Private Leverage and Sovereign Default[*]

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Abstract

In this paper we study the *passthrough* of sovereign debt crisis into the private economy using micro firm level data and a model with firm heterogeneity and sovereign default. The idea is that differential effects of firms to the government debt crisis provide information about the extent of passthrough. We use micro firm data for Italy and develop a model with a firm distribution to measure the propagation of sovereign debt crisis. We find that passthrough explains about half of the decline in GDP during the recent recession but constitutes a disciplining device for the government preventing more severe debt crises.

[*]The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1 Introduction

A salient feature of sovereign debt crises is that they go hand in hand with the financial strains of the private sector. Recent events in Southern Europe have once more highlighted this link, with borrowing rates of firms increasing sharply as interest rate spreads on bonds issued by their governments were rising. Several papers have interpreted this empirical regularity as reflecting the adverse effect that government debt crises have on the domestic financial sector and, more generally, on the risks underlying the private sector.[1] However, the literature has found it challenging to empirically evaluate these views. The main problem is that of simultaneity: debt crises do not arise at random, as governments find it hard to service their debt precisely when the economic conditions of the private sector deteriorate.[2] Therefore, a positive comovement between government spreads and private sector interest rates is not informative on whether the government debt crisis contributes to the financial stress of the private sector, or whether it is a reflection of it.

In this paper we address this issue by looking at a different source of variation in the data. We develop a sovereign debt model with firms' dynamics, and use cross-sectional variation in firms' performance in periods of high sovereign stress to measure the effects of the debt crisis on the economy. In our environment, the risk of a government default can affect the performance of firms through its impact on their borrowing costs. The strength of this mechanism depends on firms characteristics, as firms with higher borrowing needs are more severely harmed by an increase in their interest rates. Therefore, in our theory, the output costs of a sovereign debt crisis are tightly linked to the behavior of firms in the cross-section. Our approach consists in using these cross-sectional implications of the model, along with detailed firm-level data during the Italian debt crisis of 2008-2012, to indirectly measure the effect of the sovereign crisis on the real economy. We document that this channel is of first order importance, explaining roughly half of the GDP decline in Italy during the crisis.

In our framework, a government receives fluctuating tax revenues and borrows internationally in order to finance valuable public goods. The government can default on its debt obligations, and bond prices compensate lenders for this default risk. Output is produced with capital and labor by firms that are heterogeneous in their productivity and financing

[1]For example, Sosa Padilla (2013), Gennaioli, Martin, and Rossi (2014), Bocola (2016), and Perez (2015) among others push forward the idea that debt crises may harm the balance sheet of domestic financial intermediaries, and spill-over to the funding costs of non-financial firms. Arellano, Atkeson, and Wright (2015) suggests that the link between the borrowing costs of the government and those of the firms may be due to the incentives of governments to interfere with private contracts conditional on default.

[2]This is a key prediction of models of defaultable debt, see Arellano (2008). See Tomz and Wright (2007) for evidence of a negative (although weak) relation between economic output and sovereign default.

needs. This heterogeneity leads to differences in leverage and performance (output) across firms. The economic environment is perturbed by two types of aggregate shocks, a shock that moves the productivity process of firms, and a shock to the outside option of the government. This latter shock generate variation in default risk that is orthogonal to aggregate productivity, and it can be interpreted as capturing time variation in the enforcement of sovereign debt.[3]

As in the canonical models of Eaton and Gersovitz (1981), Arellano (2008), and Aguiar and Gopinath (2006), the risk of a government default is endogenous and it responds to changes in the state of the economy. The key feature of our environment is that this variation in default risk can potentially feedback on real economic activity. Following the work of Neumeyer and Perri (2005) and Corsetti, Kuester, Meier, and Müller (2013), we assume that private sector interest rates depend on the interest rates spreads paid by the government according to a flexible reduced form specification. This assumption implies that the firms' choices of inputs and their production are depressed when sovereign spreads are high because of their impact on the marginal costs of borrowing. The strength of this channel in the model is regulated by a parameter that governs the *pass-through* of sovereign spreads into the private sector borrowing rate, and that we are ultimately interested in learning from the data.

We apply our framework to the Italian sovereign debt crisis of 2008-2012. We obtain information on firms' balance sheets using the ORBIS-AMADEUS dataset, which covers a large fraction of the Italian manufacturing sector during the 2005-2012 period, including both privately held and publicly held firms. We estimate the firms' productivity process, and use these results to discipline most of the technological parameters of our model. The remaining parameters, and importantly the ones governing the sovereign risk pass-through, are chosen so that our model replicates salient feature of aggregate time series and cross-sectional data for the Italian economy.

In order to understand why cross-sectional moments are useful to measure the transmission of sovereign risk to real economic activity, suppose that our economy reaches a state in which the government becomes at risk of a default. Interest rates spreads on government bonds rise as lenders demand compensation for the heightened default risk. When the pass-through is sizable, private sector interest rates increase too. Importantly, however, the implication of these higher interest rates are not homogeneous in the population of firms

[3]Practically, this second shock allows the model to fit variation in Italian interest rate spreads that would otherwise be hard to rationalize with the behavior of aggregate productivity. For example, Bocola and Dovis (2016) show that a benchmark model of sovereign debt driven by income shocks has hard time fitting the rise in Italian interest rate spreads in 2011. In the context of the euro-area debt crisis, there has been a progressive deterioration in the enforcement of the fiscal rules defined by the Maastricht treaty, and this shock may proxy these dynamics.

because an increase in the cost of borrowing hurts more the firms that are in need of borrowing. Therefore, when the propagation of sovereign risk is quantitatively sizable, we should observe firms with high borrowing needs to cut on their production by more than firms that are less in need of borrowing during a sovereign crisis. We measure this sensitivity in the data by running firm-level regression of aggregate and firm-specific covariates on firms' sales: the coefficient of interest is the interaction between an indicator of firm leverage and interest rate spreads on Italian government bonds. We find that, controlling for other factors, highly levered firms experience a larger contraction in their sales during periods of high Italian government spreads than less levered firms. Specifically, a 100 basis point increase in sovereign spreads is associated with a decline is sales growth of 3.0% for firms with leverage at the 75^{th} percentile and a decline of 2.2% for firms with leverage at the 25^{th} percentile. Our calibration ensures that we replicate this elasticity in model simulation.

