Sovereign Risk and Intangible Investment*

Minjie Deng† Chang Liu‡

Simon Fraser University Stony Brook University

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Abstract

This paper measures the output and TFP losses from sovereign risk, considering firm-level intangible investment. Using Italian firm-level data, we show that firms reallocated from intangible assets to tangible assets during the 2011-2012 Italian sovereign debt crisis. This asset reallocation is more pronounced among small firms and high-leverage firms. This reallocation affects aggregate output and TFP. To explain the reallocation pattern and quantify the output and TFP losses, we build a sovereign default model incorporating firm intangible investment. In our model, sovereign risk deteriorates bank balance sheets, disrupting banks' ability to finance firms. Firms with greater external financing needs are more exposed to sovereign risk. Facing tightening financial constraints, firms shift their resources towards tangibles because they can be used as collateral. We find that elevated sovereign risk explains 45% of the observed output losses and 31% of the TFP losses in Italy from 2011 to 2016.

Keywords: Sovereign debt crisis, intangible asset, firm investment, TFP loss

JEL classification: F34, E22, E44, G12, G15

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†Email: minjie.deng16@gmail.com; Address: Department of Economics, Simon Fraser University, 8888 University Dr, Burnaby, BC V5A 1S6, Canada.

‡Email: changliu863@gmail.com; Address: Department of Economics, Stony Brook University, Social & Behavioral Sciences Building, 6th floor, Stony Brook, NY 11794-4384, USA.

1 Introduction

The European sovereign debt crisis of 2010-2012 was associated with substantial declines in real economic activities, emphasizing the pass-through of sovereign risk to the real sector. One important transmission channel, especially for the European countries, is the banking sector (Gennaioli et al. (2014), Perez (2018), Bocola (2016), Arellano et al. (2019), Bottero et al. (2020)). Because banks are often the main creditors of governments, sovereign risk deteriorates bank balance sheets and disrupts private lending to firms. Tightening financing conditions for the firms depress firm activities and thus the real economy. We quantify the the real economic impacts of sovereign risk on the private sector by considering firm-level investment, especially investment in intangible assets.

Investment in intangible assets accounts for an increasing proportion of total investment. Intangible assets, such as research expenses, development expenses, and other expenditures with a long-term effect, differ from tangible assets like buildings and machinery. The positive effects of intangible assets on firm productivity and performance are well-established in the literature (Griliches (1958), Griliches (1979), Geroski (1989), Hall et al. (2010)). Declines in investment in intangible assets (hereafter, intangible investment) affect firm productivity and output. However, intangible investment has often been ignored in previous sovereign default literature, thus missing a key component of output and productivity losses.

Using Italian firm-level data covering the Italian sovereign debt crisis of 2011-2012, we start by empirically documenting the impact of sovereign risk on firms' intangible and tangible investment. First, during the Italian sovereign debt crisis, financially constrained firms reduced their investment in both intangible assets and tangible assets. Second, intangible investment fell more than tangible investment for small firms and high-leverage firms, as they reallocated assets towards tangible investments. We refer to this behavior as *asset reallocation*. This is because of the fact that financial institutions typically prefer tangible assets as collateral. Firms, especially small and high-leverage firms, reallocate more towards tangible assets to alleviate their tightening financial constraints. As a result, intangibles are reduced more during debt crisis, which has significant implications for future growth and output. Our results are robust to alternative measures for investment, sovereign risk, and firm-level variables, and are also robust to different empirical specifications.

To explain the investment decline, asset reallocation and measure the aggregate costs of sovereign risk, we build a sovereign default model incorporating firm intangible investment. In our framework, an increase in government default risk results in deteriorating bank balance sheets, which leads to a higher loan interest rate for firms. The firm-specific loan interest rate also depends on each firm's collateral. Thus, firms reallocate their resources to tangible investment to offset the tightening borrowing constraint. The declines in intangible investment hurt future productivity and output. Firms are not equally affected by the elevated sovereign risk and higher loan interest rate: firms heavily relying on external borrowing from banks are more exposed to sovereign risk and reallocate by more.

Our framework incorporates heterogeneous firms with intangible investment into an otherwise canonical general equilibrium model of sovereign debt and default. The economy is composed of final goods firms, heterogeneous intermediate goods firms, financial intermediaries, households, and a central government. The government collects tax revenues from the final goods firms and borrows from the financial intermediaries to finance lump-sum transfers to the households and service the outstanding government debt. The government may default on its bonds, following an exogenous process. The final goods firms are competitive and they convert intermediate goods to final goods. The intermediate goods firms need to borrow from the financial intermediaries to finance a fraction of their investment and they differ in their productivity and external financing needs.

The financial intermediaries play a key role in transmitting sovereign risk to the firms: they use their net worth to purchase government bonds and provide loans to firms. An elevated sovereign default risk deteriorates the financial position of intermediaries and hence their private lending to the firms. Tightening financing conditions for the firms depress both intangible and tangible investment. However, since intangible assets can not be used as collateral, firms reduce their intangible investment by more. Lower intangible investment hurts firms' future productivity and output.

We parametrize the model using annual Italian data from 2006 to 2016 to highlight the role of intangible investment in assessing the output and productivity losses due to sovereign risk. We target sample moments that pertain to the behavior of firms, banks, and government. Using the calibrated model, we show that with an increase in sovereign spreads, firms' future intangible and tangible assets decline, but intangible assets decline by more. With fewer capital inputs, firm output declines. The decline in intangible investment further decreases future firm TFP. The model endogenously generates the output decline and the TFP decline when the sovereign spread increases, as opposed to a large previous literature that assumes exogenous declines in endowment, output, or TFP when the government defaults.

We then feed the model with a series of exogenous shocks to replicate the observed path of Italian sovereign risk and real GDP from 2006 to 2016. Using the 2006-2016 model-simulated sample, we run the same regression as in the empirical part. We show that the model can replicate the empirical findings: firms increase their tangibles-to-intangibles ratio during a sovereign debt crisis. Moreover, small firms and high-leverage firms reallocate their assets more aggressively compared to other firms.

Our model includes intangible investment that endogenously determines TFP, thus allowing us to measure TFP losses (and output losses) due to sovereign risk. We construct a scenario in which the Italian economy does not experience a debt crisis. We then compare the results of our benchmark model and the counterfactual model with no debt crisis. The differences between the economies of the benchmark model and the *no-debt-crisis* counterfactual model isolate the impact of the sovereign crisis on the Italian economy. We find that the losses associated with sovereign default risk are sizable. During 2011-2016, on average, output is 4.8% below trend, while it would have been 2.63% below trend without the sovereign debt crisis. As for TFP, on average, TFP is 3.72% below trend, while it would have been 2.55% without the debt crisis. Our quantitative results show that elevated sovereign risk was responsible for 45% of the observed output losses and 31% of the TFP losses from 2011 to 2016.

We also construct two reference models to highlight the role of intangible assets. In the first reference model, we eliminate intangible assets and firms can only invest in tangibles. We denote this as the *no-intangible-asset* model. In the second reference model, we fix intangible assets at the median level of the invariant distribution from the benchmark model and call this the *fixed-intangible-asset* model. We recalibrate both of the reference models. The comparison between the benchmark model and the reference models isolates the role of endogenous intangible investment. Amid a sovereign debt crisis, firms reduce their intangible investment, thus reducing measured TFP, further reducing output. Without intangible investment, our reference models are silent on the TFP decline and generate less decline in output during a sovereign debt crisis. With one standard deviation increase in spread, output declines by 2.2% in the benchmark model, 0.43% in the no-intangible-asset model, and 0.2% in the fixed-intangible-asset model.

Related literature. Our paper measures TFP and output losses of sovereign risk by focusing on firm-level intangible investment responses, thus combining elements of the sovereign default literature with literature on the impact of firm financial frictions.

The model builds on the sovereign default models pioneered by Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008). Most sovereign default literature assumes exogenous endowment declines when a sovereign defaults, while most of the rest features a production economy and assumes an exogenous TFP decline when a sovereign defaults (e.g., Arellano et al. (2018), Alessandria et al. (2020), Deng (2024), Deng and Liu (2022)). By introducing firm intangible investment, our model endogenously generates the TFP and output declines during a sovereign debt crisis.

Recent papers in the sovereign debt and default literature study the links between sovereign default risk and the private sector through financial intermediation. During a sovereign debt crisis, firms lose access to external financing and cut their production, leading to reduced output (Mendoza and Yue (2012)). The link between sovereign default and the private sector through banking and finance is also analyzed in Perez (2018), Sosa-Padilla (2018), Arellano et al. (2019), D'Erasmo et al. (2020), and Moretti (2020). Empirical findings using micro data also highlight the impacts of bank balance sheet on firm-level variables, such as credit (Bofondi et al. (2018), Acharya et al. (2018), Bottero et al. (2020)), sales (Arellano et al. (2019)), and tangible investment (Kalemli-Özcan et al. (2018). Our paper shares the focus of studying the transmission of sovereign risk to the firms through the financial intermediation. Our contribution is to examine the impacts of sovereign risk on firm investment, especially intangible investment, and quantify the aggregate losses from sovereign risk.

