(k) = k^\nu$, where $\nu \in (0,1)$. Capital depreciates at a constant rate $\delta > 0$.

The technology shock process for a given firm $(z_t)_{t \geq 0}$ follows a geometric Brownian motion

$$\frac{dz_t}{z_t} = \mu_z dt + \sigma_z dW_t,$$

where μ_z and σ_z are positive, and $(W_t)_{t \geq 0}$ is a standard Brownian motion representing the firm-specific uncertainty.[2]

3.1 Firm profits

We define operating profits of the firms as the value of total output valued minus the cost of its inputs usage:

$$\pi(z, p) = pzk^\nu - (r + \delta)k$$

where r is the rental rate. We obtain the following optimality condition

$$k = z^\gamma \left(\frac{p\nu}{r + \delta} \right)^\gamma,$$

where $\gamma \equiv (1 - \nu)^{-1}$. Hence, output y will be given by

$$y = z^\gamma \left(\frac{p\nu}{r + \delta} \right)^{\gamma\nu}.$$

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[2]Since the process $(z_t)_{t \geq 0}$ is non-stationary, Miao (2005) includes an exogenous Poisson firm-death process with arrival rate η. However, for our purposes of studying an average firm, and not the distribution, this is not needed. Additionally, we abstract from taxes as well. Even though taxes are necessary in this type of models to obtain positive amounts of debt, we will not include them for tractability. Incorporating taxes and firm-death processes would not alter our comparative statics.

We define

$$a(p) \equiv p^\gamma (1 - \nu) \left(\frac{\nu}{r + \delta} \right)^{\nu \gamma},$$

such that firm profits can be expressed as a function of price, technology shocks and other parameters

$$\pi(z, p) = a(p) z^\gamma.$$

3.2 Corporate debt and debt maturity

In order to stay within a homogeneous time setting, we will use infinite-term debt contracts. Departing from Miao (2005), we introduce a notion of debt maturity by assuming that the firm pays a constant coupon b only under a shock that has arrival rate φ, as in Chaterjee and Eyigungor (2012). This implies that at any given moment, there is an instantaneous probability φ of having to pay the debt in full. The parameter φ represents the term of the debt, i.e., the time to maturity. Under any exponential distribution, the expected duration under no-default is given by $1/\varphi$. This means that the higher the parameter φ, the shorter the duration.

After paying debt, the shareholders receives the remaining cash flows. If the firm defaults, it is immediately liquidated and the proceeds go to the existing creditors; in this case, the shareholders receive nothing in return.

3.3 Liquidation value and the value of the unlevered firm

After default, the firm is immediately liquidated and exits the industry. The liquidation value is a fraction $\alpha \in (0, 1)$ of the value without leverage of the firm $A(z, p)$. Since we have set fixed costs of entry to zero,[3] we can readily find this value as

$$A(z, p) = \frac{a(p)}{\lambda} z^\gamma, \quad \lambda \equiv r - \mu_z \gamma - \frac{1}{2} \sigma_z^2 \gamma (\gamma - 1) > 0.$$

Notice that the value of liquidation $A(z, p)$ corresponds to the discounted present value of profits without leverage $\Pi(z, p)$.

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[3]In Miao (2005), the abandonment threshold is a function of costs of entry. When this is zero, this threshold for z is zero.

3.4 Liquidation decision and value of equity under leverage

At each date t, after servicing the debt b, the residual cash flows are distributed to shareholders as dividends. The shareholders choose investment and default policy to maximize the value of their claims taking price p as given. Assume that default is triggered when the shareholders choose to cease raising additional equity to meet the payments. The value of their claims is then represented by

$$e\left(z,b,p\right) = \sup_{T \in \mathcal{T}} E^z \left[\int_0^T e^{-rt} \pi\left(z_t, p\right) dt - \int_0^T e^{-(r+\varphi)t} b dt \right]$$

where $\mathcal{T}$ is the set of all stopping times, over which maximization takes place, relative to the filtration generated by the Brownian motion $(W_t)_{t \geq 0}$. As Miao (2005) shows, the value of equity is increasing in z, and hence default will be triggered when z falls below a threshold z_d, which will be determined endogenously. Investment only happens under the no-default region $z > z_d\left(b; p\right)$. This threshold is determined by the smooth-pasting condition:

$$\left. \frac{\partial e(z, b; p | z_d)}{\partial z} \right|_{z=z_d} = 0$$

which determines the value of equity as:

$$e\left(z,b,p\right) = \left[\Pi\left(z; p\right) - \frac{b}{r+\varphi} + \left(\frac{b}{r+\varphi} - \Pi\left(z_d; p\right) \right) \left(\frac{z}{z_d} \right)^{\vartheta} \right], \quad z > z_d$$

where

$$\vartheta = \frac{1}{\sigma_z^2} \left[\left(\frac{1}{2}\sigma_z^2 - \mu_z \right) - \sqrt{2\left(r+\varphi\right)\sigma_z^2 + \left(\frac{1}{2}\sigma_z^2 - \mu_z \right)^2} \right] < 0,$$

and

$$z_d = \left[\frac{\vartheta \lambda b}{\left(\vartheta - \gamma\right)\left(r+\varphi\right) a\left(p\right)} \right]^{\frac{1}{\gamma}}$$

Notice that the higher the debt and the longer its maturity, the higher its threshold, and

hence, the higher its probability of default. The value of liquidation of the firm is given by

$$\Pi(z_d, p) = \frac{\vartheta}{\vartheta - \gamma} \frac{b}{r + \varphi}$$

3.5 Expected investment

Since the distribution of z is not stationary, we must ensure stationarity by dividing the capital stock by z. The expected stock of the detrended capital at any given moment is given by

$$Ek = z^{-1} \left[1 - \left(\frac{z}{z_d} \right)^{\vartheta} \right] y^{\frac{1}{\gamma}}$$

where it can be easily seen that the capital stock will be increasing in output, decreasing in debt, and decreasing in debt maturity, i.e., $1/\varphi$.

We can linearize the previous equation by using a first-order Taylor approximation of the log of the variable around its steady state, those variables being y, b, and φ, respectively. Define the coefficients

$$\alpha_x = E \frac{\partial k}{\partial x} \bigg|_{\mathbf{x}=\mathbf{x}^*}, \quad \forall x \in \mathbf{x}$$

where $\mathbf{x} = y, b, \varphi$ and x^* correspond to the deterministic steady state. With these, we obtain:

$$E\tilde{k} = \alpha_b \tilde{b} + \alpha_y \tilde{y} + \alpha_\varphi \tilde{\varphi}$$

Where $\alpha_y, \alpha_\varphi > 0$ and $\alpha_b < 0$. Since the variables $\tilde{x}$ are deviations from the steady state, we could substitute those variables by $\Delta x / x^*$ instead. We can manipulate terms to obtain:

$$E \left(\frac{\Delta k}{k^*} \right) = \hat{\alpha}_b \frac{\Delta b}{y^*} + \hat{\alpha}_{\varphi^*} \frac{\Delta \varphi}{y^*} + \hat{\alpha}_{k^*} \frac{\Delta y}{y^*}$$