We use the calibrated model to interpret the sources underlying Italian debt crisis. In an event study, we feed the aggregate productivity series measured in the data and we retrieve the path for the enforcement shock that guarantees that the model matches the sovereign spreads over the episode. The data calls for a continuous decline in enforcement since 2008 in order to replicate the dynamics of the interest rate spreads series. As an overidentifying restriction of our theory, we show that the model replicates 80% of the decline in Italian GDP, and 70% of the increase in the average credit spreads of non-financial firms during the event.

The main counterfactual experiment consists in measuring the pass-through from the government debt crisis to the private sector. To this end, we feed the same sequence of shocks to a variant of the model where government interest rate spreads do not pass-through into firms borrowing costs. We find that GDP in this counterfactual falls by about 60% less than in our benchmark specification. We conclude that the pass-through from sovereign debt crises to the private economy is essential for rationalizing the severe output declines observed in Italy. Moreover, and in line with the logic of models of sovereign debt, we find that these severe output losses associated to the debt crisis discipline the borrowing behavior of the government: in absence of a pass-through, government spreads would have increased by about XXX basis points relative to their increase in the benchmark.

While our analysis improves over existing studies that rely exclusively on variation in aggregate time-series, it is not robust to misspecification of the underlying structural model. A major concern is that we are failing to account for factors that could affect sovereign risk while hurting the performance of highly levered firms. Our measurement strategy would then overstate the size of the sovereign-risk pass-through because these omitted factors magnify the interaction coefficient between government spreads and leverage in the firm-level regressions that we estimate. To control for this issue, we perform a series of robustness checks in our firm-level regressions by incorporating proxies for plausible candidates of these omitted factors: volatility indexes, stock prices, and house prices. We document that the interaction coefficient varies little and remains statistically significant in all these specification.

This paper is related to the literature on sovereign debt crises and the financial imperfections impacting firm dynamics.

Many papers have studied the link between sovereign interest rates and output fluctuations. One literature has focus on one the effects of exogenous sovereign risk on output. Neumeyer and Perri (2005) and Uribe and Yue (2005) find that the large movements in sovereign rates have sizable effects on output in models where firms face financial frictions in the form of working capital loan requirements with interest rates equal to that of the sovereign government. These papers, however, take as given the movements in sovereign interest rates. A complementary literature has focused precisely on modeling sovereign interest rates arising from default risk which responds to exogenous output variations. Arellano (2008) and Aguiar and Gopinath (2006) find that the output movements induces default probabilities that can rationalize the movements in sovereign rates in emerging markets.

Our paper, as that of Mendoza and Yue (2012), combines these two effects, by analyzing how sovereign rates affect output and how output affects sovereign rates. In Mendoza and Yue (2012), default affects output because it disrupts financial intermediation of imported intermediate goods in a model of a representative firm. We model output produced by heterogeneous firms and use the differential effect of firms to parameterize how sovereign risk affect domestic credit conditions.

Our assumption that sovereign default risk affects financing conditions of firms is based on literature on the link between sovereign default and the domestic banking sector. Gennaioli, Martin, and Rossi (2014), and Baskaya and Kalemli-Ozcan (2016) show empirically that sovereign default risk negatively affect the conditions of domestic banks. Bocola (2016) and Sosa Padilla (2013) model financial intermediaries and show how increases in sovereign rates worsens intermediaries' balance sheets which in turn tightens domestic credit and increases domestic interest rates. Bocola (2016) estimates his structural model to Italy and finds that this channel is important for rationalizing the output movements. In contrast to our work, all these paper however, rely on aggregate data.

Firm dynamics and financial frictions: Discuss Gopinath, et al (2016) and Arellano, Bai, Kehoe (2016).

2 Model

We consider a dynamic economy with heterogeneous firms and a government. Firms differ in their productivity and their financing needs. They produce a homogeneous good using capital and labor, and they borrow from lenders to finance a portion of their input costs. The government receives tax revenues and it borrows from the lenders to finance public goods and to service its outstanding debt. Both the firms and the government can default on their debt, and the interest rates at which they borrow compensates lenders for the losses suffered in case of a default.

The economy is perturbed by two aggregate shocks. The first shock, p_t, is an aggregate shock to the firms' productivity. The second shock ν_t affects the utility of the government in case of a default, and it controls the enforcement of sovereign debt.

The timing of events within the period are as follows. In the beginning of the period, the aggregate shocks are realized. The government chooses whether to default and how much to borrow, while firms make production and borrowing choices. At the end of the period, the idiosyncratic shocks to firms productivity are realized, and firms choose whether to default or not. We now describe the decision problem of the agents and define a recursive equilibrium for this economy.

Firms A measure one of heterogeneous firms produce output in this economy. Each firm i combines capital $k_{i,t}$ and labor $\ell_{i,t}$ in order to produce output $y_{i,t}$ using a decreasing return to scale technology. The production is subject to firm-specific productivity shocks, $z_{i,t}$. The output produced by firm i at time t is then

$$y_{i,t} = z_{i,t}^{1-\eta}(\ell_{i,t}^{\alpha} k_{i,t}^{1-\alpha})^{\eta}. \tag{1}$$

Firms' productivity is affected by an aggregate and an idiosyncratic component. We model the aggregate shock following the literature on disaster risk (Gourio, 2012): every period, there is a probability p_t that a firm's productivity declines by θ. This probability is common across firms, and it is drawn every period from a distribution $\Pi^p(p)$. The idiosyncratic shock is a standard normal random process $\varepsilon_{i,t}$. The process for firms' productivity is then

$$\begin{aligned} \ln z_{i,t} &= \rho_z \ln z_{i,t-1} - I_{i,t}\theta + \sigma_z \varepsilon_{i,t}, \\ Pr(I_{i,t} = 1) &= p_t. \end{aligned} \tag{2}$$

Note that p_t affects not only the average productivity in this economy, but also higher moments such us standard deviation and skewness. As we will discuss in the quantitative section, this specification allows us to capture time-variation in the cross-sectional distribution of firms' productivity in Italy during the period of analysis.