This paper also connects to the literature that studies the real effects of credit constraints, especially on investment. For example, Fakos et al. (2022) found that reduction in credit supply has significant real effects, explaining 11–32% of the investment slump during the Greek depression. We study both tangible and intangible investment. Our finding of declines in intangible investment due to financial frictions is consistent with Garcia-Macia (2017), Demmou et al. (2020), and Lopez and Olivella (2018). We further document the asset reallocation pattern in response to elevated sovereign risk. Our unique contribution is to bring two strands of literature (sovereign debt literature and intangible investment in business cycles literature) together and quantify the aggregate losses due to sovereign risk through the intangible investment channel.

Our model implications for the TFP losses of sovereign debt crises relate to an extensive literature that studies intangible assets and productivity. The positive effects of intangible assets on firm productivity and economic performance are well established in the literature. This branch of literature traces back to Griliches (1958). Research on intangible investment and firm productivity has bloomed ever since (Griliches (1979), Geroski (1989), Hall et al. (2010), Gunn and Johri (2011), Johri and Karimzada (2021), among others). Several recent studies show that low firm-level incentives to invest in intangibles would result in TFP and output losses. The lack of incentive can be caused by either distortions (Ranasinghe (2014)), monetary policy (Moran and Queralto (2018)), equity financing shocks (Bianchi et al. (2019)), or financial crises (Queralto (2020)). Although traditional literature shows that intangible investment is countercyclical due to the lower opportunity cost of long-term innovative investments in recessions than in booms (Bean (1990), Aghion and Saint-Paul (1998)), more recent literature, such as Aghion et al. (2012), shows that this traditional view is only true for firms that are not financially constrained. Several contributions also highlight the key role of credit constraints in intangible investment more generally (Brown et al. (2012), Hall et al. (2016), Peia and Romelli (2020), Xue et al. (2021)).

Road map. This paper proceeds as follows. Section 2 shows the data and key empirical findings. Section 3 presents our model with sovereign default risk, financial intermediaries, and firm investment in tangible and intangible assets. Section 4 calibrates the model, measures the aggregate losses of sovereign risk, and highlights the role of intangible investment by comparing our benchmark model with reference models. Section 5 concludes.

2 Empirical facts

This section documents the empirical results about the impact of sovereign risk on firm tangible and intangible investment. Section 2.1 describes the construction of the variables of interest and provides summary statistics. Section 2.2 shows the empirical results and explains the asset reallocation pattern.

2.1 Data description

Firm-level variables. Our main sample uses annual manufacturing firm-level data from the Orbis dataset, covering the period 2006-2016. The dataset covers a large majority of Italian firms including both private and public firms, and includes rich balance-sheet information. The core variables in our analysis are firm investment (investment in intangible fixed assets and tangible fixed assets), key balance sheet indicators (total assets, short-term debt, and long-term debt), and additional firm-level variables. We provide details on variables and sample selection in the online appendix.

Intangible fixed assets in the Orbis dataset are defined as all balance sheet intangible assets such as formation expenses, research expenses, goodwill, development expenses, and all other expenses with a long-term effect. Following literature, we measure investment using log difference of the fixed assets. We focus on the real terms and deflate the intangible and tangible fixed assets with the price of intangibles and tangibles every year.

In our baseline regression, leverage is defined as the ratio of total debt to total assets, where total debt is the sum of short-term debt and long-term debt. As standard in literature, we define size, liquidity, sales growth, and the net current asset ratio. Table 1 reports a set of summary statistics for the main variables.

Table 1: Summary statistics

	Obs.	Mean	St.Dev.	Min.	Max.	P25	Median	P75
Leverage	390652	0.203	0.196	0	0.983	0	0.166	0.35
Size	390652	10.123	1.202	4.565	12.844	9.283	10.146	11.012
Liquidity	390652	0.075	0.111	0	0.848	0.004	0.025	0.1
Investment in intangibles (log-diff)	390652	-0.124	0.746	-2.769	3.623	-0.462	-0.197	0.046
Investment in tangibles (log-diff)	390652	-0.04	0.397	-1.877	2.484	-0.204	-0.086	0.041

Notes: Statistics are calculated using the manufacturing firm-level data from the Orbis dataset, covering the period 2006-2016. We restrict the sample to observations with available intangible investment and tangible investment, to guarantee that the firm-level investment responses are comparable across different assets. The detailed sample selection can be found in the online appendix.

Sovereign debt crisis. The Italian economy was hit by the global financial crisis in 2008-2009 and recovered slightly in 2010. Then the economy experienced a second deep recession featuring a sovereign debt crisis in 2011-2013, when real GDP further declined by 4.4%. Figure 1 plots annualized sovereign spreads for Italy, which is defined as the gap between Italian and German 10-year government bond yields, measuring the severity of the Italian sovereign debt crisis. Notably, during 2011-2013, the spread surged to above 5%. Throughout this sovereign debt crisis period, rating agencies such as Standard & Poor's (S&P) downgraded the rating for Italian bonds from A+ to A in 2012, followed by further downgrades to BBB+ in 2012 and BBB in 2013.

Figure 1: Sovereign spreads

Notes: Italian sovereign spreads (annualized spreads at a monthly frequency). The spread is defined as the gap between 10-year Italian and German sovereign yields. Data is obtained from GFDFinaeon.

2.2 Firm-level responses during a sovereign debt crisis

We focus on how firm investments react differently during a sovereign debt crisis. We first examine and estimate how the heterogeneous effects of sovereign risk on investment (including intangible and tangible investment) depend on firm characteristics, controlling for sector-year fixed effects. To assess the economic significance of the heterogeneous effects of sovereign risk, we relax the sector-year fixed effects and include more aggregate controls in a second estimation. This specification allows us to include government spreads in the regression to obtain the average effects. After examining the responses of intangible investment and tangible investment, we test for asset reallocation pattern during the sovereign debt crisis and discuss potential explanations.

2.2.1 Heterogeneous responses to default risk

To estimate the responses of firm-level investment to sovereign risk and how the responses depend on firm-level characteristics, we estimate the following:

$$\Delta \log(assets_{i,t+1}) = \beta(x_i \times sp_t) + Controls + \delta_i + \eta_{st} + \epsilon_{it}, \tag{1}$$

where *assets* represent two types of assets: intangible assets or tangible assets. The dependent variable $\Delta \log(assets_{i,t+1}) \in \{\Delta \log(intangibles_{i,t+1}), \Delta \log(tangibles_{i,t+1})\}$ denotes intangible investment or tangible investment of firm i at time t, which are defined as the log-difference of intangible assets $[\log(intangibles_{i,t+1}) - \log(intangibles_{it})]$ or the log-difference of tangible assets $[\log(tangibles_{i,t+1}) - \log(tangibles_{it})]$. sp_t is the sovereign spread at year t, which is the average of the monthly data. $x_i \in \{size_{i,2006}, leverage_{i,2006}\}$ refers to a binary variable that measures firm's size or leverage. $size_{i,2006}$ takes value 1 if the size of firm i is larger than the median in 2006, 0 otherwise. $leverage_{i,2006}$ is similarly constructed. We use firm characteristics in the first year of the sample to guarantee the variables are pre-determined. *Controls* contains the interaction term of x_i and GDP growth (ΔGDP_t) to control for the general economic condition, and a vector of firm-level variables at time $t - 1$, which includes size, leverage, liquidity, sales growth, the ratio of liabilities to total assets, and the ratio of net current assets to total assets. δ_i controls for firm fixed effects, which capture permanent differences in investment behavior across firms. η_{st} is a sector-year fixed effect, which captures differences in sectoral exposure to aggregate shocks. ϵ_{it} is a residual. We cluster the standard errors at the firm level. Our main coefficient of interest is β, which depicts how firms invest in response to the sovereign spread, conditional on firm characteristics.

Column (1)-(3) of Table 2 report the results from estimating this baseline specification (1) for intangible investment. Column (1) shows the results when only focusing on firm heterogeneity in size. Column (2) reports the results when focusing on firm heterogeneity in leverage. Column (3) adds both interactions with size and leverage, which is our main focus for interpretation. The results show that a large firm has a 2.20 *higher* intangible investment in response to sovereign spread, compared to small firms. A high-leverage firm has approximately a 0.60 *lower* intangible investment than low-leverage firms.

Column (1)-(3) of Table 3 show the results of estimating Eq. (1) for tangible investment. Column (3) shows that a large firm has approximately a 0.62 *higher* tangible investment than small firms, and a high-leverage firm has approximately a 0.34 *higher* tangible investment when compared to low-leverage firms. Comparing the estimation results for both intangible and tangible investment, we find that firms at each leverage level have opposite responses in terms of intangible and tangible investment: a high-leverage firm would invest less in intangible assets but invest more in tangible assets, compared to low-leverage firms, during a sovereign debt crisis.