Where $\hat{\alpha}_x = \alpha_x y^* / k^*$, $\forall x \in \mathbf{x}$. As in Bloom et al. (2007), we can add an error correction representation:

$$\frac{\Delta k}{k^*} = \theta \alpha_0 + \hat{\alpha}_b \frac{\Delta b}{y^*} + \hat{\alpha}_\varphi \frac{\Delta \varphi}{y^*} + \hat{\alpha}_y \frac{\Delta y}{y^*} - \left(\theta k - \theta_b \frac{b}{k^*} - \theta_y \frac{y}{k^*} - \theta_\varphi \varphi \right) + v \tag{1}$$

where $\theta_x = \theta \alpha_x k^*$ for $x = \{b, y\}$ and $\theta_\varphi = \theta \alpha_\varphi$. Notice that the left-hand side corresponds to the net investment rate of the firm. On the right-hand side, the second term captures the ratio of financial expenses to earnings before interest, taxes, depreciation and amortization (i.e., interest paid/EBITDA); the third term captures the change in debt maturity; the fourth term can be captured by the growth of operating revenue or sales; and the terms in the error correction model proxy for size (k), leverage (b/k^*), cash flow (y/k^*), and the inverse of debt maturity (φ). In normal times, we expect investment to be increasing in φ and decreasing in leverage and cash flow, on account of bankruptcy and agency costs. The idiosyncratic shock v can contain (firm-specific and country-sector-year) fixed effects, as in Bloom et al. (2007):

$$v_{i,t} = \alpha_i + \alpha_{c,s,t} + \varepsilon_{i,t}$$

The expression in equation 1 motivates our main empirical specifications – equations 2, 3, and 4 as shown below.

4 Data

In this section we describe the data and variables used in the paper, before turning to the empirical framework and identification of the effects we are interested in.

4.1 Firm-Level Data

We use the Orbis global database, from Bureau van Dijk (BvD)—a Moody's Analytics company. Orbis is the largest cross-country firm-level database, covering over 200 countries and 200 million firms that can be used for research focusing on linking firms' financial accounts, ownership structure and production decisions. The database includes all industries and both private and public firms. BvD collects data from various sources, in particular, publicly available national company registries, and harmonizes the data into an internationally comparable format.

The coverage of firms varies both by country, industry, over time and across variables.

The reason for variation in firm coverage by country is that different countries have different laws in terms of which firms are required to file their financial accounts.[4] For countries where the law requires every firm to file with the national company registry, the data obtained via Orbis will be identical to that contained in the country's financial accounts prepared by official statistical offices.[5]

The coverage of firms in Orbis database can vary by time and industry and this may be a source of discrepancy between various studies. The cause of this problem is the common practice in the literature of using a single vintage of Orbis database (or a single download from Wharton Research Data Services (WRDS)). As, explained in detail in Kalemli-Ozcan et al. (2015), the only way to get around this problem and have consistent coverage of firms over time and by industry is to use the historical vintages and match the firm data over time using unique firm identifiers. If a single vintage is used, firms will be missing since Orbis drops firms over a certain period of time from the database and also some variables, such as value-added and intermediate inputs, will be missing since every vintage does not cover all the variables. The industry classification will also be misleading since these classifications change over time due to firms' expanding their operations and/or firm and industry ID changes made by the national statistical offices. Due to such missing information, Orbis single vintage data will generally over-represent larger firms and under-represent smaller firms, requiring imputations and re-weighing of the data to ensure an adequate representation of small firms. As shown in Kalemli-Ozcan et al. (2015), there is no need to re-weigh and impute the data if the historical vintages are used, as this produces the nationally representative data mimicking the firm size distributions of the official statistics of each country.

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[4]There is a common misconception that data from countries' national statistical offices always have better coverage than Orbis. If the country regulation is such that all firms have to file with the business registry then the coverage obtained from Orbis will be representative. For the other countries where the regulation is such that firms over a certain size threshold files their financial accounts, then the national statistical offices might have administrative surveys that can cover some of the differences in coverage of firms' financial accounts. A case in point is the United States, where private firms are not required to file financial accounts but there are select surveys covering certain set of firms in certain years such as the Federal Reserve Board of Governors' survey on "small business finance," which is a repeated cross-section that comes in four waves and covers only 3000-5000 firms and is not nationally representative.

[5]Country censuses are administrative datasets and will cover the universe of firms in a country; however, census datasets typically do not provide information on individual firms' financial accounts as company registries do.

We follow Kalemli-Ozcan et al. (2015) to construct and clean our firm-level data. The main financial variables used in the analysis are total assets, sales, operating revenue (gross output), tangible fixed assets, intangible fixed assets, liabilities, and cash flow. We transform nominal financial variables into real variables using country-specific consumer price indices with 2005 base and converting to US dollars using the end-of-year 2005 US dollar/national currency exchange rate. In other words, the value of variables is expressed in constant prices at constant exchange rates. We drop financial firms and government-owned firms, and keep all the other sectors. As shown in Kalemli-Ozcan et al. (2015), the coverage of our sample when compared to official statistics is extensive, ranging from roughly 70 to over 90 percent depending on the country.

4.2   Matching Firm- and Bank-Level Data

We create a novel data set of bank-firm relationships in Europe by matching our firm-level data to their banks. For each firm, there is a variable called BANK in our firm-level database showing the name(s) of the firm's main bank(s), which, following the literature on firm-bank lending relationships, we assume to be the main bank(s) that the firm borrows from. We obtain this information through our firm-level database but the original source is KOMPASS.[6] This data has been used before by Giannetti and Ongena (2012), among others, to study bank-firm relationships. We use the 2013 data entries by firms of their main banks, including both the primary and secondary bank-firm relationship. We checked the stability of bank-firm relationships with the 2015 data entries and confirmed that bank-firm relationships are sticky and do not significantly change over short periods of time. [7]

For each main bank, we obtain bank balance sheet data from BANKSCOPE. This data set is also from Bureau Van Dijk, containing balance sheet information about more than 30,000

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[6]KOMPASS provides the bank-firm connections in 70 countries including firm address, executive names, industry, turnover, date of incorporation and, most importantly the firms' primary bank relationships. KOMPASS collects data using information provided by chambers of commerce and firm registries, but also conducts phone interviews with firm representatives. Firms are also able to voluntarily register with the KOMPASS directory, which is mostly sold to companies searching for customers and suppliers.

[7]Giannetti and Ongena (2012) use both the 2005 and 2010 vintages and also find that bank-firm relationships are sticky. Other research has shown that these relationships are sticky also in the United States (see, for instance, Chodorow-Reich (2014)).

banks spanning most countries and data up to 16 years. Linking the main bank name to its equivalent in BANKSCOPE is a significant hurdle since there is no standardized procedure to match KOMPASS and BANKSCOPE bank names. We make use of the programs *OpenRefine* and *OpenReconcile* that offer several approximate-matching algorithms. We use these programs to match the BANK variable to the bank names in BANKSCOPE. Our match rate is very high: 87.6% of all bank name observations. Most of the unmatched observations correspond to small cooperative banks for which financial data is anyway not available in BANKSCOPE.

4.3 Matching Bank-Level Data to Sovereigns

Banks in the BANKSCOPE database are all recorded as domestic legal entities, including the subsidiaries of foreign parent companies. To determine the country of origin of each bank in our sample, we need to trace its ownership information to the ultimate owner. We set the country of origin of each bank equal to the country of origin of the ultimate owner of the bank, even if this entity is incorporated in a foreign country, under the assumption that it is the strength of the parent bank that determines the strength of each subsidiary. We trace this information using the Global Ultimate Owner (GUO) variable. Then, we use its consolidated balance sheet reported directly in BANKSCOPE.