Firms enter the beginning of the period with productivity $z_{i,t-1}$, and they choose capital $k_{i,t}$ and labor $\ell_{i,t}$. We introduce heterogeneity in the borrowing needs of firms by assuming that they face a working capital constraint requiring them to pay λ_i fraction of their input costs before production takes place. This firm-specific attribute is time-invariant, and it is drawn from $\Pi^{\lambda}(\lambda)$. Firms borrow by issuing a defaultable debt $b_{i,t}$ at price $q_{i,t}$. Accordingly, we have

$$q_{i,t}b_{i,t} = \lambda_i(r^k k_{i,t} + w\ell_{i,t}), \tag{3}$$

where r^k and w are factor prices that are taken as given by the firms and assumed to be constant.[4]

At the end of the period, the idiosyncratic shock is realized and production takes place. Assuming that a firm repays its debt, it also repays the remainder of the input costs and a fixed cost $\xi_{i,t}$ which is drawn from a distribution $\Pi^{\xi}(\xi)$. In this case, the profits of firm i are

$$\pi_{i,t} = y_{i,t} - (1 - \lambda_i)(w\ell_{i,t} + r^k k_{i,t}) - b_{i,t} - \xi_{i,t}. \tag{4}$$

We assume that a firm's payouts are required to be positive, $\pi_{i,t} \geq 0$. When profits are positive, the firm repays its debt, $d_{i,t} = 0$, and rebates $\pi_{i,t}$ to the household sector. When profits are negative, the firm defaults, $d_{i,t} = 1$, and exits with a value of zero. During default, the firm's resources from production are used to pay for the inputs and for the fixed costs, while the lenders obtain a payout of zero. Any short fall of resources for input costs and fixed cost is paid by the government with a transfer f such that

$$f_{i,t} = max\{d_{i,t}[(1 - \lambda_i)(w\ell_{i,t} + r^k k_{i,t}) + \xi_{i,t} - y_{i,t}], 0\} \tag{5}$$

A defaulting firm is the replaced next period with another firm with the same idiosyncratic state.

Government The government finances public goods G_t and collect a fraction τ of aggregate output Y_t as tax revenues. It borrows from financial intermediaries short term loans B_{t+1} at price q^g_t to pay for its government expenditures, outstanding debt B_t, and any remainder

[4] We abstract from variation in wages and rental rates of capital given the focus in our quantitative analysis on a short event period and to maintain computational tractability.

input costs from defaulting firms F_t. The government budget constraint is

$$B_t + G_t = q_t^g B_{t+1} + \tau Y_t - F_t \tag{6}$$

The government can default on its debt. When the government defaults, it reduces its outstanding debt to R. The budget constraint of the government during a default is similar to (6), but with outstanding debt $B_t = R$. We assume that the government suffers a stochastic utility loss $\exp\{v_t\}$ when it defaults, and this shock follows the stochastic process

$$\nu_t = \bar{\nu} + \rho_\nu \nu_{t-1} + \sigma_\nu \epsilon_{\nu,t},$$

with $\epsilon \sim \mathcal{N}(0,1)$.

The government's objective is to maximize the present discounted value of the utility derived from public goods net of any default costs,

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t (u_g(G_t) - D_t \exp\{\nu_t\}), \tag{7}$$

where $D_t = 1$ when the government is in default, and zero otherwise.

Financial intermediaries Government's bond prices compensate financial intermediaries for the losses suffered in case of default. The lenders discount the future at the international interest rate r. The government bond price is then given by

$$q_t^g = \mathbb{E}_t \left[\frac{1 - D_{t+1}(1-R)}{1+r} \right]. \tag{8}$$

Interest rate spreads on government bonds are defined as the difference in the yield of the bond relative to the risk free rate

$$s_t^g = \frac{1}{q_t^g} - (1+r). \tag{9}$$

Similarly, firms' bond prices compensate lenders for the losses in case of default.[5] In addition, we follow Neumeyer and Perri (2005) and Corsetti et al. (2013) in assuming that the interest rates faced by firms depend on the interest rate spreads on government's bonds.

[5]Given the intra-period nature of the firms' debt contract, we assume that lenders do not discount the payments.

Specifically, the bond prices of firm i are

$$q_{i,t} = \mathbb{E}_t \left[\frac{1 - d_{i,t}}{1 + \beta s_t^g} \right]. \tag{10}$$

When $\beta > 0$, an increase in interest rate spreads of the government leads to depressed bond prices for firms, and thus to higher borrowing costs. Therefore, the parameter β in the model governs the extent of the pass-through of sovereign risk on the financing costs of firms. We view the reduced form relation in equation (10) as standing in for the detrimental effects that a decline in the price of government securities has on the balance sheet of financial intermediaries, and trough this channel, on the borrowing costs of non-financial firms.[6]

2.1 Recursive problems

We now describe the recursive problems for firms and the government and define the equilibrium. We consider a Markov equilibrium where the government takes into account that its policy choices affect the private economy.

In the beginning of the period, the aggregate state of the economy includes the aggregate shocks for default costs and productivity, $s = \{\nu, p\}$, the endogenous distribution of firms Λ, and government debt B. Given these state variables $\{\nu, p, \Lambda, B\}$, the government chooses its default policy D, and new borrowing B'. These choices result in a government spread which is a function of aggregate shocks, distribution of firms, and the borrowing level B', $s^g = s^g(\nu, p, \Lambda, B')$. Let these end of the period variables be $X = \{\nu, p, \Lambda, B'\}$.

The firms problem depend on the aggregate states and the government policy B' because their borrowing rate depend on the government spread. The recursive structure of the problems makes it admissible to set X as the aggregate state in the firms problems. Firms also make choices that depend on their idiosyncratic state, which consist of their lag productivity z_{-1} and their time invariant financing needs λ. The firms' idiosyncratic and aggregate states are $\{z_{-1}, \lambda, X\}$.