The estimated interaction coefficient β suggests firm heterogeneity in size and leverage. However, the economic significance of the estimated heterogeneous effects cannot be evaluated, as the sector-year fixed effects absorb the average effect of sovereign risk. We now relax the sector-year fixed effects and instead include aggregate controls by estimating

$$\Delta \log(assets_{i,t+1}) = \beta_0 sp_t + \beta_1 (x_i \times sp_t) + Controls + AggControls + \delta_i + \epsilon_{it}, \qquad (2)$$

where we include a vector of aggregate controls $AggControls$, which includes GDP growth (ΔGDP_t) and its interactions with firm characteristics ($x_i \times \Delta\text{GDP}_t$). Our coefficients of interest are β_0 and β_1. β_0 shows the average effects of sovereign spread on firm investment, and β_1 measures how firm responses in investment depend on firm size or leverage.

Table 2: Responses of intangible investment

Dependent variable	$\Delta \log(intangibles_{i,t+1})$					
	(1)	(2)	(3)	(4)	(5)	(6)
sp_t				-0.869***	0.609***	-0.609**
				(0.219)	(0.217)	(0.261)
$size_{i,2006} \times sp_t$	2.133***		2.200***	2.289***		2.352***
	(0.294)		(0.296)	(0.293)		(0.295)
$leverage_{i,2006} \times sp_t$		-0.370	-0.602**		-0.316	-0.570*
		(0.292)	(0.294)		(0.292)	(0.294)
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	No	No	No
Observations	304,458	304,458	304,458	304,458	304,458	304,458
R-squared	0.025	0.025	0.025	0.013	0.012	0.013
Number of id	59,922	59,922	59,922	59,922	59,922	59,922

Notes: Results from estimating Eq. (1) and (2) for intangible investment. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Column (4)-(6) of Table 2 and 3 report the results from estimating Eq. (2) for intangible and tangible investment, respectively. The coefficients for the interaction terms are similar to the ones estimated from Eq. (1). The coefficient of sp_t for intangible or tangible investment is around 0.5-0.9 in absolute value. Thus, the interaction coefficients imply an economically meaningful degree of heterogeneity. When sovereign spread is high during the debt crisis, small and low-leverage firms on average have both negative intangible and tangible investment (coefficients -0.609** and -0.873***), which can be interpreted as the base group. The coefficients of *size*×*spread* show that the large firms would be less affected in both investment when sovereign spread increases. The coefficients of *leverage*×*spread* show that the high-leverage firms would reduce more in intangible investment, and reduce less in tangible investment. Combining those findings, we conclude that the financially constrained firms, which are small and highly leveraged, experience a larger decline in intangible investment and a smaller decline in tangible investment compared to the firms in the base group.

We observe that when sovereign spread increases, financially constrained firms invest less in both intangible and tangible assets. Besides, firms are heterogeneous in their investment responses. Especially, compared with other firms, small and high-leverage firms reduce intangible investment by more and reduce tangible investment by less, indicating a higher degree of asset reallocation. In the next section, we use the tangibles-to-intangibles

Table 3: Responses of tangible investment

Dependent variable	$\Delta\log(tangibles_{i,t+1})$					
	(1)	(2)	(3)	(4)	(5)	(6)
sp_t				-0.708***	-0.542***	-0.873***
				(0.116)	(0.101)	(0.134)
$size_{i,2006} \times sp_t$	0.652***		0.615***	0.680***		0.639***
	(0.140)		(0.141)	(0.138)		(0.138)
$leverage_{i,2006} \times sp_t$		0.404***	0.340**		0.431***	0.362***
		(0.133)	(0.133)		(0.132)	(0.132)
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	No	No	No
Observations	304,458	304,458	304,458	304,458	304,458	304,458
R-squared	0.068	0.068	0.068	0.042	0.042	0.042
Number of id	59,922	59,922	59,922	59,922	59,922	59,922

Notes: Results from estimating Eq. (1) and (2) for tangible investment. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

ratio as the dependent variable to examine the asset reallocation pattern.

2.2.2 Reallocation towards tangibles

When firms cut more intangible investment than tangible investment, their asset allocation changes. To better visualize the reallocation pattern indicated by the previous results, we replace the dependent variable in Eq. (1) and (2) with tangibles-to-intangibles ratio. The estimation results are shown in Table 4. The positive sign for sp_t shows that on average, firms increase their tangibles-to-intangibles ratios when the sovereign spread goes up. This asset reallocation pattern depends on firm characteristics: the negative sign for the $size \times spread$ interaction term and the positive sign for the $leverage \times spread$ show that small firms and high-leverage firms reallocate more towards tangible assets.[1]

In the online appendix, we show that our baseline results, especially this reallocation pattern, are robust to alternative measures of investment, leverage, spreads, group indicators, and other factors.

[1] The reallocation is not driven by fluctuations in the prices of tangible assets during the debt crisis. As shown in the online appendix, the prices of both intangible and tangible assets show minimal change. This reallocation pattern during crises extends to a broader set of economic crises, with further details in the online appendix.

Table 4: Responses of tangibles-to-intangibles ratio

Dependent variable	Tangibles-to-intangibles ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
sp_t				2.076***	1.223***	1.900***
				(0.184)	(0.167)	(0.213)
$size_{i,2006} \times sp_t$	-1.201***		-1.245***	-1.253***		-1.297***
	(0.227)		(0.229)	(0.227)		(0.229)
$leverage_{i,2006} \times sp_t$		0.257	0.388*		0.244	0.384*
		(0.219)	(0.221)		(0.219)	(0.222)
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	No	No	No
Observations	299,090	299,090	299,090	299,090	299,090	299,090
R-squared	0.217	0.217	0.217	0.212	0.212	0.212
Number of id	59,197	59,197	59,197	59,197	59,197	59,197

Notes: Results from estimating Eq. (1) and (2) for tangibles-to-intangibles ratio. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

2.2.3 Collateral for borrowing

In this section, we show that firms suffering from short of credit have more reallocation towards tangibles, which can be explained by the popularity of tangibles as collateral. More tangibles can be used as collateral to relax their tightening financial condition.

Using our baseline sample, we replace the dependent variable in Eq. (2) with firm financing conditions. The results are listed in Table 5. The dependent variable of Column (1) is the log-difference of total borrowing, which is measured as the sum of short-term loans and long-term debt. Column (2) and (3) present the estimation results, using short-term loans and long-term debt as dependent variables, respectively.

The negative sign for sp_t shows that firms on average borrow less, in terms of both short-term loans and long-term debt, during the sovereign debt crisis. The credit responses are also heterogeneous across firms, especially the long-term debt. Column (3) shows that firms that are less financially constrained—here the large firms and low-leverage firms—are less affected. In contrast, small firms and high-leverage firms are associated with major declines in borrowing.

Combining the fact that small firms and high-leverage firms reallocate more resources from intangible assets towards tangible assets, it is evident that firms suffering from a greater credit shortage are more motivated to make such a reallocation towards tangible

Table 5: Responses of firm borrowing

Dependent variable:	(1) Total borrowing	(2) ST loans	(3) LT debt
sp_t	-1.905***	-0.502	-3.734***
	(0.382)	(0.501)	(0.542)
$size_{i,2006} \times sp_t$	0.353	0.984**	0.857*
	(0.315)	(0.423)	(0.470)
$leverage_{i,2006} \times sp_t$	0.432	0.197	-0.901*
	(0.360)	(0.483)	(0.497)
Firm controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Sector-year FE	No	No	No
Observations	187,120	170,556	114,913
R-squared	0.155	0.159	0.100
Number of id	44,752	41,957	31,649

Notes: Results from estimating Eq. (2), which uses the log-difference of (1) total debt, (2) short-term loans, and (3) long-term debt as the dependent variable. Total debt is defined as the sum of short-term loans and long-term debt. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

assets. This can be explained by the preference of tangibles as collateral.

Collateral is widely used in debt contracts, which can alleviate concerns on ex ante information gaps between borrowers and lenders, adverse selection, ex post moral hazard, and so on (Stiglitz and Weiss (1981), Bernanke and Gertler (1986), Cooley et al. (2004), Berger et al. (2011), among others). The value of tangible assets is easier to evaluate and features less ex-ante asymmetric information, compared to intangible assets. Firms with higher proportion of tangible assets can borrow by more, as documented in the previous literature (see Rampini and Viswanathan, 2013; Rampini and Viswanathan, 2020; Ivashina et al., 2022, among others), because lenders are subject to lower agency cost when dealing with borrowers with more tangible assets.