Whenever the GUO information is missing, a couple of criteria are used. First, some of the banks listed are actually branches of foreign banks. These are matched by hand to their GUO abroad. Second, some banks are reported to be independent or "single location" (i.e., they have only one branch). For these banks, the GUO is the bank itself. And finally, using the independence indicator provided by Bureau Van Dijk, for banks with high degree of independence (i.e., values B-, B or B+), the GUO will be also the bank itself, as in the previous case. The sovereign of each bank is defined as the sovereign country of the entity that is the ultimate owner of the bank.

Data on total sovereign bond holdings come from BANKSCOPE. The limitation of these data is that they do not indicate the nationality of the sovereign. We therefore complement this data with data on *own* sovereign's holdings of the bank from the the European Central Bank

(ECB)'s proprietary database of Individual Balance-Sheet Items (IBSI). The difference between the two datasets is that the BANKSCOPE data captures all sovereign bonds while the IBSI data captures domestic bonds only. In practice, the difference between the two data series should be small since most of a bank's total sovereign bond holdings consist of domestic bonds. Indeed, according to the IBSI data for our sample of banks, around 70% of euro area banks' sovereign bond holdings are domestic, with a even higher percentage in peripheral countries.

4.4 Descriptive Statistics

Investment in real capital expenditures can be measured on a gross or net basis (i.e., with or without depreciation). If investment expenditures just match the depreciation of capital equipment, then gross investment is positive, but net investment remains unchanged. Therefore, net investment matters most for future productivity. Consequently, we use net investment rate in our empirical work, computed as the annual change in fixed tangible assets.[8] We measure net investment rate as the ratio between net fixed capital stock increase and the initial net fixed capital stock, i.e., $\Delta K_t / K_{t-1}$. Fixed capital is measured as the firm's gross capital stock minus depreciation.

We capture firm leverage using the ratio of total debt to total assets. Total debt is measured as the sum of long-term debt, loans, credit, and other current liabilities. To capture the drag on finances stemming from debt payments, we include the debt service ratio calculated as total interest paid by the firm over its earnings before taxes, depreciation and amortisation of capital (EBITDA).

To capture rollover risk we use the share of long-term debt in total debt, which in the tables we refer to as "maturity". Long-term debt comprises all borrowing from credit institutions (loans and credits) and bonds, whose residual maturities are longer than one year. Short-term debt comprises all current liabilities, i.e., loans, trade credits and other current liabilities, with residual maturities shorter than one 1 year. An increase in short-term debt (i.e., a decrease in maturity) poses increased rollover risk during bad times. Small firms finance investment

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[8]Using net investment is common in the literature; see, for example, Lang et al. (1996).
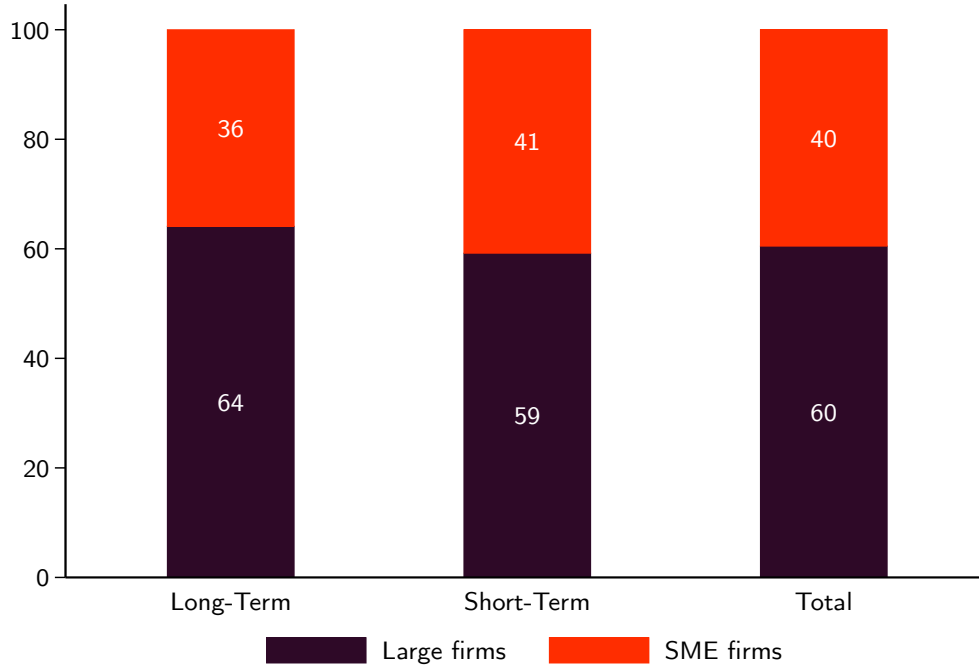
Figure 3: Debt by Maturity and Firm Size

Note: Aggregated from firm-level data. SMEs are firms with fewer than 250 employees and/or firms with total assets lower than 43 million euros at 2005 prices.

predominantly with short-term debt and hence there is an inherent negative correlation between long-term debt share in total debt and investment during regular times. It is therefore important to also control for firm size to assess the independent effect of debt maturity on firm investment. We thus use log of total assets as a control for firm size, labelled as "size."

Figure 3 shows the importance of including small and medium-sized firms when analyzing the maturity structure of debt. Even though most of the total debt in the euro area is held by large firms, small firms hold a large fraction of 41 percent of the overall short term debt outstanding.

We control for growth opportunities using net sales growth. We cannot use Tobin's Q or other market-based proxies for growth opportunities because market values are only available for listed firms which are less than 1% of our sample. We also control for cash flow as is standard in these regressions.

We measure bank weakness of the firm's main bank, WEAK BANK, using the share of total sovereign holdings of the bank over total assets of the bank. We use both BANKSCOPE and IBSI data on sovereign bond holdings to construct the variable WEAK BANK since IBSI data starts only in the fourth quarter of 2007 and covers fewer banks. In an extension, we only consider own sovereign exposure for banks from peripheral countries because exposure to own sovereigns in core countries need not indicate weakness. While this is our preferred specification it is also the most limited in terms of data coverage.

We also explored alternative measures of bank weakness based on bank leverage and total capital ratio. However given that most bank assets and liabilities are not marked to market, these balance sheet variables are very stable and do not register large enough movements over time to qualify as reliable measures of bank weakness. Moreover, sovereign bond holdings are a more direct measure of exposure to sovereign risk of each bank, and therefore more directly captures bank-sovereign linkages.

All firm-level variables are winsorized such that their kurtosis falls below a threshold of 10. This implies that net investment to lagged capital, debt to assets ratio, interest paid to EBITDA, cash flow to assets, sales growth and log of capital stock are winsorized at the 5%, 3%, 3%, 2%, 2%, and 1% level respectively.

Table 1 presents how many of the firm-bank relationships in the sample are multiple relationships (i.e., with more than one bank) and cross-border (i.e., with banks whose parent company is foreign). Having relationships with more than one bank is not very common for firms across euro area countries with the exception of Greece. Having a foreign bank is even less common in this sample. In the case where multiple bank relationships are reported, the first listed bank is considered the main bank. For Italy no firm reports their bank relationships so this country will not be included in the analysis.

Table 1: Firm-Bank Relationships
(percentage of the total number of firms)

Country	With more than one bank[1] (percent)	Without any foreign bank[2] (percent)
Austria	20.4	99.5
France	0.0	100.0
Germany	32.2	99.8
Greece	50.4	99.9
Ireland	0.0	100.0
Netherlands	0.4	100.0
Portugal	37.9	97.9
Spain	40.3	99.0

[1] Share of firms in matched-firms sample reporting more than one bank they have relationship with.
[2] Share of firms that report having relationships only with domestic banks.