Firms Recursive Problem In the beginning of the period, before the idiosyncratic shocks are realized, firms choose inputs (k, ℓ) and borrowing b. At the end of the period, firms observe the realization of their idiosyncratic shocks to productivity z and cost ξ and decide whether to default or not d. The firms' bond price schedule depend on their choices as well

[6]For example, Bocola (2016) considers a model where financial intermediaries hold risky government debt in their balance sheet and are subject to occasionally binding leverage constraints. A decline in the price of long term government securities entails net worth losses for financial intermediaries, tightening their leverage constraints. As the supply of funds tightens, the borrowing costs of non-financial firms increase.

as their idiosyncratic state and aggregate state, $q(b, k, \ell, z_{-1}, \lambda, X)$. The firm value, denoted by $v(z_{-1}, \lambda, X)$, is given by the following program

$$v(z_{-1}, \lambda, X) = \max_{b,k,\ell} \mathbb{E} \max_{d=\{0,1\}} \left\{ \left[\pi(b, k, \ell, z, \xi, \lambda, X) + \frac{1}{1+r} v(z, \lambda, X') \right] [1-d] \right\} \tag{11}$$

subject to their financing requirement (3), the profit function (4) required to be non-negative $\pi(b, k, \ell, z, \xi, \lambda, X) \geq 0$, the bond price function (10), and the evolution of the aggregate states $X = \{\nu, p, \Lambda, B'\}$ and aggregate function $s^g(X)$.

The evolution of shocks $\{\nu, p\}$, in the aggregate state X, are given by their Markov structure. The evolution of the distribution of firms is given by

$$\Lambda'(z, \lambda) = H_\Lambda(\Lambda(z_{-1}, \lambda), p) \tag{12}$$

The transition for distribution of firms over idiosyncratic states $\{z, \lambda\}$ only depends on the productivity shock p because of the assumption that the measure of firms is constant, and defaulting firms are replaced with new firms that have identical idiosyncratic states.

The evolution of government debt policy B' in the aggregate state is shock dependent $B''_{(\nu',p')}$ and the function for spread $s^g(X)$ are given by the rules

$$\begin{aligned} B''_{(\nu',p')}(X) &= H_B(X) \\ s^g(X) &= H_s(X) \end{aligned}$$

This problem gives decision rules for firms' demand for capital $k = k(z_{-1}, \lambda, X)$, labor $\ell = \ell(z_{-1}, \lambda, X)$, and borrowing $b = b(z_{-1}, \lambda, X)$, which are decided before idiosyncratic shocks are realized, as well as default $d(z_{-1}, z, \xi, \lambda, X)$, which is decided after idiosyncratic shocks are realized.

We now define private equilibrium given government policies

Private Equilibrium Given government policies for debt $B''(\nu', p') = H_B(\Lambda', B')$ and the spread function $s^g(X) = H_s(X)$, the private recursive equilibrium consists of policy and value functions of firms $k(z_{-1}, \lambda, X)$, $\ell(z_{-1}, \lambda, X)$, $b(z_{-1}, \lambda, X)$, $d(z_{-1}, z, \xi, \lambda, X)$, and $v(z_{-1}, \lambda, X)$, bond price schedule for firms $q(b, k, \ell, z_{-1}, \lambda, X)$, and the transition function for the distribution of firms $H_\Lambda(\Lambda(z_{-1}, \lambda), p)$, such that: (*i*) the policy and value functions of firms satisfy their optimization problem, (*ii*) the bond price schedule satisfies equation (10), and (*iii*) the evolution of the distribution of firms is consistent with the equilibrium behavior of firms.

Government Recursive Problem We now describe the government's recursive problem. The government chooses its policies taking as given the private sector equilibrium which determines the tax revenue for the government as well as any costs incurred by the government from defaulting firms. We denote by $T(\{\nu, p, \Lambda, B'\})$ the tax revenue function

$$T(\nu, p, \Lambda, B') = \sum_{z_{-1},\lambda} \Lambda(z_{-1}, \lambda)\mathbb{E}_{z,\xi}\{\tau y(z, z_{-1}, \lambda, X) - f(z, \xi, z_{-1}, \lambda, X)]\} \tag{13}$$

where $\tau y(z, z_{-1}, \lambda, X)$ is the tax revenue contribution of each firm with state (z_{-1}, λ, X) and productivity shock z, and $f(z, \xi, z_{-1}, \lambda, X)$ is the cost incurred by the government to pay inputs from each defaulting firm with state (z_{-1}, λ, X) and shocks (z, ξ) as defined in (5).

The recursive problem of the government follows the quantitative government default literature. The government can choose to default any period. Let $W(\nu, p, B, \Lambda)$ be the value of the option to default. After default the debt B is reduced to R and the government pays the default cost ν. The value of the option to default is then

$$W(\nu, p, B, \Lambda) = max_{D=\{0,1\}}\{(1 - D)V(\nu, p, B, \Lambda) + D\ (V(\nu, p, R, \Lambda) - \nu)\} \tag{14}$$

where $D = 1$ in default and 0 otherwise, and $V(\nu, p, B, \Lambda)$ is the value of repaying debt B and given by

$$V(\nu, p, B, \Lambda) = \max_{B'} u_g(G) + \beta^g E\ W(\nu', p', B', \Lambda')$$

subject to its budget constraint

$$G + B \leq T(\nu, p, \Lambda, B') + q^g(\nu, p, \Lambda, B')B'$$

and subject to the private sector equilibrium.

The bond price schedule for the government is given by

$$q^g(\nu, p, \Lambda, B') = \frac{1}{1 + r}E\ (1 - D(\nu', p', B', \Lambda')(1 - R/B')) \tag{15}$$

The bond price takes into account that for every unit of borrowing for a loan of size B', lenders get a unit tomorrow in states of no default $D' = 0$ and get the recovery rate R/B' in states of default $D' = 1$. [7]

This problems gives government decision rules for default $D(\nu, p, B, \Lambda)$, debt choices

[7] We have assumed that recovery values R are exogenous and calibrated to match observed recovery rates. In models of endogenous recoveries from bargaining games between lenders and the government, such as Yue (2010) and Benjamin and Wright (2014), the empirical recoveries are obtained from varying bargaining parameters.