Financial institutions commonly prefer tangible assets as collateral. For example, disclosures from some Italian banks directly show the composition of their collateral. Intesa Sanpaolo, the largest Italian bank by total assets, revealed in its 2022 disclosures that the majority of collateral obtained by taking possession and execution processes consists of property, plant and equipment (PP&E) and immovable property (e.g., land), which account for 31.6% and 53.8%, respectively. The remaining portion is mainly equity and debt instruments. UniCredit, another big bank in Italy, indicated in its 2022 disclosures that its collateral obtained by taking possession and execution processes is mainly composed of commercial immovable property, accounting for 48.6%. The rest mainly consists of equity and debt instrument, at 49.3%. Moreover, UniCredit's 2022 disclosures also present the collateral valuation for loans and advances, with immovable property constituting 76.4% of the total collateral for loans and advances.

Though our baseline sample does not have direct information on collateral, some other firm-level survey data demonstrates that banks have a preference for tangibles when issuing loans to firms. We explore a recent survey for Italy from the World Bank Enterprise Survey data, which provides information from 2019. In this survey, firms were asked about the types of collateral required. 73% of firms in the sample reported to use land and buildings as collateral, and 68% of firms have used equipment as collateral for the most recent loan. For external reference, we also use the Federal Reserve Board's Survey of Small Business Finance (SSBF) for the U.S., conducted in 2003, to demonstrate that U.S. small businesses commonly prefer tangible assets for collateral. The 2003 survey reveals that 55% of the participants were required to use collateral to secure their most recent loan. Among the seven types of collateral provided[2], for firms that reported using only one single type of collateral (71.1% of firms that use collateral), 29.5% and 27.9% were using business equipment or vehicles, and inventory or accounts receivable as collateral, respectively. The remainder mainly used either business real estate, at 21%, or personal real estate, at 14.3%. Those pieces of evidence from bank disclosures and firm surveys show that tangible assets are commonly used as collateral.

Given this empirical evidence, we assume that only tangible assets can be used as collateral in our baseline model. Therefore, firms may consider shifting their focus towards tangible investment to overcome financial constraints during a time of tightening credit. This reallocation, brought on by limited access to credit, could have significant effects on productivity and overall output given the important role that intangible assets play. We will discuss in detail in our theoretical part.

[2]Survey participants were asked what collateral was used to secure this most recent loan, with the options being "1=YES, 2=NO" for seven categories: (1) inventory or accounts receivable, (2) business equipment or vehicles, (3) business securities or deposits, (4) business real estate, (5) personal real estate, (6) other personal assets, (7) other collateral.

3 Model

The economy is composed of a central government, heterogeneous firms, financial intermediaries, and households. The government borrows by issuing long-term bonds to the financial intermediaries. Government can default on its debt. The probability of a government default evolves over time according to a reduced-form stochastic process. Government issues bonds and collects tax revenues from final goods firms to finance the lump-sum transfers to the households and service the outstanding government debt.

There are two types of firms: final goods firms and intermediate goods firms. Final goods firms are competitive, and they convert intermediate goods to final goods. Intermediate goods firms operate under monopolistic competition, and they use both tangible capital and intangible capital to produce differentiated goods. They borrow from the financial intermediaries to finance a fraction of investment costs, and the borrowing interest rate is firm-specific, depending on the firm's collateral. To simplify, we assume that only tangible assets can be used as collateral. The intermediate goods firms are exogenously heterogeneous in productivity and financing need.

Households are composed of consumers and bankers, and they own the intermediate goods firms. Households decide on their consumption and how much to save with the financial intermediaries. The financial intermediaries are run by bankers who use repayments of prior loans and the savings of households to lend to the intermediate goods firms and the government.

The timing within the period is as follows. First, the aggregate shock on government default risk and the idiosyncratic shocks for intermediate goods firms are realized. Given the aggregate shock that exogenously determines the default risk, the government chooses borrowing and lump-sum transfers. The intermediate goods firms choose investment on intangible capital and tangible capital, and how much to borrow. The households save by depositing with the financial intermediaries. At the end of the period, production takes place. The financial intermediaries receive payments from firms and the government, and repay household deposits.

We start by describing the problems of each type of agent: the government, final goods firms, intermediate goods firms, consumers, and financial intermediaries. We then define the equilibrium for this economy.

3.1 The government

The government provides transfers to households. It finances the transfers T_t by issuing long-term bonds to the financial intermediaries and levying a tax on aggregate final goods Y_t at rate τ. In every period, a fraction ϑ of debt matures and the remaining fraction remains outstanding. The government can default on its debt in every period by writing off a fraction $f \in [0,1]$ of its outstanding obligations.

Following Bocola (2016), we assume an exogenous process for government default risk. Assume that in every period the economy is hit by a shock ε_d that follows a standard logistic distribution. The default process follows:

$$d_{t+1} = \begin{cases} 1 & \text{if } \varepsilon_{d,t+1} < s_t \\ 0 & \text{otherwise,} \end{cases} \tag{3}$$

where s is an AR(1) process: $\log(s_t) = (1-\rho_s)\log(s^*) + \rho_s \log(s_{t-1}) + \sigma_s \varepsilon_{st}$, where $\varepsilon_{st} \sim N(0,1)$. This default process is consistent with literature showing that self-fulfilling beliefs were key drivers of sovereign risk during the European debt crisis. It also allows us to isolate the economic mechanisms underlying the propagation of sovereign default risk. The probability of default is then given by $p_t^d \equiv \text{Prob}(d_{t+1} = 1 | s_t) = \exp(s_t)/(1+\exp(s_t))$.

Every period, the government maximizes transfers T_t by choosing a new stock of bonds B_{t+1}, subject to its budget constraint:

$$q_t[B_{t+1} - (1-\vartheta)(1-d_t f)B_t] + \tau Y_t = \vartheta(1-d_t f)B_t + \frac{\phi_b}{2}[B_{t+1} - (1-\vartheta)(1-d_t f)B_t]^2 + T_t, \tag{4}$$

where q_t is the government bond price and B_t is the stock of bonds at time t. When the government defaults, $d_t = 1$ and a fraction $f \in [0,1]$ of its outstanding obligations is written off. ϕ_b parametrizes the bond adjustment cost.[3]

[3]This is a parsimonious way to pin down government bonds. Alternatively, one could set a reduced-form fiscal rule, and then government bonds would balance the budget constraint as in Bocola (2016).

3.2 Final goods firms

The final good Y_t is produced from a fixed variety of intermediate goods $i \in [0, 1]$ using the technology:

$$Y_t \leq [\int (y_{it})^{\eta} di]^{\frac{1}{\eta}}, \tag{5}$$

where the elasticity of demand is $\frac{1}{1-\eta} > 1$. We normalize the price of final goods to one, so total taxes paid to the government is τY_t. The price of intermediate good i is p_{it}. The final goods producers choose quantities of intermediate goods $\{y_{it}\}$ to solve $\max_{\{y_{it}\}} (1-\tau) Y_t - \int p_{it} y_{it} di$, subject to (5). Thus, the demand function y_{it} for intermediate good i is solved as:

$$y_{it} = (\frac{1-\tau}{p_{it}})^{\frac{1}{1-\eta}} Y_t. \tag{6}$$

Demand function (6) shows that the demand for good i is negatively correlated with price p_{it}, and positively correlated with total output Y_t.

3.3 Intermediate goods firms

There is a unit measure of intermediate goods firms producing differentiated goods. We abstract from firm entry and exit for simplicity. Each firm i produces output y_{it} with tangible capital $k_{T,it}$ and intangible capital $k_{I,it}$ using a CES production function:

$$y_{it} = z_{it} \left[\nu k_{T,it}^{\frac{\sigma-1}{\sigma}} + (1-\nu) k_{I,it}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\alpha\sigma}{\sigma-1}} \tag{7}$$

where z_{it} is the idiosyncratic productivity shock that follows $\log(z_{it}) = \rho_z \log(z_{it-1}) + \sigma_z \varepsilon_{it}$, where ε_{it} follows a standard normal random process. $k_{T,it}$ is the stock of tangible capital, and $k_{I,it}$ is the stock of intangible capital. ν is the weight on tangible capital, σ is the elasticity of substitution between two types of capital, and α is the capital share. TFP is calculated from the Solow residual, which is the portion of an economy's output growth that cannot be attributed to the accumulation of tangible capital (Olley and Pakes (1996), Levinsohn and Petrin (2003)). Tangible capital depreciates every period at the rate δ_T, and there is an adjustment cost for changing the capital stock. Thus, the investment in tangible capital at period t is given by $i_{T,it} = k_{T,it+1} - (1-\delta_T)k_{T,it} + \Theta(k_{T,it+1}, k_{T,it})$, where $\Theta(k_{T,it+1}, k_{T,it}) = \frac{\theta_T}{2}(k_{T,it+1}/k_{T,it} - 1 + \delta_T)^2 k_{T,it}$ is the convex adjustment cost for tangible capital. Similarly, the investment in intangible capital at period t is given by $i_{I,it} = k_{I,it+1} - (1-\delta_I)k_{I,it} + \Theta(k_{I,it+1}, k_{I,it})$, where δ_I is the depreciation rate for intangible capital, and $\Theta(k_{I,t+1}, k_{I,t}) = \frac{\theta_I}{2}(k_{I,t+1}/k_{I,t} - 1 + \delta_I)^2 k_{I,t}$ is the adjustment cost for investing in intangible capital.