Table 2 shows descriptive statistics for the sample of cross-sectional changes and also for the panel. Investment rates average about 10.4 percentage points during sample period but declined by about 8.4 percentage points during the crisis period relative to the pre-crisis period. On average, debt accounts for about two-third of assets and about one-third of total debt is long term (i.e. with a remaining maturity over 1 year). Financial expenses account for about 17 percent of EBITDA on average. Exposures to sovereign bond holdings are modest on average, at about 4 percent of total assets, but there is much variation with some banks holding more than one-third of their assets in sovereign bonds.

Table 2: Summary Statistics[†]

Variables	Obs.	Mean	St. Dev.	Min.	Median	Max.
Cross-section[1]						
Δ Net investment/Capital[2]	1,283,890	−0.084	0.596	−2.922	−0.028	2.922
Δ Sales growth[3]	690,327	−0.127	0.321	−3.005	−0.076	3.005
Δ Maturity[4]	1,455,245	−0.002	0.275	−1.000	0.000	1.000
Δ Size[5]	1,456,994	0.086	0.599	−11.548	0.049	12.476
Δ Debt/Assets	1,456,615	−0.025	0.267	−2.119	−0.027	2.119
Δ Int. Paid/EBITDA	692,081	−0.010	0.354	−2.754	−0.004	2.754
Δ Cash Flow/Assets	743,292	−0.030	0.104	−1.134	−0.023	1.134
Δ Bank's own sovereign bonds/Assets	628,067	0.012	0.019	−0.070	0.010	0.111
Δ Bank's total sovereign bonds/Assets	1,077,232	0.006	0.027	−0.296	0.004	0.256
Panel						
Net investment/Capital[2]	11,088,755	0.104	0.608	−0.539	−0.056	2.383
Sales growth[3]	7,763,804	0.011	0.324	−1.410	−0.003	1.595
Maturity[4]	13,006,719	0.338	0.384	0.000	0.160	1.000
Size[5]	13,033,680	13.766	1.750	0.104	13.682	26.245
Debt/Assets	13,020,803	0.674	0.401	0.050	0.658	2.170
Interest Paid/EBITDA	6,824,180	0.170	0.397	−1.188	0.100	1.566
Cash Flow/Assets	7,497,526	0.073	0.119	−0.600	0.063	0.534
Bank's own sovereign bonds/Assets	3,902,994	0.030	0.025	0.000	0.023	0.175
Bank's total sovereign bonds/Assets	7,950,132	0.043	0.041	0.000	0.031	0.382

[†] Based on unbalanced sample of matched firms (to their banks) in the euro area.
[1] Cross section variables are calculated as the difference between the mean for the period starting 2008 and the mean before 2008 (2009 for own sovereign bonds).
[2] Increase in real capital stock over lagged real capital stock.
[3] Logarithmic change of real sales.
[4] Long-term share of total debt.
[5] Logarithm of total real assets.

5 Empirical Framework and Identification

In this section we explain the framework and identification strategy we use to investigate the role of debt overhang and rollover risk in affecting corporate investment in Europe.

As we show above, we add long-term debt by means of stochastically maturing debt as in Chaterjee and Eyigungor (2012) to the model of Miao (2005), and then transform the expected capital into a linear error-correction model of investment following Bloom et al. (2007), focusing on debt variables rather than uncertainty. This extension produces a role for debt maturity in shaping investment.

This stylized simple model serves to motivate our empirical setup, and specifically the inclusion of debt maturity as a determinant of corporate investment as well as the set of control variables. In this simple model with bankruptcy costs and agency costs, short-term debt will generally be preferred over long-term debt to finance investment because it is cheaper, given the agency costs associated with long-term debt. A natural extension of this model would be to consider self-fulfilling rollover crises, as in Chaterjee and Eyigungor (2012). If such rollover crises are probable, this would increase the attractiveness of long-term debt. We do not explicitly model these rollover crises but rely on the existing literature. What matters for the empirical application is that there exists a possible tradeoff in the use of short-term debt, where investment will be financed by short-term debt during the boom and short-term debt will affect investment negatively during the bust.

We use a difference-in-difference approach, both in the cross-section and in panel structure, to identify the effect of corporate debt overhang and rollover risk on investment. We implement this approach by assessing the differential impact on investment of different levels of leverage and debt maturity pre-post crisis, where we define the pre period as 2000–2007 and the post period as 2008–2012. The analysis controls for the usual determinants of investment and also for debt service since the debt to assets ratio may not fully capture the effects of lingering debt overhang when debt is measured at book value. We condition on aggregate demand shocks since it is possible that firms decreased investment due to negative demand (or productivity) shocks rather than the debt overhang and rollover risk channels we focus on. We do so by including four-digit industry×country fixed effects (in the cross-sectional regressions) or four-digit industry ×country×year fixed effects (in the panel regressions). These effects will absorb the impact of changes in credit demand at the four-digit sector level as well as changes in country-level demand conditions, including those arising from changes in sovereign risk and general uncertainty conditions. Where feasible, we control for bank fixed effects to capture the role of pre-existing bank relationships.

Our identification approach is valid as long as any remaining variation in *ex post* firm-specific demand conditions does not vary systematically with the *ex ante* level and maturity structure of the firm's indebtedness. We think this is a reasonable assumption. To see why, let's

assume that firms with positive demand shocks during the boom years accumulated a lot of debt to be able to produce and meet that demand. Then, our identification strategy using triple differences-in-differences would be invalid if firms a) suffer from negative demand shocks, b) operate in a different four-digit industry, and c) have accumulated more long-term than short-term debt during boom years. We think it is not plausible that all these conditions are met simultaneously. It is more likely that firms with positive demand shocks in the boom years accumulated more short-term debt, as this was a cheaper source of financing, and that firms operating in the same four-digit sector tend to be hit by similar demand shocks (be it positive or negative) over time.

We limit the analysis to firms in the euro area. These firms were subject to the same monetary policy when they experienced diverging conditions in terms of banking and sovereign risk during the crisis. We run a cross-sectional regression using average changes for each firm-level variable between the period 2000–2007 to 2008–2012 as follows (the estimation equation below can directly be mapped into the equation (1)):

$$\Delta\left(\frac{\text{Investment}}{\text{Capital}}\right)_i = \beta\,\Delta\left(\frac{\text{Debt}}{\text{Assets}}\right)_i + \delta\,\Delta\text{Maturity}_i + \phi\,\Delta\left(\frac{\text{Interest Paid}}{\text{EBITDA}}\right)_i + \quad (2)$$
$$\Delta\mathbf{X}_i{}'\,\gamma + \alpha_{c,s} + \varepsilon_i$$

where $\alpha_{c,s}$ are country$\times$four-digit sector fixed effects. Debt/Assets is the ratio of total debt to total assets, capturing the financial leverage of the firm. Maturity is the ratio of long-term debt to total debt, denoting rollover risk. Interest Paid/EBITDA is financial expenses to earnings before interest, depreciation, and amortization. The vector $\mathbf{X}_i$ contains control variables, such as changes in sales growth, cash flow, and firm size, and most importantly an indicator of whether firm's main bank is a *weak bank* or not. We will detail below how we will include this variable.