$B'(\nu, p, B, \Lambda)$, public consumption $G(\nu, p, B, \Lambda)$.

We now define the recursive equilibrium of this economy.

Recursive Equilibrium The recursive Markov equilibrium consists of government policy functions for the government for default $D(\nu, p, B, \Lambda)$, debt choice $B'(\nu, p, B, \Lambda)$, public consumption $G(\nu, p, B, \Lambda)$, and value functions $V(\nu, p, B, \Lambda)$ and $W(\nu, p, B, \Lambda)$ and the bond price function $q^g(\nu, p, \Lambda, B')$ such that (i) the policy and value functions for the government satisfy its optimization problem, ii) government bond price function satisfies (15); and (iii) the private equilibrium is satisfied.

The optimal borrowing choice B' for the government results from the interplay of standard consumption smoothing incentives, as well as default probabilities and importantly the shapes of the bond price schedule and tax revenue schedule which the government internalizes. For illustration, assume that the bond price schedule and the repayment value function is differential. The optimal borrowing choice for the government satisfies

$$u_g'(G)\left[q^g + \frac{\partial q^g}{\partial B'}B' + \frac{\partial q^g}{\partial B'}\tau \int_i MPK_i \frac{\partial k_i}{\partial q^g}\right] = \beta E[u_g'(G')|D' = 0] \tag{16}$$

This Euler equation resembles those that arise in models of sovereign default as in (**??**). In those models, as is the case here, the Euler condition equates the marginal gain in utility today from borrowing to the marginal reduction in utility from repaying tomorrow taking into account two factors. First the cost of repaying the debt only occurs in states where the government chooses to repay, namely the repayment states when $D' = 0$. Second, the borrower takes into account that the price of borrowing depend on the quantity of debt. Given that incentives to repay decline with the borrowing, bond prices are decreasing in borrowing levels $\frac{\partial q^g}{\partial B'} < 0$. This effect is captured in the second term in squared brackets. The new effect in this model is last term in the squares brackets and encodes the negative effects of sovereign spreads on firms' tax revenues. As borrowing B' increases, the government spread increases, which reduces private production and tax revenues. The depressed production is an additional cost of borrowing and reduces the incentives to borrow. The extent of passthrough is crucial in determining the power of this mechanism. In the next section we discuss how we use data to determine its strength.

3 Measuring the propagation of sovereign risk

We are interested in using the model to measure the propagation of sovereign default risk to real economic activity. This effect is governed by several structural parameters, most notably the parameter that controls the passthrough of sovereign interest rate spreads on the financing costs of the firm, β. Before turning to the quantitative analysis, it is useful to discuss in more details why firm-level data allow us to discipline this parameter.

To this end, we can work with a simplified version of the model where firms' are not subject to the risk of default. This simplified model results from the same problem as in 11 but with an additional assumption that firms can access equity freely hence do not face a non-negative equity payout requirement. In this case, one can show that firms optimally choose capital and labor in fixed proportion, and that the demand of capital by firms i is

$$k_{i,t} = \eta^{\frac{1}{1-\eta}} r_{i,t}^{\frac{1}{\eta-1}} \{\mathbb{E}[z_{i,t}^{1-\eta} | z_{i,t-1}, p_t]\}^{\frac{1}{1-\eta}},$$

where $r_{i,t} = [1 + \beta s_t^g \lambda_i] \frac{1}{\alpha} r_k$ is the rental price of capital. Firms demand more capital when they expect end of period productivity to be high, and they demand less when the borrowing rate $r_{i,t}$ is high.

Using the production function, we can express the output of firm i as

$$y_{i,t} = M e^{(1-\eta) z_{i,t}} \eta^{\frac{\eta}{1-\eta}} \left\{ [1 + \beta s_t^g \lambda_i] \frac{1}{\alpha} r_k \right\}^{\frac{\eta}{\eta-1}} \left\{ e^{(1-\eta)\rho z_{i,t-1}} \left[e^{\frac{[(1-\eta)\sigma]^2}{2}} [1 + p_t (e^{-(1-\eta)\mu} - 1)] \right] \right\}^{\frac{\eta}{1-\eta}},$$

with $M = \left(\frac{r_k (1-\alpha)}{w\alpha} \right)^{(1-\alpha)\eta}$. Taking logs of the above expression, and using the approximation $\log(1 + x) \approx x$, we then have

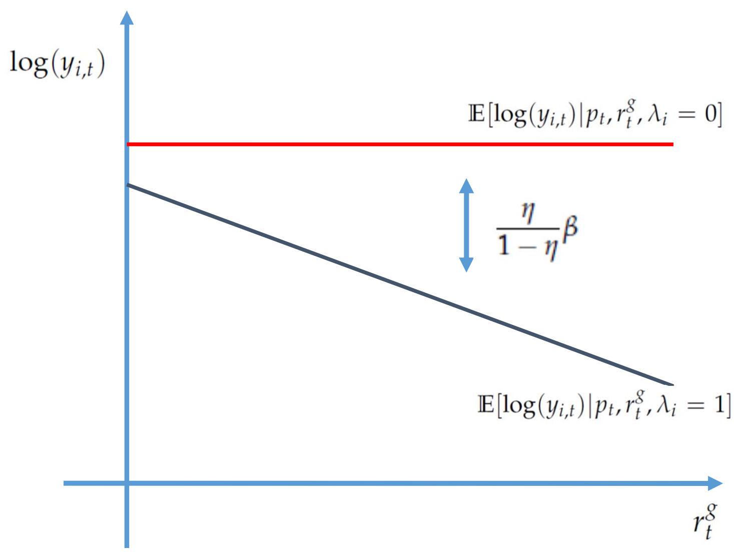
$$\log(y_{i,t}) \approx \overline{y}_i + z_{i,t-1} - \frac{\lambda_i \eta}{1-\eta} \beta s_t^g + \left[e^{-(1-\eta)\mu} - 1 \right] \frac{\eta}{1-\eta} p_t + (\varepsilon_{i,t} - I_i \mu), \tag{17}$$

where $\overline{y}_i$ is a convolution of model's parameters. Equation (17) summarizes the relation between firm-level output, sovereign interest rates, and the aggregate productivity shock p_t in this simplified version of the model.