At the beginning of each period, firm i's idiosyncratic productivity z_{it} is realized. Then firm i chooses next period tangible capital $k_{T,it+1}$ and intangible capital $k_{I,it+1}$. We assume that firms need to borrow a fraction of their investment before production, and the financing needs λ_i are firm-specific and time-invariant. Heterogeneity in λ_i captures the heterogeneous borrowing requirement. The financial intermediaries provide loans b_{it} to firm i at a firm-specific interest rate R_{it}, and the working capital requirement for firm i is:

$$b_{it} = \lambda_i(i_{T,it} + i_{I,it}). \tag{8}$$

The firm-specific interest rate R_{it} depends on the tangible capital of firm i. The financial intermediaries' problem in Section 3.4 will introduce the functional form of the firm-specific interest rate.

At the end of the period, production takes place. Firm i decides on the price p_{it} for its production y_{it}, taking the demand function (6) as given, and repays its debt $R_{it}b_{it}$. The dividend of firm i at period t is $D_{it} = p_{it}y_{it} - [k_{T,it+1} - (1-\delta_T)k_{T,it} + \Theta(k_{T,it+1}, k_{T,it})] - [k_{I,it+1} - (1-\delta_I)k_{I,it} + \Theta(k_{I,it+1}, k_{I,it})] + b_{it} - R_{it}b_{it}$. Taking aggregate demand Y_t and interest rate R_{it} as given, the intermediate goods firm i chooses intangible and tangible investment to maximize the present value of the dividends $\sum_{t=0}^{\infty} \beta^t D_{it}$, subject to the demand function (6) and the working capital constraint (8).

3.4 Households

The representative household is composed of consumers and bankers. The household's preferences over consumption C_t are given by $U = \mathbb{E}_0[\sum_{t=0}^{\infty} \beta^t C_t]$, where $\beta \in (0,1)$ is the discount factor and C_t is consumption in period t. Each period, the household sends bankers to operate the financial intermediaries, and provides them with net worth N_t. At the end of the period, the bankers bring back their returns from operations F_t to the household. The household can save using one-period deposits M_t with the financial intermediary at the price q_t^m.

In each period, the household also receives dividends D_t from the intermediate goods firms and a lump-sum transfer T_t from the government. The budget constraint of the household is:

$$C_t + q_t^m M_t + N_t = M_{t-1} + D_t + F_t + T_t. \tag{9}$$

The household maximizes its utility U subject to (9). The optimality condition indicates that the price of deposits is given by $q_t^m = \beta$, which is constant over time.

Financial intermediaries. The bankers run the financial intermediaries. The financial intermediaries use their net worth N_t and the deposits of the household M_t to purchase government bonds and issue loans to firms. The financial intermediaries are competitive.

The net worth N_t the household provides to the bankers consists of a constant transfer $\bar{n}$ and the value of government bonds that did not mature: $N_t = \bar{n} + (1 - d_t f)(1 - \vartheta) q_t B_t$. The evolution of government default risk drives the dynamics of the government bond price q_t, as well as actual default behavior d_t, both of which change the value of the net worth for the financial intermediaries. At the beginning of the period, the *budget constraint* of the financial intermediaries is:

$$q_t B_{t+1} + \int b_{it} di \leq \underbrace{\bar{n} + (1 - d_t f)(1 - \vartheta) q_t B_t}_{N_t} + q_t^m M_t. \tag{10}$$

Aside from the budget constraint, the financial intermediaries are also subject to a *deposit constraint* that limits the amount of deposits the financial intermediaries can get from households:

$$q_t^m M_t \leq q_t B_{t+1} + \int \theta_{it} b_{it} di. \tag{11}$$

Here we assume that government bonds can be fully pledged, while loans to firms can only be partially pledged. This assumption captures the fact that the European Central Bank, for example, conducts refinancing operations where it lends money to banks, accepting government securities as collateral.[4] θ_{it} denotes the fraction of firm i's debt that can be pledged. This fraction θ_{it} depends on firm i's tangible capital share. We assume the firm-specific fraction θ_{it} that can be pledged is given by $\theta_{it} = k_{T,it}/\bar{k} < 1$, where $\bar{k}$ is a constant and $k_{T,it}$ is the stock of tangible capital of firm i at time t. $\theta_{it} < 1$ reflects that firms' loans can't be fully pledged.

Combining the budget constraint (10) and the deposit constraint (11) gives that the unpledged amount of firm debt is bounded by the financial intermediaries' net worth, and we label this as the *leverage constraint*:

$$\int (1-\theta_{it}) b_{it} di \leq N_t. \tag{12}$$

At the end of the period, the financial intermediaries receive payments from firms and the government, and repay household deposits. The return for the financial intermediaries equals: $F_{t+1} = (1-d_{t+1}f)[\vartheta B_{t+1} + q_{t+1}(1-\vartheta)B_{t+1}] + \int R_{it} b_{it} di - M_t$. The financial intermediary chooses $\{M_t, B_{t+1}, b_{it}\}$ to maximize the expected return $\mathbb{E}_t[\beta F_{t+1}]$ subject to (10) and (12). The optimality conditions give the following pricing conditions for government bonds and firm loans:

$$q_t = \mathbb{E}_t \beta [(1-d_{t+1}f)(\vartheta + q_{t+1}(1-\vartheta)], \tag{13}$$

$$R_{it} = \frac{1 + (1-\theta_{it})\zeta_t}{\beta}, \tag{14}$$

where ζ_t is the Lagrange multiplier on the leverage constraint (12). The price for firm i's loans (14) implies that firm i will pay a premium $\frac{(1-\theta_{it})\zeta_t}{\beta}$ over the risk-free rate when the leverage constraint of the financial intermediaries binds. When firms determine their investment in tangible and intangible capital, they are aware of how their capital decisions affect their financing costs through θ_{it}.

[4]This assumption can easily be relaxed by assuming government bonds can also be partially pledged with a parameter θ_g. Alternatively, θ could be interpreted as the relative pledgability of corporate loans compared to government bonds.

3.5 Equilibrium

We now define the equilibrium for this economy. Define $S = [s, B, d, \Lambda]$ as the state variables, where s is the government default risk process, B denotes the government debt, $d(s)$ is the default event determined by the exogenous default risk process, and $\Lambda(z, \lambda, k_T, k_I)$ is the distribution of the intermediate firms. We omit the time subscript t and use x' to denote a variable x in the next period.

Given an aggregate state S, the equilibrium consists of: (i) intermediate goods firms' policies for tangible capital $k'_T(z, \lambda, k_T, k_I; S)$, intangible capital $k'_I(z, \lambda, k_T, k_I; S)$ and borrowing $b(z, \lambda, k_T, k_I; S)$, and final goods firms' output $Y(S)$; (ii) policies for aggregate tangible capital $K_T(S)$, aggregate intangible capital $K_I(S)$, and consumption $C(S)$; (iii) price functions for firm borrowing rates $R(k_T, S)$, a government bond price function $q(s)$, and a constant deposit price q^m; and (iv) the distribution of firms over idiosyncratic productivity and capitals $\Lambda(z, \lambda, k_T, k_I)$ such that: (a) policy functions of intermediate and final goods firms satisfy their optimization problem; (b) intermediate firms' borrowing rates satisfy (14) and the leverage constraint (12) holds; (c) the distribution of firms is consistent with the idiosyncratic shocks; (d) policies for households satisfy their optimal conditions; (e) next period government bonds satisfy the government budget constraint; (f) the government bond price satisfies (13); and (g) the markets for capital, goods, and bonds clear.

Next, we analyze key conditions that explain how an increase in sovereign risk affects private loan interest rates and firm investment choices. Recall that the financial intermediaries hold government bonds and face a leverage constraint which could be binding. When the sovereign spread increases, the value of the government bonds on the financial intermediaries' balance sheets falls, which leads to a lower net worth N_t.

Recall that the loan interest rate for firm i is given by

$$R_{it} = \frac{1 + (1 - \theta_{it})\zeta_t}{\beta}, \text{where } \theta_{it} = \frac{k_{T,it}}{\bar{k}} < 1. \tag{15}$$

The Lagrange multiplier $\zeta_t > 0$ when the leverage constraint (12) binds. A decline in financial intermediaries' net worth N_t reduces credit supply and further tightens the leverage constraint, leading to an increase in ζ_t and thus in the loan interest rate R_{it}. The firm specific interest rate R_{it} also depends on its tangible assets through θ_{it}. Thus, firms internalize the impact of tangible capital on interest rates when choosing tangible and intangible investment. Tangible investment helps offset tightening financial conditions by decreasing a firm's interest rate, while intangible investment does not ($\partial R_{it}/\partial k_{T,it} < 0$ and $\partial R_{it}/\partial k_{I,it} = 0$ when the leverage constraint binds).