Our main variables of interest are $\Delta\left(\frac{\text{Debt}}{\text{Assets}}\right)_i$, $\Delta\text{Maturity}_i$, and $\Delta\left(\frac{\text{Interest Paid}}{\text{EBITDA}}\right)_i$. We expect β and ϕ to be negative on account of debt overhang effects. And we expect the coefficient δ to be positive as rollover risk increases during the crisis for firms with shorter maturity debt.

Alternatively we can estimate the model using a panel regression where we interact all

variables (in levels and lagged one period) with the variable $POST_t$, which is a binary variable equal to 1 starting in the year 2008, which we take as the beginning of the global financial crisis:[9]

$$\left(\frac{\text{Investment}}{\text{Capital}}\right)_{it} = POST_t \times \mathbf{W}_{it-1}{}'\boldsymbol{\beta} + \mathbf{W}_{it-1}{}'\boldsymbol{\delta} \tag{3}$$
$$+ POST_t \times \mathbf{X}_{it-1}{}'\boldsymbol{\gamma} + \mathbf{X}_{it-1}{}'\boldsymbol{\omega} + \alpha_i + \alpha_{c,s,t} + \varepsilon_{it}$$

The vector $\mathbf{W}_{i,t-1}$ contains our main variables of interest—debt, maturity, and interest paid— and the vector of control variables $\mathbf{X}_{it-1}$, α_i are firm-specific fixed effects, and $\alpha_{c,s,t}$ are country×four-digit sector×year fixed effects. This specification allows to test for differential effects during the crisis. Specifically, we expect that the coefficient on Maturity switches sign from negative in normal times to positive during crisis times, consistent with rollover risk materializing during crisis periods.

Thus far we have considered rollover risk as a general phenomenon during crises for highly indebted firms that finance their investment primarily using short-term debt, without a special role for banks. One particular channel through which rollover risk can manifest itself is when weak bank balance sheets trigger a reduction in the supply of credit exactly at a time when firms need to rollover their bank loans. In our setting, firms borrow from banks with holdings of risky sovereign debt. These bank-sovereign linkages can affect firm investment via a bank lending channel when increases in sovereign risk weaken bank balance sheets, reducing the supply of loans to firms and increasing rollover risk.

In order to gauge the impact of the crisis and the role of sovereign exposures as a specific manifestation of rollover risk, our next strategy is to run a triple difference-in-difference regression, conditioning on both the crisis and bank's exposure to sovereign bonds. Specifically, we will interact all variables with the variables $POST_t$ and Weak Bank$_{ibt-1}$. $POST_t$ is a binary variable equal to 1 starting in the year 2008, which we take as the beginning of the global financial crisis.[10] Weak Bank$_{ibt-1}$ is the amount of sovereign bond holdings on the balance sheet

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[9]For most countries in our sample, this is also the starting year of a major recession.

[10]When using IBSI data on banks' sovereign exposure, we start the variable POST in 2009 because the IBSI data starts only in the fourth quarter of 2007.

of the firm's main bank. The regression capturing the role of sovereign exposures is as follows:

$$\left(\frac{\text{Investment}}{\text{Capital}}\right)_{it} = POST_t \times \text{Weak Bank}_{ibt-1} \times \mathbf{W}_{it-1}{}'\boldsymbol{\beta} + \tag{4}$$

$$POST_t \times \mathbf{W}_{it-1}{}'\boldsymbol{\delta} + \text{Weak Bank}_{ibt-1} \times \mathbf{W}_{it-1}{}'\boldsymbol{\theta} +$$

$$POST_t \times \text{Weak Bank}_{ibt-1}{}'\boldsymbol{\eta} + \mathbf{W}_{it-1}{}'\boldsymbol{\mu} + \alpha_i + \alpha_b + \alpha_{c,s,t} + \varepsilon_{it}$$

where α_i are firm-specific fixed effects, α_b are bank-specific fixed effects, and α_{cst} are country $\times$ four-digit sector $\times$ year fixed effects. α_b is estimated for firms that have relationships with more than one bank (single relationships are equivalent to a firm fixed effect). The vector $\mathbf{W}_{i,t-1}$ contains our main variables of interest—the ratio of total debt to assets, the ratio of long-term debt to total debt (Maturity), and the debt service ratio (Interest Paid/EBITDA)—and also all control variables, including sales growth ($\Delta \log$ Sales), cash flow and firm size measured as log of total assets. Changes in sovereign risk that affect bank weakness through their holdings of sovereign bonds are taken to be largely exogenous to the bank, such that the bank's pre-crisis holdings of sovereign bonds are a meaningful proxy for changes in bank weakness during the crisis.

Our main coefficients of interest are formed by the vector β. We expect a negative coefficient on the interaction term $POST_t \times \text{Weak Bank}_{ibt-1} \times \Delta (\text{Debt/Assets})_{it-1}$ on the premise that debt overhang effects are more pronounced for firms linked to weak banks. In addition, we expect a positive coefficient on the interaction term $POST_t \times \text{Weak Bank}_{ibt-1} \times \Delta \text{Maturity}_{it-1}$ as firms that predominantly borrow long term are less affected by the risk of weak banks not being able to roll over loans during the crisis.

An important assumption underlying the use of the difference-in-difference methodology is that there is a parallel trend in the dependent variable for different cross sections of the data over which the difference in explanatory variables is taken and that this difference diverges after the shock (i.e., after the crisis starting in 2008). Figure 4 shows the behavior of the average net investment rate for firms with high and low leverage. A firm is considered to have high leverage if its leverage before 2008 is above the median of the sample. It is clear that the investment behavior of these different sets of firms was similar before the crisis but diverged
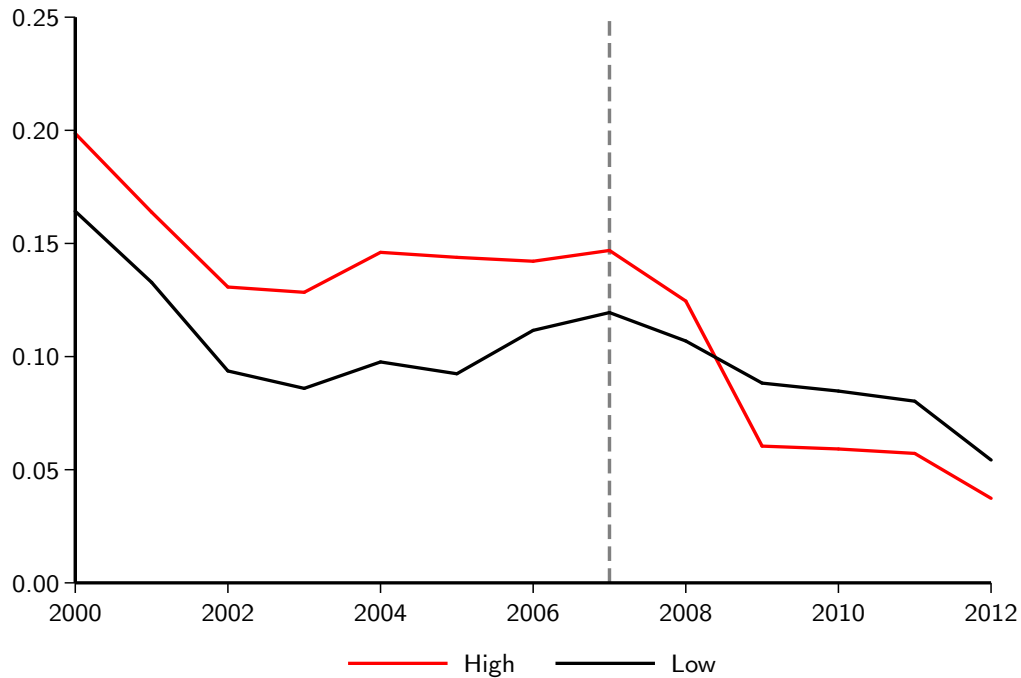
Figure 4: Evolution of Average Net Investment Rate by Leverage

Note: A firm is considered to have a high leverage if its ratio of total debt to total assets before 2008 is above the median.

after the crisis in favor of our results such that high leverage firms reduced investment more. This provides evidence in support of the parallel trend assumption and the empirical approach we take.