A key feature of the above equation is that changes in s_t^g have different effects on a firm's output depending on its leverage. When $\beta > 0$, an increase in s_t^g translates into higher borrowing costs for all the firms in the economy. However, such an increase in borrowing costs is more harmful for the firms that need to finance a larger share of their inputs (high λ firms). This property, in turn, implies that changes in the cross-section of firms' output are informative about β, the key parameter governing the propagation of sovereign risk to output in our model.

Figure 1 describes the logic of our argument. In the figure, we plot firm-level output as a function of sovereign interest rate spreads for two types of firms: a firm that does not need to finance its input costs in advance ($\lambda = 0$), and a firm that needs to finance all of its inputs in advance ($\lambda = 1$). Suppose now that s_t^g increases, holding fixed aggregate productivity p_t.[8] If $\beta > 0$, the increase in sovereign spreads is passed-on private sector interest rates, and the firm with $\lambda = 1$ will cut on its factors' demand and decrease production. The production choices of the firm with $\lambda = 0$, instead, is not affected by this increase in s_t^g. If $\beta \approx 0$, instead, the relative performance of the two types of firms would not change as sovereign risk increases. Because of this property, one can indirectly infer β by studying how the relative performance of firms with high and low borrowing needs varies when sovereign risk increases.

Figure 1: Sovereign risk and the cross-section of firms' output



In what follows, we build on this insight and we incorporate in the empirical targets of our calibration the coefficients of a more sophisticated version of equation (17) that we estimate using firm-level data. In view of this discussion, the main empirical target will be the coefficient on the interaction between sovereign interest rate spreads and an indicator of firms' leverage, our proxy for the financing needs of firms. Before turning to this part of the analysis, though, it is important to discuss some potential pitfalls of our approach.

First, the simplified version of the model we discussed in this section has the implication that productivity shocks have no differential effects on firms' output once we condition on

[8] This could be accomplished in our model with a shock to ν_t.

s_t^g. This restriction is not necessary for our argument, and it will not hold in the model described in the previous section. When firms' are subject to the risk of default, a negative shock to aggregate productivity will typically increase their interest rates: firms with a high λ will need to cut their factors' demand by more than low λ, this making their output more sensitive to p_t. Not controlling for these effects in our firm level regressions could lead us to overstate the propagation of sovereign risk to the real economy because an increase in p_t increases the probability of a default by the government and at the same time could hurt more highly levered firms. Because of this reason, the reduced form regression that we estimate in the data will also feature the interaction between p_t and our proxy for the firms' borrowing needs.

Second, we might be excluding from the analysis some aggregate factors that could affect the interest rate spreads of the government, and at the same time have different effects on firms based on their leverage. Omitting these factors will tend to bias the interaction coefficient between sovereign spreads and firms' leverage in the firm-level regression, inducing us to overstate or to understate the propagation of sovereign risk. While formally incorporating additional aggregate shocks in the model is challenging due to the complexity of its numerical solution, we will nonetheless check the sensitivity of our results to the inclusion of several aggregate factors in our firm-level regressions.

4 Model Parametrization and Data

This section discusses the parametrization of the model. The calibration strategy uses micro and aggregate data for Italy as well as parameter estimates in the literature. We denote by $\theta = [\theta_1, \theta_2, \theta_3]$ the vector of structural parameters which consists of 3 types of parameters. The parameters $\theta_1 = [\eta, \alpha, \gamma, r_k, \tau]$ are set based on other studies. The parameters $\theta_2 = [\rho^z, \sigma^z, \mu, \Pi^p(p)]$ controlling the productivity process for firms comes from estimates using micro data for Italian firms. Finally, the parameters

$$\theta_3 = [\Pi^\xi(\xi), \Pi^\lambda(\lambda), \bar{\nu}, \sigma^\nu, \rho^\nu, \beta_g, R, \beta]$$

are calibrated jointly such that the model reproduces target moments in the data.

We start by describing the micro data we use for the parametrization of the productivity process as well as the target moments. An important target moment comes from results on the firm-level regression discussed in the previous section. Finally, we describe how we calibrate the remaining model's parameters.

4.1 Firm Data

We conduct our empirical analysis using Italian data. The firm-level data are obtained from AMADEUS. This dataset provides balance sheet information for public and private firms for several European countries. Such a feature is important for our analysis because publicly listed firms in Italy represents only a limited share of the country's employment and output.

We download the data using WRDS for the sample period 2004-2013, restricting our attention to the manufacturing sector (two-digits NACE codes from 05 to 43). For each firm, we obtain a set of balance sheet variables, see Appendix x for detailed definitions. We implement the following steps to correct for basic reporting mistakes. First, we drop firm-year observations with missing, zero, or negative values for total assets, tangible fixed assets, operating revenue, sales, number of employees, material costs, and the wage bill. Second, we drop firm-year observations with negative values for intangible fixed assets. Finally, we drop firm-year observations with negative values for value added, defined as operating revenue minus material costs.

The resulting sample is mostly composed by small and medium sized firms that account for a significant fraction of the manufacturing sector in Italy. We use these data for two different purposes. First, we estimate the productivity process for the firms in our sample, and use these results to parameterize θ_2. Second, we estimate firm-level regressions motivated by equation (17), and use the estimated coefficients as empirical targets in the calibration of the remaining model's parameters θ_3. These two steps are carried out on a balanced panel of firms for the 2004-2013 period, this leaving 178,810 firm-year observations in our data set.

4.2 Productivity process

In this section, we describe the parameters in θ_2. We estimate the stochastic process for revenue TFP z_i, by estimating the production function of firms at the sector level s. Following standard methodology, we estimate

$$\log(y_{i,t}) = \beta_{s,t} + \beta_1 \log(l_{i,t}) + \beta_2 \log(k_{i,t}) + \epsilon_{i,t}, \tag{18}$$

where $y_{i,t}$ is the value added of firm i at time t, $l_{i,t}$ is its labor input measured by its wage bill, $k_{i,t}$ is its capital measured by the book value of fixed assets, and $\beta_{s,t}$ is an industry specific time effect. Industry level s is defined at the 2-digits NACE level. We scale value added and the wage bill with a value added deflator constructed for each two-digits NACE industry using National Accounts data from Eurostat. The book value of fixed assets is deflated using the producer price index of domestic investment goods obtained from the FRED database.