For analytical purpose, Eq. (16) shows the first order condition for firm i's next period tangible capital $k_{T,it+1}$ without capital adjustment costs. The left-hand-side is the marginal cost of increasing tangible capital, and the right-hand-side is the marginal benefit of tangible capital. Unlike intangible capital, investing in tangible capital has an extra benefit of decreasing the firm's interest rate, as shown in the bracket.

$$
\begin{aligned}
[1+(R_{it}-1)\lambda_i] =& \beta[\eta(1-\tau)Y_{t+1}^{1-\eta}y_{it+1}^{\eta-1}\frac{\partial y_{it+1}}{\partial k_{T,it+1}} \\
&+(1-\delta_T)[1+(R_{it+1}-1)\lambda_i] \\
&\underbrace{-\Big[k_{T,it+2}-(1-\delta_T)k_{T,it+1}+k_{I,it+2}-(1-\delta_I)k_{I,it+1}\Big]\lambda_i\frac{\partial R_{it+1}}{\partial k_{T,it+1}}]}_{\text{extra benefit of tangible capital investment}}
\end{aligned}
\tag{16}
$$

During sovereign debt crises, the net worth of the financial intermediaries shrinks, thus tightening the leverage constraint. When ζ_t increases, the impact of tangible capital on private sector interest rates is larger, i.e., a higher absolute value of $\partial R_i/\partial k_{T,i}$. For firms who largely rely on external financing (high-λ firms), the marginal benefit of investing in tangibles is larger. This explains our empirical finding that high-leverage firms reallocate more resources from intangible capital to tangible capital during the Italian sovereign debt crisis. The movements in the loan interest rate affect firms' input choices, which then affect aggregate TFP and output.

4 Quantitative Analysis

We now fit the model to Italian data. This section proceeds in four steps. Section 4.1 parametrizes the model. Section 4.2 studies the impulse responses of firm investment, output, and TFP to an increase in government default risk, as well as the model counterpart of firm heterogeneous responses. Section 4.3 reports the results of our quantitative experiment, in which we use the model to measure the output and TFP losses due to Italian debt crisis. Section 4.4 highlights the role of endogenous intangible investment by comparing our benchmark model to two reference models.

4.1 Parameterization

The model is at an annual frequency. There are two groups of parameters. The parameters in the first group are fixed exogenouly and are taken directly from the literature or from our empirical exercise, and those in the second group are jointly chosen to match a set of moments relating to the Italian economy and its constituent firms. Table 6 lists all the parameter values.

The fixed parameters are $\{\alpha, \eta, \delta_T, \delta_I, \tau, \rho_z, \sigma_z, \beta, \vartheta, \rho_s, f\}$. The parameters $\{\alpha, \eta\}$ affect the shape of the production function of intermediate and final goods firms. We set α to 0.48 as the average share of labor compensation in GDP at current national prices for Italy in our sample period is 0.52. η is set to be 0.75, which is the conventional value in the literature. The depreciation rate for intangible assets δ_I is 24.3% and the depreciation rate for tangible assets δ_T is 10.1%, according to our estimation for Italian depreciation rates in 2006 using the EU KLEMS database. The tax rate τ is 0.24, which is the corporate tax rate in Italy. The persistence and standard deviation of the firm productivity shock are set to be 0.9516 and 0.0033, following Lopez and Olivella (2018). The discount factor β is set to match an annual risk-free rate of 2%. The fraction of bonds maturing ϑ is set to be 0.05. The parameter governing the persistence of the sovereign risk process ρ_s is taken from Bocola (2016). The haircut fraction f is consistent with empirical evidence in Cruces and Trebesch (2013).

The remaining parameters in the model include parameters in the production function $\{\nu, \sigma\}$, parameters governing investment adjustment costs $\{\theta_T, \theta_I\}$, parameters for the working capital requirement $\{\lambda_l, \lambda_h\}$, a constant transfer to the financial intermediaries $\bar{n}$, a parameter ϕ_B measuring government bond adjustment cost, and parameters for the sovereign risk process $\{\sigma_s, s^*\}$. To set these parameters, we target 10 sample moments that reflect the behaviors of firms, banks, and government. We solve the model using global methods. Given the model policy functions, we perform simulations to obtain the model-implied counterparts of our targets. We jointly choose the fitted parameters to match these 10 sample moments by minimizing the sum of the distance between the moments in the model and their corresponding counterparts in the data. The elasticity of substitution between tangible and intangible capital is 0.51, close to 0.5 used in Falato et al. (2022).

Although we choose all parameters jointly to match the moments, we can provide a heuristic description of how the moments inform specific parameters. First, firm tangibility and correlation between two types of capital investment mostly inform the weight on tangible capital ν and the elasticity of substitution σ between two types of capital in the production function. Second, firm capital volatilities in the data mostly inform the capital adjustment costs $\{\theta_T, \theta_I\}$. Third, the leverage statistics mainly pin down the working capital parameters $\{\lambda_l, \lambda_h\}$. Fourth, there is a tight relationship between $\bar{n}$—the lowest lending ability of financial intermediaries—and the ratio of credit to non-financial corporations to government credit. Fifth, the ratio of government bonds to tax revenue disciplines the government adjustment cost parameter ϕ_B. Finally, the mean and volatility of the spread primarily inform the sovereign risk process parameters $\{\sigma_s, s^*\}$. Table 7 reports the moments in the data and model. The model generates similar statistics as in the data.

4.2 Effects of elevated sovereign risk

During sovereign debt crises, facing higher borrowing costs, firms reduce their investment. To offset tightening financial conditions, firms also reallocate their investment from intangible capital to tangible capital. That is to say, although they reduce both their tangible and intangible investment, they cut their intangible investment more.

To see this in the model, we plot the firms' impulse response functions (IRFs) to a positive spread shock s so that the government spread increases by one standard deviation. We simulate 2,000 paths for the model for 500 periods. From periods 1 to 400, the aggregate s shock follows its underlying Markov chain. In period 401, there is a positive shock to s so that the government spread increases by one standard deviation. From period 401 on, the s shocks follow the conditional Markov process. The impulse responses plot the average, across the 2,000 paths, of the variables for the last 100 periods.

Table 6: Parameters

Parameter	Description	Value	Target/Source
Fixed parameters			
α	Income share of capital	0.48	Penn World Table
η	Markup parameter	0.75	Conventional value
δ_T	Depreciation of tangible capital	0.101	Our estimation
δ_I	Depreciation of intangible capital	0.243	Our estimation
τ	Tax rate	0.24	Corporate tax rate
ρ_z	Persistence of firm productivity shock	0.9516	Lopez and Olivella (2018)
σ_z	Volatility of firm productivity shock	0.0033	Lopez and Olivella (2018)
β	Discount factor	0.98	Annual risk-free rate of 2%
ϑ	Fraction of bonds maturing	0.05	Conventional value
ρ_s	Sovereign risk process	0.95	Bocola (2016)
f	Haircut fraction	0.37	Cruces and Trebesch (2013)
Fitted parameters			
ν	Weight on tangible capital	0.82	Firm tangibility
σ	Elasticity of substitution	0.51	Correlation between investment
θ_T	Adjustment cost of tangible investment	2.63	Vol(tangible capital)/Vol(sales)
θ_I	Adjustment cost of intangible investment	0.08	Vol(intangible capital)/Vol(sales)
$[\lambda_l, \lambda_h]$	Working capital requirements	[0.122,1.72]	Average leverage of firms
$\bar{n}$	Constant transfer	0.02	Credit to firms/Credit to government
ϕ_B	Bond adjustment cost	72	Average government bonds/Tax revenue
σ_s	Sovereign risk process	0.23	Volatility of spread
s^*	Sovereign risk process	-3.4	Average spread

Figure 2 shows these impulse responses for the firms when there is a one standard deviation increase in sovereign spreads (Panel (a)). When sovereign spreads increase, the balance sheets of the financial intermediaries deteriorate. With lower net worth, the financial intermediaries' leverage constraint binds, increasing the interest rates offered to firms (Panel (b)). Face a higher borrowing cost, the firms lower both their tangible assets and intangible assets (Panel (c)). However, firms reduce their intangible investment by more because intangible assets can't be used as collateral. Tangible assets, as collateral, can help lower their loan interest rate. Panel (d) confirms this asset reallocation pattern where the ratio of tangible assets to intangible assets increases following the shock. Since capital decreases, firms' output decreases in response (Panel (e)). Because firms decrease their intangible investment, their TFP decreases (Panel (f)). Note that the only shock here is the s shock. Thus, the model endogenously generates the output decline and TFP decline when the sovereign spread increases.