6 Empirical Results

This section presents the results for the estimations outlined in the previous section. We will begin with the cross-sectional specifications to explore the medium-term link between firm investment, debt and maturity, by regressing the difference between the pre- and post-crisis average investment rates on the difference between the pre- and post-crisis averages for debt, maturity and control variables. Then, we move to a panel setting where we use a dynamic investment framework in yearly frequency to explore how the crisis affects the relation between

investment, debt and maturity. Then we will use the role of weak bank balance sheets from exposures to sovereign bond holdings as a supply-side shock to investment and as a channel of rollover risk during the crisis. We end this section with inference of the aggregate effects on investment of the firm financial frictions explored in this paper.

6.1   Debt Overhang and Rollover Risk

In this section we describe the results of estimating the cross-sectional first-difference equation 2. Table 3 shows our benchmark results where we include our main variables of interest— leverage, interest coverage, and debt maturity—one-at-a-time to investigate the impact of each of these three variables. All regressions include four-digit sector-country fixed effects to absorb demand effects. All variables are expressed in differences, resulting in a fully balanced panel of firms, equivalent to including firm-fixed effects on the same variables in levels. The differences are computed as the difference for each firm-level variable between its average over the crisis period (2008–2012) and its average over the pre-crisis period (2000–2007).

The objective of these regressions is to gain a medium-term perspective on the effects of financial frictions on firm investment, since the build-up of financial imbalances takes some time to build, as well as on the de-leveraging process. Moreover by focusing on averages of investment rates over subperiods we also smooth out any lumpiness in investments within subperiods. The alternative is to identify the effect we are interested in from year-to-year changes in the variables of interest, as we will do next.

The results in Column 1 of Table 3 indicate that firms that ended up with higher indebtedness (leverage) had on average a significantly lower investment rate as compared to the pre-crisis period. The same holds for an increase in the associated debt service burden, as captured by the ratio of interest expenses to EBITDA, as seen in Column 2. Taken together, these results point to significant debt overhang. An increase in debt maturity between the pre- and post-crisis periods, however, is associated with higher investment, as seen in Column 3. This means that firms with longer maturity debt had relatively higher investment rates during the crisis (i.e., decreased investment less). This result points to increased rollover risk during the

Table 3: Debt Overhang, Rollover Risk, and Investment

Dependent variable: Δ Net investment / Capital

	(1)	(2)	(3)	(4)
Δ Debt/Assets	−0.0569***			−0.0701***
	(0.0060)			(0.0070)
Δ Int. Paid/EBITDA		−0.0161***		−0.0174***
		(0.0031)		(0.0031)
Δ Maturity			0.0563***	0.0798***
			(0.0069)	(0.0078)
Δ Cash Flow	−0.1443***	−0.1274***	−0.1041***	−0.1639***
	(0.0178)	(0.0179)	(0.0166)	(0.0193)
Δ Sales growth	0.2963***	0.2921***	0.2942***	0.2954***
	(0.0164)	(0.0169)	(0.0163)	(0.0169)
Δ Size	0.0308***	0.0345***	0.0287***	0.0294***
	(0.0037)	(0.0048)	(0.0038)	(0.0039)
Sector-Country FE	Yes	Yes	Yes	Yes
Observations	377,576	340,054	377,550	340,002
R^2	0.06	0.06	0.06	0.06

Standard errors are in parentheses, clustered at the sector-country level.
All variables are expressed in differences between their pre-2008 firm-specific mean and their firm-specific mean over the period 2008–2012. Debt/Assets is total debt scaled by total assets. Interest paid is scaled by EBITDA, ratio that corresponds to the coverage ratio. Maturity is the ratio of long-term debt to total debt. Sales is the change in logarithm of sales. Size is measured by the logarithm of total assets. Cash flow is scaled by total assets.
$^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

crisis associated with the accumulation of short-term debt during the boom period, which had to be rolled over at more restrictive conditions during the crisis.

Turning to the control variables, we find that sales growth enters positively, as expected, signifying the positive effect of growth opportunities on firm investment. Firm size enters positively, as expected, capturing the presence of increasing returns to scale in investment and/or the fact that small firms tend to be more affected by financial shocks. Cash flow enters with a negative sign, showing that firms who hoarded cash during the crisis invested less.

Our results are economically significant. Based on the estimates in Table 3), a one standard-deviation increase in the debt variable—capturing worsening debt overhang—implies a decrease in the investment rate equivalent to 23% of its average change.[11] Similarly, a decrease of one standard deviation in maturity explains about 26% of the average change in the invest-

[11]This economic effect is computed as follows: we first obtain the standard deviation of the variable of interest for the sample being used in the estimation; then we calculate the product of the coefficient (shown in Table 3) of a given independent variable with its standard deviation; then we produce the economic effect by dividing this number by the absolute value of the mean of the left-hand-side variable, since we are interested in scaling the effects. This produces an estimate of the effect of a standard-deviation change in the value of an independent variable on the average value of the dependent variable.

ment rate.

Table 4 presents the panel regressions with annual frequency. Column 2 of this table includes interactions with the Post crisis dummy. All other explanatory variables are lagged one period to mitigate simultaneity bias. The results are consistent with the results obtained in Table 3. Moreover, we can now interpret the positive coefficient on the Maturity variable obtained in the cross-sectional regressions, where all variables are included in first-differences. The level effect of this variable in the panel regression is negative, suggesting that more long-term debt is affecting investment negatively, consistent with debt overhang. The coefficient on the interaction between the Post and Maturity variables, however, flips sign, turning positive during the crisis, consistent with an increase in rollover risk during the crisis period.

The results are economically significant and broadly similar to those obtained using cross-sectional regressions. Based on the estimates in column 2 of Table 4, a one standard deviation increase in leverage implies a relative decline in the investment rate during the crisis equivalent to 17% of its average level. Similarly, a one standard deviation decrease in maturity implies a relative decline in the investment rate during the crisis equivalent to 11% of its average level.

Next, we want to understand what drives these changes from regular to crisis times. Therefore, we investigate the role of bank-sovereign linkages as potential drivers of these changes. But before turning to this, we first consider the direct effect of bank weaknesses on investment, also to make sure that the effects found so far are not contaminated by supply side effects arising from weak balance sheets.