We estimate the production function using the two-steps GMM implementation of Levinsohn and Petrin (2003) developed in Wooldridge (2009), see Appendix XX for a detailed description. Given estimates for the coefficients in 18, we compute for each firm in our panel the implied (log) of productivity,

$$\hat{z}_{i,t} = \log(y_{i,t}) - [\alpha_{s,t} + \beta_1 \log(l_{i,t}) + \beta_2 \log(k_{i,t})]$$

We then use demeaned firm-level productivity, $z_{i,t} = \hat{z}_{i,t} - (1/T)\sum_{t=1}^{T} \hat{z}_{i,t}$ to inform the productivity process in 2. Our panel has a fairly small time dimension, hence for the benchmark, we fix ρ_z to 0.9, a conventional value in the literature that estimated firm level productivity using longer panel for the U.S. economy Foster and Syverson (2008). We also do sensitivity on this parameter. We also set μ to -0.3 which corresponds to the 5 percentile of the panel data for $z_{i,t}$. Given these two parameters, from our productivity process 2, we can construct an empirical counterpart to p_t and σ^z as follows,

$$p_t = -\max\left\{\frac{\overline{z}_{i,t} - \rho_z \overline{z}_{i,t-1}}{\mu}, 0\right\},$$

where $\overline{z}_{i,t}$ denotes the cross-sectional mean of firms' productivity at time t.

With the time-series for p_t at hand, we can now recover an estimate for volatility σ^z. We compute for every period t in the sample

$$(\hat{\sigma}^z)_t^2 = \text{var}_t[z_{i,t} - \rho_z z_{i,t-1}] - [0.3^2 p_t(1 - p_t)].$$

Under our productivity process the right hand side of this expression provides an estimate for σ^z. We thus set $(\sigma^z)^2$ to the time average of $\hat{\sigma}_t^2$. This resulting parameter estimate is $\sigma^z = 0.074$, which is in line with estimates in Foster and Syverson (2008).

The plots in Figure 2 describe the behavior of firm's productivity during our sample. The top left panel reports percentiles of the cross-sectional distribution of $z_{i,t}$ for each year t. We can see that on average productivity fell sharply in 2008-2009 and it recovered little after that. The figure also shows that the left tail of the distribution declined substantially in 2009, and in 2012. The top right panel of the figure explores this last point further. There, we plot the entire distribution of firms' productivity for two different years, 2007 and 2009. We can see how in 2009 there was a leftward shift in the distribution of firms' productivity, and a fattening of its left tail. Our model fits these distributional dynamics with time-variation in p_t. The bottom panel of the figure plots the p_t process that we recover from the data. Consistent with the distributional plots, we can verify a sharp increase in p_t in 2008-2009, and a somewhat smaller increase in 2012. The process for p_t is parameterize with 3 values and associated probabilities which approximate well the observed time series.

In summary, the parameters in θ_2 controlling the productivity process are calibrated from firm micro data and are

$$\theta_2 = [\sigma^z = 0.074, \rho^z = 0.9, \mu = -0.3, p_t = \{0, 0.12, 0.37\}, \pi^p = \{0.6, 0.33, 0.07\}]$$

4.3 Firm-level regressions

We now estimate an empirical version of equation (17). The *differential effect* on firms' production from movements in government spreads based on firms' leverage is important target in the parametrization of the model. The benchmark regression specification is

$$\Delta y_{i,t} = a_i + a_1 s_t^g \times \text{lev}_{i,t} + a_2 p_t \times \text{lev}_{i,t} + a_3 s_t^g + a_4 p_t + \gamma' \mathbf{x}_{i,t} + \eta_{i,t} \tag{19}$$

$\Delta y_{i,t}$ is sales growth for firm i at time t, s_t is the interest rate spreads on Italian government bonds, $\text{lev}_{i,t}$ is the leverage for firm i at time t, p_t is our retrieved productivity process, and $\mathbf{x}_{i,t}$ a set of firm and time specific controls which include the $\text{lev}_{i,t}$ and $\log(\text{sale}_{i,t})$. The regressions include firm specific fixed effects and the standard errors which are clustered two ways across i and t.

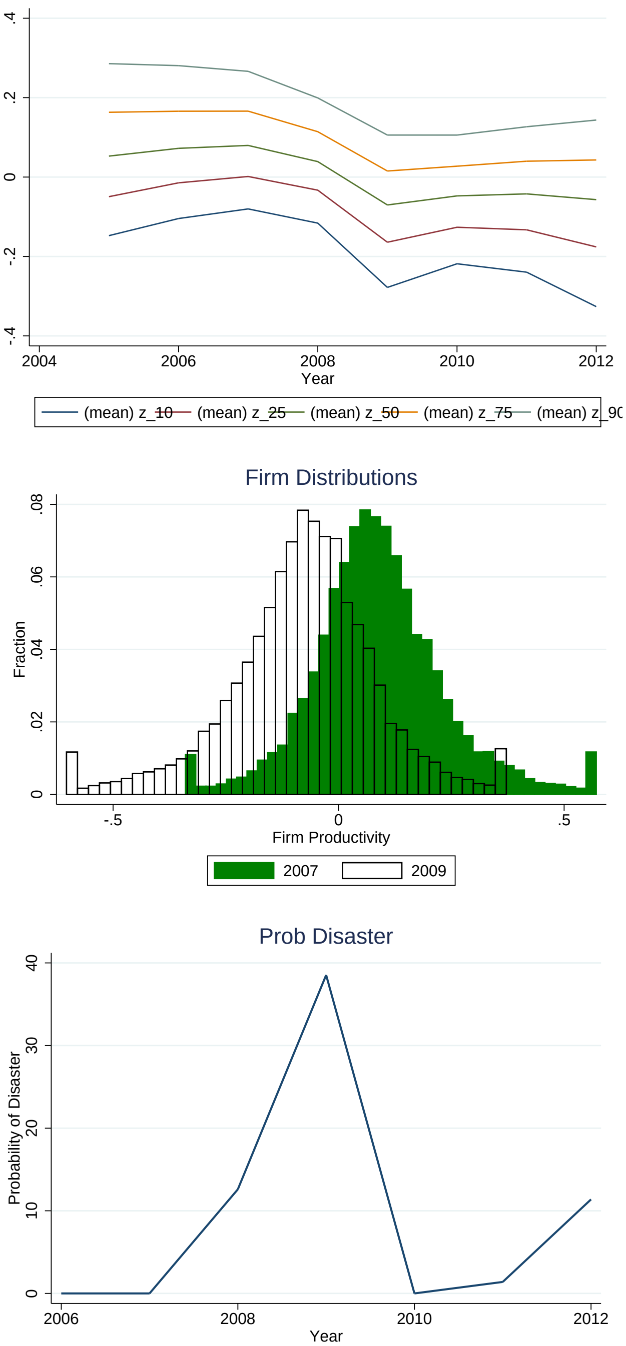
Table 1: Government spreads, firm's leverage and sales growth