Next we show that the model can also replicate the observed heterogeneous asset reallocation pattern, as in the empirical section. We use the calibrated model to mimic the Italian economy and generate model-simulated data. Consistent with the sample length in

Table 7: Moments in the data and model

	Data	Model
mean(firm tangibility)	0.740	0.727
corr(intangible investment, tangible investment)	0.217	0.206
std(tangible capital)/std(sales)	1.678	1.514
std(intangible capital)/std(sales)	3.373	3.283
mean(leverage) for low-leverage firms	0.023	0.023
mean(leverage) for high-leverage firms	0.359	0.339
government bonds/tax revenue	2.595	2.476
credit to firms/credit to government	0.630	0.690
mean(spread)	0.016	0.016
std(spread)	0.012	0.012

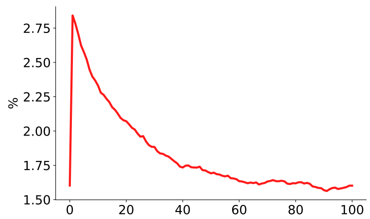
Notes: See online appendix for the construction of moments in the data.

our empirical section, we focus on the Italian economy from 2006 to 2016. We feed the model with a sequence of s_t shocks and z_t shocks such that the model replicates the observed path of Italian sovereign spread and real GDP. The z_t shocks summarize the shocks that are not directly induced by the sovereign debt crisis, e.g., aggregate demand declining due to the global recession. Then we simulate the model to generate a panel sample of heterogeneous firms. Using the model-simulated sample, we run the same regressions as those in Table 4, where the dependent variable is tangibles-to-intangibles ratio. We investigate how the sovereign debt crisis affects this ratio and how firm characteristics (size and leverage) affect the magnitude of the reallocation.

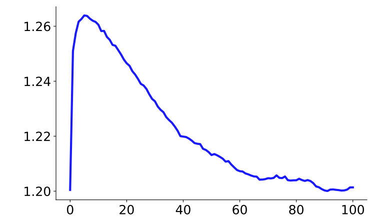
Table 8 compares the estimated coefficients using the Italian data with those using the model-simulated data. The coefficients from the Italian data are taken from column (6) in Table 4. The model generates a similar asset reallocation pattern as in the data: firms increase their tangibles-to-intangibles ratio during the sovereign debt crisis. Moreover, small firms and high-leverage firms reallocate more towards tangible investment compared with other firms. However, the model fails to match the magnitude of the regression coefficients.

4.3 Output and TFP losses from the Italian debt crisis

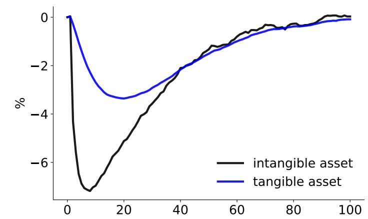
In this section, we quantify the output and TFP losses from the Italian sovereign debt crisis using our model with intangible investment. First, we feed the model with a sequence of s_t



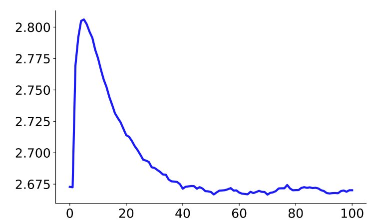
(a) Sovereign spread



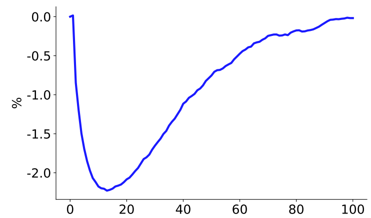
(b) Loan interest rate R



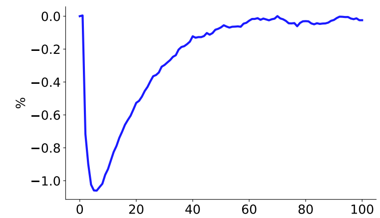
(c) Asset



(d) Tangibles-to-intangibles



(e) Output



(f) TFP

Figure 2: IRFs to a one standard deviation increase in sovereign spreads

Notes: Impulse response functions to a positive s shock (so that the sovereign spread increases by one standard deviation).

Table 8: Regression results: data and model

	Data	Model
sp_t	1.900***	1.428***
$size_{i,2006} \times sp_t$	-1.297***	-0.883***
$leverage_{i,2006} \times sp_t$	0.384*	1.811***

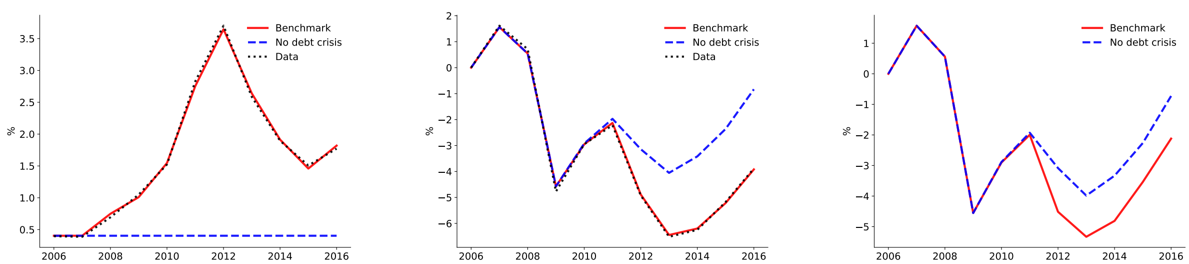
Notes: Regression coefficients for the data and the model. The coefficients from the data are taken from column (6) in Table 4. The model regression specification mimics the data regression as much as possible. The sample time length is consistent with data regression.

shocks and z_t shocks such that the model replicates the observed path of Italian sovereign spread and real GDP. Then we construct a scenario in which the Italian economy does not experience a sovereign debt crisis. We then compare the result of our benchmark model and that of the counterfactual model with no debt crisis. The differences between the paths of key variables in the benchmark model and those in the *no-debt-crisis* counterfactual model isolate the impact of the sovereign crisis on the Italian economy.

Figure 3 reports the time paths for sovereign spreads, GDP, and TFP during 2006-2016. The black dotted lines plot the paths in the data, the red solid lines plot the result of the benchmark model, and the blue dashed lines plot the result of the counterfactual scenario where there was no debt crisis. The unit of sovereign spreads in Panel (a) is percentage points. Panel (b) and Panel (c) plot the percentage changes of GDP and TFP from the 2006 level.

By construction, the benchmark model (red solid lines) matches the sovereign spread and GDP in the data (black dotted lines). In general, the model needs a negative z shock and a positive s shock to reproduce the dynamics of sovereign spreads and GDP observed in the data. The sovereign spread increases from 0.4% in 2006 to 3.7% in 2012. Real GDP decreases by 4.7% from 2006 to 2009, recovers slightly in 2010, and then decreases another 4.3% during 2011-2013.

The blue dashed lines show the corresponding result in the *no-debt-crisis* counterfactual case, where we adjust the series of s_t shocks to fix the sovereign spread at their 2006 level throughout the simulation. Thus, the sovereign spread is constant in this counterfactual case. In this scenario, there is no increase in sovereign default risk and there is no transmission of sovereign risk to the financial intermediaries or the firms.



(a) Sovereign spreads (b) GDP (c) TFP

Figure 3: Paths for spreads, GDP and TFP

Notes: Paths for Italian sovereign spreads, GDP and TFP during 2006-2016. The black dotted lines plot for the data, the red solid lines plot for the benchmark model results, and the blue dashed lines plot the results from the counterfactual scenario where there was no debt crisis.

Output and TFP are still below the trend after the year 2013, indicating a prolonged recession. To quantify the losses, Table 9 reports output and TFP during and after the sovereign debt crisis. During 2011-2016, on average, output is 4.8% below trend, while it would have been 2.63% below trend without the sovereign debt crisis. As for TFP, on average, TFP is 3.72% below trend, while it would have been 2.55% without debt crisis.

Therefore, our model predicts that sovereign risk was responsible for about 45% of the output losses and 31% of the TFP losses from 2011 to 2016.

Table 9: Output and TFP losses

	2011	2012	2013	2014	2015	2016	Avg. 11-16
output	-2.13	-4.89	-6.45	-6.20	-5.22	-3.92	-4.80
output-no debt crisis	-1.97	-3.14	-4.05	-3.42	-2.36	-0.83	-2.63
TFP	-2.00	-4.51	-5.33	-4.81	-3.54	-2.12	-3.72
TFP-no debt crisis	-1.93	-3.09	-3.98	-3.33	-2.26	-0.73	-2.55

Notes: "output" and "TFP" are the dynamics for the benchmark model. "output-no debt crisis" and "TFP-no debt crisis" are the dynamics for the no-debt-crisis counterfactual case. Output and TFP are reported as the percentage deviation from their 2006 value.

4.4 Role of intangible assets

To highlight the role of intangible assets, we compare the benchmark model with those without intangible investment. We use two ways to shut down intangible investment and call them reference models. In the first reference model, we eliminate intangible assets completely. We refer to this model as the *no-intangible-asset* model. In the second reference model, we fix intangible assets for each firm (and no depreciation) to the median level of the invariant distribution from the benchmark model and call this the *fixed-intangible-asset* model. Then we compare the benchmark model to these reference models to highlight the role of intangible assets.