Table 4: Rollover Risk During the Crisis

Dependent variable: Net investment / Capital

	(1)	(2)
Debt/Assets$_{t-1}$	-0.0952***	-0.0704***
	(0.0028)	(0.0034)
Int. Paid/EBITDA$_{t-1}$	-0.0116***	-0.0194***
	(0.0009)	(0.0014)
Maturity$_{t-1}$	-0.2525***	-0.2705***
	(0.0023)	(0.0030)
Cash flow$_{t-1}$	0.1683***	0.1842***
	(0.0047)	(0.0064)
Sales growth$_{t-1}$	0.0628***	0.0568***
	(0.0012)	(0.0017)
Size$_{t-1}$	-0.2248***	-0.2286***
	(0.0013)	(0.0014)
Post$_t$×Debt/Assets$_{t-1}$		-0.0440***
		(0.0030)
Post$_t$×Int. Paid/EBITDA$_{t-1}$		0.0138***
		(0.0017)
Post$_t$×Maturity$_{t-1}$		0.0298***
		(0.0031)
Post$_t$×Cash flow$_{t-1}$		-0.0293***
		(0.0078)
Post$_t$×Sales growth$_{t-1}$		0.0116***
		(0.0023)
Post$_t$×Size$_{t-1}$		0.0068***
		(0.0005)
Firm FE	Yes	Yes
Sector-Country FE	Yes	Yes
Bank FE	No	No
Observations	3,722,889	3,722,889
R^2	0.20	0.20

Standard errors are in parentheses, clustered at the firm-level. Post is a dummy taking the value of 1 starting in 2008 and 0 otherwise. Debt/Assets is total debt scaled by total assets. Interest paid is scaled by EBITDA, ratio that corresponds to the coverage ratio. Maturity is the ratio of long-term debt to total debt. Sales is the change in logarithm of sales. Size is measured by the logarithm of total assets. Cash flow is scaled by total assets.
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

6.2   The Role of Weak Banks

Table 5 runs multivariate regressions similar to those in Table 3 with the difference that we now include a Weak bank variable. Each column uses a different definition of the Weak Bank variable, based on the main bank's exposure to total sovereign holdings, domestic sovereign holdings, and periphery country sovereign holdings, respectively. Periphery countries include

Greece, Ireland, Italy, Portugal, and Spain.

Table 5: The Role of Weak Banks
(Alternative Sovereign Exposures)

Dependent variable: Δ Net investment / Capital

	(1)	(2)	(3)
	Δ All Sovereign	Δ Own Sovereign	Δ Own Sovereign (Periphery)
Δ Debt/Assets	−0.0559***	−0.0536***	−0.0535***
	(0.0086)	(0.0095)	(0.0095)
Δ Int. Paid/EBITDA	−0.0131***	−0.0119***	−0.0119***
	(0.0037)	(0.0040)	(0.0040)
Δ Maturity	0.0531***	0.0575***	0.0575***
	(0.0081)	(0.0083)	(0.0083)
Δ Weak Bank	−0.0670*	−0.2754***	−0.2581**
	(0.0358)	(0.0992)	(0.1075)
Δ Cash Flow	−0.1793***	−0.1770***	−0.1769***
	(0.0230)	(0.0238)	(0.0238)
Δ Sales growth	0.2905***	0.2957***	0.2957***
	(0.0192)	(0.0175)	(0.0175)
Δ Size	0.0143***	0.0146***	0.0146***
	(0.0044)	(0.0047)	(0.0047)
Sector-Country FE	Yes	Yes	Yes
Observations	294,255	226,412	226,412
R^2	0.07	0.07	0.07

Standard errors are in parentheses, clustered at the sector-country level.
All variables are expressed in differences between their pre-2008 firm-specific mean and their firm-specific mean over 2008–2012 (2009–2012 for the case where weak bank corresponds to own-sovereign bond holdings of the bank). Debt/Assets is total debt scaled by total assets. Interest paid is scaled by EBITDA, ratio that corresponds to the coverage ratio. Maturity is the ratio of long-term debt to total debt. Weak Bank measures the exposure of the firm's main bank to sovereign bonds, scaled by total assets. In column 1, it includes all sovereign bond holdings; in column 2, it includes only own-sovereign bond holdings (domestic sovereign bonds); and lastly, in column 3, it includes own-sovereign bond holdings if the parent bank of the firm's main bank (or the main bank itself in case it does not have a parent bank) is located in a Periphery country (Periphery domestic sovereign bonds), and otherwise it is set equal to 0. Sales growth is the change in logarithm of sales. Size is measured by the logarithm of total assets. Cash flow is scaled by total assets.
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

The Weak bank variable enters negatively and statistically significant, indicating that there is a direct negative effect on investment due to reduced credit supply from weak banks. Results are qualitatively similar across specifications, although the statistical significance on the Weak Bank variable increases when using own sovereign bond holdings instead of total bond holdings. This is to be expected as using own sovereign holdings increases the precision regarding the factor that contributes to bank weakness during the European sovereign debt crisis (i.e., sovereign exposure). Importantly, controlling for Weak banks does not alter the results on our main variables of interest: Debt/Assets and Maturity. The coefficients and statistical sig-

nificance of both variables are hardly affected when including the Weak bank variables. Taken together these results indicate that debt overhang becomes a drag on investment during the crisis when rollover risk associated with short term debt surfaces. In addition, investment is depressed during the crisis period because of a weakening of bank balance sheets on account of sovereign debt exposures.

Next we run a panel difference-in-difference specification that includes triple interactions, where we interact all firm-specific variables with the Post crisis dummy and the Weak Bank variables. This specification compares firm investment before and after the crisis as a function of the debt overhang and rollover risk variables, differentiating between firms that are linked to weak banks and those that are not. As before, we measure bank weakness using three alternative measures of sovereign exposure. First, we measure bank weakness as total sovereign bond-holdings over total assets of the firm's main bank. Second, we define bank weakness as its exposure to domestic sovereign bond holdings scaled by total assets. Using data on domestic holdings has the advantage that one can more accurately measure exposure to weak sovereigns, though this comes at the cost of a reduced sample size due to data availability. Third, we refine our measure of bank weakness even further, by setting the exposure to domestic sovereign debt to zero for those banks whose parent entity resides in a non-periphery euro-area country. In principle, periphery sovereign bonds were the ones subject to the highest stress during the crisis, and hence the condition of banks holding these bonds should have been affected the most. All regressions include firm fixed effects, bank fixed effects, and four-digit sector-country-year effects. The sample period covers the years 2000 to 2012 and the Post crisis dummy variable takes on a value of one starting in the year 2008. The bottom panel reports the estimated total effects of our key variables: leverage, debt service, maturity and weak bank. The results are presented in Table 6.

Table 6: The Role of Weak Banks During the Crisis
(Alternative Sovereign Exposures)

Dependent variable: Net investment$_t$ / Capital$_{t-1}$

	(1)	(2)	(3)
	All Sovereign	Own Sovereign	Own Sovereign (Periphery)
Interaction effects:[†]			
Post$_t \times$ Weak Bank$_{t-1} \times$ Debt/Assets$_{t-1}$	−0.4383***	−0.9515***	−1.1088***
	(0.0905)	(0.2902)	(0.2680)
Post$_t \times$ Weak Bank$_{t-1} \times$ Int. Paid/EBITDA$_{t-1}$	0.0404	0.159	0.1654
	(0.0557)	(0.1734)	(0.1642)
Post$_t \times$ Weak Bank$_{t-1} \times$ Maturity$_{t-1}$	−0.1104	0.5232**	0.9303***
	(0.0765)	(0.2512)	(0.2416)
Post$_t \times$ Weak Bank$_{t-1} \times$ Cash Flow$_{t-1}$	−0.0201	−1.3726	−1.2479
	(0.2791)	(0.8645)	(0.7884)
Post$_t \times$ Weak Bank$_{t-1} \times$ Sales growth$_{t-1}$	0.1980***	0.5248**	0.4543**
	(0.0746)	(0.2410)	(0.2268)
Post$_t \times$ Weak Bank$_{t-1} \times$ Size$_{t-1}$	−0.0142	0.0038	0.0337
	(0.0138)	(0.0492)	(0.0459)
Total effects:[‡]			
Debt/Assets$_{t-1}$	−0.1165***	−0.0920***	−0.0921***
	(0.0052)	(0.0070)	(0.0070)
Int. Paid/EBITDA$_{t-1}$	−0.0072***	−0.0046***	−0.0047***
	(0.0012)	(0.0015)	(0.0015)
Maturity$_{t-1}$	−0.2404***	−0.2229***	−0.2235***
	(0.0034)	(0.0046)	(0.0046)
Weak Bank$_{t-1}$	0.0364	0.0609	0.0603
	(0.0231)	(0.0500)	(0.0504)
Firm FE	Yes	Yes	Yes
Sector-Country-Year FE	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes
Observations	2,135,137	1,315,060	1,315,060
R^2	0.32	0.34	0.34