For the no-intangible-asset model, we discard intangible assets and keep the implied labor share constant. We then choose $\{\theta_T, \lambda_l, \lambda_h, \bar{n}, \phi_B\}$ to match the relative volatility of tangible capital, the average leverage for firms within the low-leverage and high-leverage groups, the ratio of government bonds to tax revenues, and the ratio of credit to non-financial corporations to government credit.

For the fixed-intangible-asset model, we fix each firm's intangible assets to the median level of the invariant distribution from the benchmark model and assume no depreciation of intangible assets. We then choose $\{\theta_T, \lambda_l, \lambda_h, \bar{n}, \phi_B\}$ to match the same set of moments as in the no-intangible-asset model. Table 10 reports the parameters in each reference model after recalibration. The bottom panel shows that the benchmark model and the reference models generate similar moments as in the data. The top panel lists the parameters that are different from the benchmark.

Table 10: Parameters and moments in different models

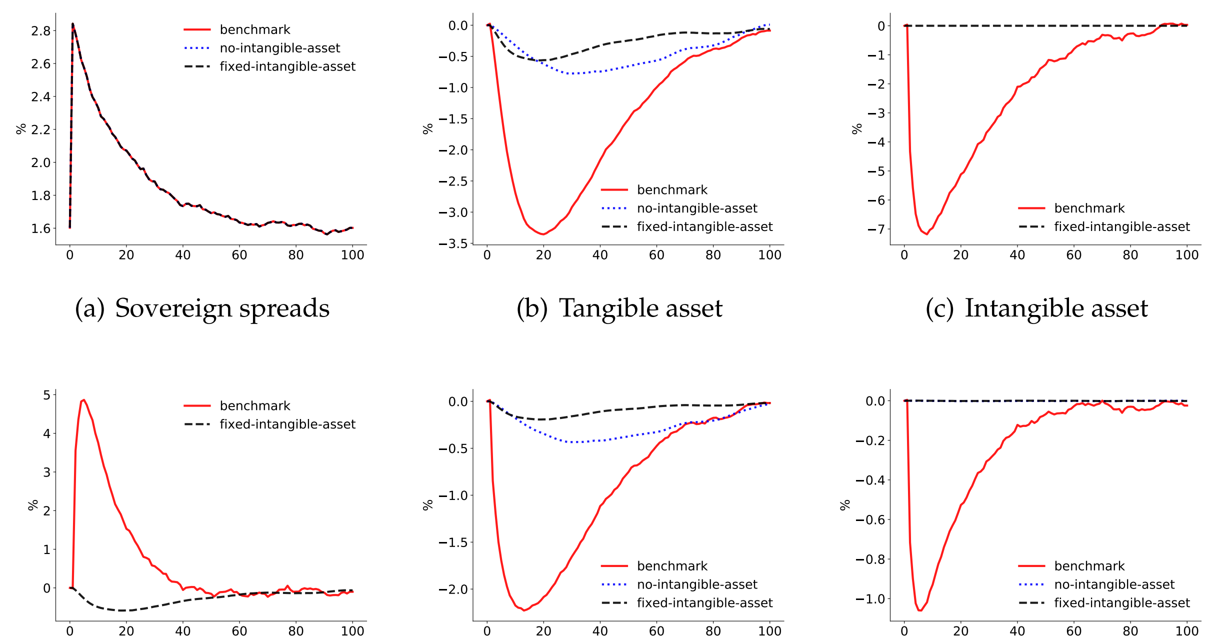
	benchmark	no-intangible-asset	fixed-intangible-asset
Parameters changed from benchmark			
Weight on tangible capital ν	0.82	-	0.82
Elasticity of substitution σ	0.51	-	0.51
Depreciation of intangible capital δ_I	0.243	-	0
Adjustment cost of tangible investment θ_T	2.63	6.3	9.6
Adjustment cost of intangible investment θ_I	0.08	-	-
Working capital requirements $[\lambda_l, \lambda_h]$	[0.122,1.72]	[0.138,2.04]	[0.18,2.54]
Constant transfer $\bar{n}$	0.02	0.03	0.074
Bond adjustment cost ϕ_B	72	39	40
Model moments			
mean(firm tangibility)	0.727	-	0.715
corr(intangible investment, tangible investment)	0.206	-	0
std(tangible capital)/std(sales)	1.514	1.629	1.555
std(intangible capital)/std(sales)	3.283	-	0
mean(leverage) for low-leverage firms	0.023	0.023	0.024
mean(leverage) for high-leverage firms	0.339	0.361	0.335
government bonds/tax revenue	2.476	2.676	2.760
credit to firms/credit to government	0.690	0.623	0.642
mean(spread)	0.016	0.016	0.016
std(spread)	0.012	0.012	0.012

With the recalibrated reference models, we compare the IRFs in Figure 4. The IRFs plot the responses following the same positive s shock so that the sovereign spread increases by one standard deviation (Panel (a)). The red solid lines are the responses for our benchmark model, the blue dotted lines are for the no-intangible-asset model, and the black dashed lines are for the fixed-intangible-asset model.

Panel (b) of Figure 4 plots the responses of tangible assets. The benchmark model (red solid line) generates a larger decline than the reference models. This is because the decline in intangible assets (as shown in Panel (c)) reduces measured TFP, lowering the marginal product of tangible assets in the benchmark model, thus leading to lower optimal tangible assets. Panel (d) plots the tangibles-to-intangibles ratio. In the benchmark model, firms that experience tighter financing conditions respond by shifting their assets towards tangible assets, resulting in an increase in the tangibles-to-intangibles ratio. This pattern is not shown in both references models. In the no-intangible-asset model, this ratio does not exist. In the fixed-intangible-asset model, because intangible asset is fixed by assumption, a decline in tangible assets due to higher sovereign risk directly leads to a decline in the tangibles-to-intangibles ratio.

Panel (e) plots the IRFs of output. The benchmark model exhibits the largest decline, with a 2.2% drop following a one standard deviation increase in the spread. In the no-intangible-asset model, output decreases by 0.43%, and in the fixed-intangible-asset model, by 0.2%. The reduction of intangible assets leads to a decrease in measured TFP as depicted in Panel (f), which contributes to the larger decline in output observed in the benchmark model. In contrast, the reference models do not show any responses in TFP.

In sum, our benchmark model generates the key empirical implications for intangible assets, asset reallocation, and measured TFP as in the data, while the reference models are silent on those empirical patterns. Also, the TFP losses and output losses would be underestimated if we ignore the responses in intangibles, highlighting the role of intangible assets when quantifying the impact of sovereign risk. The relevance of intangible capital during crises is even greater when intangible and tangible capital are less substitutable.



(a) Sovereign spreads (b) Tangible asset (c) Intangible asset

(d) Tangibles-to-intangibles ratio (e) Output (f) TFP

Figure 4: IRFs in benchmark model and reference models

Notes: Impulse response functions to a positive s shock in the benchmark model (red solid lines), no-intangible-asset model (blue dotted lines), and fixed-intangible-asset model (black dashed lines).

5 Conclusion

Sovereign debt crises can have detrimental impacts on firm investment. Evidence shows that financially constrained firms decrease investment in both intangible and tangible assets during a crisis. Despite reducing both investment, small and high-leverage firms tend to shift their investment toward tangible assets, which are more widely accepted as collateral. This reallocation pattern could apply to a broader set of financial crises that hit the banking sector.

We build a sovereign default model with firm intangible investment to explain these empirical findings and measure the aggregate output and TFP costs of sovereign risk. Firms internalize that tangibles can serve as collateral and thus can mitigate financial constraints. When sovereign risk is transmitted to firms through the financial intermediaries, firms lower their investment, especially investment in intangible assets. Quantitatively, sovereign risk explains a large fraction of the output and TFP losses during the Italian debt crisis.

We focus on firm investment, and our approach could be generalized to other dimensions. Sovereign risk may impact firms though different channels. Our estimation of reallocation patterns also partially aligns with other potential explanations. For example, firms connected to banks that are more exposed to sovereign risk might have more pronounced reallocation behaviour. Besides, high-risk firms may be more heavily affected by sovereign risk compared to risk-free firms (Hegarty et al. (2024)) and might rely more on collateralized borrowing. Sovereign debt crises could also affect firms' entry and exit decisions (Chaumont et al. (2023)), or their import and export choices. We believe that using firm-level data to estimate the impact of sovereign risk and explore other potential mechanisms offers a compelling opportunity for future research.

Due to data limitations, we do not observe substantial details on the nature of firm intangible asset holdings. It would also be interesting to decompose intangible assets and explore if different types of intangible assets play different roles in explaining firm choices and outcomes. Understanding the heterogeneous investment behaviors of firms during crises, especially in terms of investment—which has beneficial long-run effects—provides key information for policy makers. We leave these applications to future research.

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