[†] Value of the coefficient of the corresponding triple interaction.
[‡] Total effects of a variable are calculated as the sum of all coefficients where the variable is present using the mean value of the corresponding weak-banker variable.
Standard errors are in parentheses, clustered at the firm-level if no banker fixed effect is included and at firm-bank-level otherwise. Post is a dummy variable equal 1 starting 2008 (2009 in the case of domestic sovereign bonds, due to data availability). Debt/Assets is the ratio of total debt to total assets. Interest paid is scaled by EBITDA, ratio that corresponds to the coverage ratio. Maturity is the ratio of long-term debt to total debt. In Column 1, Weak Bank is measured as the exposure to all sovereign bonds of the firm's main bank, scaled by the bank's total assets. In Column 2, Weak Bank is measured as the exposure to domestic sovereign bonds of the firm's main bank, scaled by the bank's total assets. In Column 3, Weak Bank is measured as the exposure to domestic sovereign bonds of the firm's main bank, scaled by the bank's total assets, and is set to zero if the parent bank of the firm's main bank is not located in a Periphery country (i.e., Greece, Ireland, Italy, Portugal and Spain). Sales is the change in logarithm of sales. Size is measured by the logarithm of total assets. Cash flow is scaled by total assets.
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

We find that firms with high leverage reduced their investment rates disproportionately during the crisis when their main bank has a large exposure to sovereign debt. The differential

effect of debt service and debt maturity are both insignificant when using total sovereign bond holdings to measure bank weakness (column 1). However, when measuring sovereign exposure more precisely using domestic sovereign holdings (column 2) we obtain a differential effect of debt maturity: a higher share of long-term debt is associated with higher net investment rates during the crisis for firms linked to weak banks, relative to firms whose banks are not weak. These results imply that the rollover risk associated with short term debt during the crisis is more pronounced for firms linked to weak banks. In other words, the rollover risk we identify in part operates through sovereign-bank linkages. Another implication of these results is that loan evergreening by weak banks to firms facing higher rollover risk played a limited role during the crisis as these firms decreased investment more.

We obtain very similar results when measuring bank weakness using the domestic sovereign holdings of periphery country banks only (column 3). In this case we set the exposure to domestic sovereign debt to zero for those banks whose parent entity resides in a non-periphery euro area country. In principle, periphery sovereign bonds were the ones subject to the largest decline in value during the crisis, and hence the condition of banks holding these bonds declined the most, ceteris paribus. This implies that the results are largely explained by exposure to periphery sovereigns. This provides further evidence in support of our hypothesis that the debt overhang and rollover risk effects are in part driven by increases in sovereign risk transmitted to firms through firm-bank linkages, and that these effects modify firm investment in comparison to periods of normal market functioning. In the next section we assess the quantitative role of these various effects and their aggregate implications for investment in the euro area.

6.3 Aggregate Implications

Our results imply that debt overhang and rollover risk negatively affected firm investment during the crisis. But how much of the decline in aggregate corporate investment since the onset of the crisis is due to debt overhang and rollover risk? Inferring aggregate effects from micro-level evidence faces two challenges: external validity and general equilibrium consid-

35

erations. External validity refers to the representativeness of the sample relative to firms in the economy. Since our data has extensive coverage and is representative of the official data from Eurostat, the external validity criterion is satisfied and we can use a back of the envelope calculation to link our micro estimates to the actually observed macro level decline in investment. Such aggregation of micro-level evidence abstracts from any general equilibrium effects, including the impact of the crisis on the investment demand of unconstrained firms that do not face debt overhang and rollover risk, such as those arising from a fall in aggregate demand.

According to official macroeconomic statistics from Eurostat, the average net investment rate (net investment over GDP) of the non-financial corporate sector in the Euro area fell by 60 percent during the crisis period compared to its pre crisis average level (see Figure 1). Since our estimates are predicting the decline in investment over capital for the average firm, i, $(\Delta K_i / K_i)$, we compare our predictions to the decline in aggregate gross fixed capital formation for business investment $(\Delta K / K)$, which is 20 percentage points. Using the estimates from column (3) of Table 6, we calculate the total effects of each of our variables, leverage, debt service, and maturity, for the average value of the Weak Bank variable. Next we calculate the predicted total effects for a one standard deviation change in each of our variables, which are 3, 0.1, and 9 percentage points respectively. Thus, the sum of the predicted percentage point changes is 12 percentage points. As a result, our coefficients can explain 60 percent of the 20 percentage point decline in aggregate investment (measured as the change in gross fixed capital formation), with the remainder due to a combination of aggregate demand shocks and other factors.

7   Conclusions

We quantify the role of financial factors that have contributed to sluggish investment in Europe in the aftermath of the 2008–2009 crisis. We use a very large pan-European firm-bank-time level dataset, in which we match the firms to their banks based on banking relationships in 8 countries over time. Our identification relies on a difference-in-difference estima-

tion approach, where we compare the investment of high debt (maturity) firms with low debt (maturity) firms between crisis and normal times, while absorbing demand shocks through country-four-digit industry-year fixed effects. Furthermore, we use confidential ECB data on the exposures of banks to (own) sovereign debt together with information on the main bank relation of each firm to identify the role of sovereign-bank linkages in driving the effect of debt overhang and rollover risk. Regressions also include bank fixed effects alongside firm fixed effects to abstract from any unobserved bank and firm characteristics.

Our results highlight the important interaction between the role of firm leverage, debt maturity, and weak bank balance sheets in determining firm investment. Firms with higher leverage reduce investment more and this effect strengthens when these firms are linked to weak banks. Firms that borrowed more short-term suffer from rollover risk and decrease investment more, and again this effect gets stronger when these firms are connected to weak banks. This is in sharp contrast to normal times when firms that borrow more short-term tend to invest more. The effect of bank weakness is strongest for banks in peripheral countries with large exposures to sovereign risk through their holdings of own sovereign debt. In quantitative terms, the debt overhang and rollover risk channels are both important channels. A simple back of the envelope calculation based on our firm-level estimates suggests that the debt overhang and rollover risk channels explain about 60 percent of the actual decline in aggregate corporate investment during the crisis.

These results highlight that debt overhang and rollover risk of firms, compounded by an impaired bank lending channel, played a significant role in holding back corporate investment during the European debt crisis. This is different from (and complementary to) existing explanations in the literature that have focused on aggregate demand, banking health, and sovereign-bank linkages to explain the severity of the crisis. These new findings suggest that growth-enhancing policies that more directly target the financial conditions of firms may be needed to reduce the debt overhang and stimulate the real economy. The results also point to the dangers of an overreliance on short-term debt to finance investment during good times.

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