	Benchmark	Spread Only	Productivity Only
$s_t^g \times \text{lev}_{i,t}$	-2.6^{***}	-4.2^{**}	
$p_t \times \text{lev}_{i,t}$	-0.05		-0.01
s_t^g	0.35	1.82	
p_t	-0.54^{***}		-0.54^{***}
firm controls	yes	yes	yes
firm fixed effects	yes	yes	yes
Adjusted R^2	36	28	36

Table 1 reports the estimation of equation (19). Column (1) reports the results of our benchmark specification, where we include as regressors government interest rate spreads s_t^g, productivity p_t, their interactions with firm leverage, and firm fixed effects, firms' sales and leverage as firm specific controls.

Periods in which interest rate spreads are high are associated, on average, to poor performance by firms: a 100 basis point increase in interest rate spreads is associated to a decline

Figure 2: The cross-section of firms' productivity in Italy: 2004-2012



in sales growth rate of 2.6% for the firm with the average leverage in the sample, $\text{lev}_i = 37\%$. The association between firm growth and government spreads is stronger for firms with higher leverage: sales growth falls by 0.8% more for firms with leverage equal to 52% which correspond to the 75^{th} percentile relative to firms with leverage equal to 20% which correspond to the 25^{th} percentile of the leverage distribution for a 100 basis points increase in the spread.

Periods of low productivity which correspond to high p_t are associated with lower sales growth for firms: a 1% increase in the probability of disaster is associated with a decline in firms growth of 0.54%. Importantly the relation between p_t and sales growth is not affected by how levered the firm is. The interaction between p_t and $\text{lev}_{i,t}$ is small and not significantly different from zero.

Column (2) and column (3) report simplified versions where the covariates are exclusively the government interest rate spread s_t^g or productivity p_t and its interaction with firms leverage. The results are qualitative similar to the benchmark; the interaction coefficient between the government spread and firm leverage and significant, while the interaction between productivity and firm leverage is not significant. In this simplified specification, in fact, magnitude of the interaction of government spread and firm leverage is much larger: sales growth fall by 1.3% more for firms with leverage at the 75 percentile relative to firms with leverage at the 25 percentile for a 100 basis points increase in government spread.

In Appendix (X) we report robustness of this result. We show that these results are robust to alternative definitions of leverage, and also to adding other aggregate time series including indexes for volatility VIX, Italian stock market and European stock market. Under each of these specifications the interaction of government spread and firm leverage continue to be significantly negative.

The benchmark regression estimate for the differential effect based on leverage on firms growth from movements in the government spread is important targets in the calibration of the model which we describe next.

4.4 Calibration

We first describe the parameters in θ_1 that are chosen outside the model. The parameters of the production function, α and ν, are set to 0.67 and 0.85 which are common parameters in the literature controlling the labor share and the decreasing returns to scale. The return on capital, r_k is set to 15% which reflects the annual interest rate plus the depreciation rate of capital. For the utility of public consumption, we use a standard parametrization of total consumption; $u(G) = \frac{G^{1-\gamma}}{1-\gamma}$, with $\gamma = 2$. In terms of taxes, we choose $\tau = 0.2$ to match the average government consumption relative to output in Italy given our normalization of steady state output of 1.

We now describe the calibration of the parameters θ_3. We choose these parameters to target moments of the panel of firm data and of aggregate data. These moments are the average firms' profits, average firm spreads, firms' leverage distribution, the mean and volatility of the government spread, average sovereign debt recovery rates, the average short term debt to government revenue, and the differential effect estimate from the firm panel regression. In the calibration all parameters affect all moments, but some parameters identify more directly the parameter. The stochastic process for firms' fixed cost is assumed to be that $\xi \sim \mathcal{N}(\bar{\xi}, \sigma^{\xi})$. These two parameters control firms' average profits and spreads. For tractability, we choose an equal weight two point distribution for firms' financing requirements. Hence $\lambda_i = \{\lambda_1, \lambda_2\}$ and we use these parameters to target the 25 and 75 percentile of the leverage distribution of firms. The mean of the enforcement shock $\bar{\nu}$, controls the mean debt ratio, the volatility of the enforcement shock σ^{ν} and government discount factor β_g control the mean and standard deviation of the government spread. The recovery parameter R controls the average debt recovery. The passthrough parameter β controls the differential effect in a firm panel regression. Specifically, we run in the model the same panel regression as in data, (19), and compare the resulting differential effect in the model to that in the data. Finally, for the persistence of the enforcement parameter ρ_{ν} we set it at 0.5 and perform sensitivity on it. Table 2 summarize all the parameters θ_3 chosen in the calibration to target our firm and aggregate data.

Table 2: Calibration

Moment	Parameter	Data	Model
Firms spread	σ^{ξ}	1.1	2.5
Firms profits	$\bar{\xi}$	2.5	3
Firms leverage	$[\lambda_1, \lambda_2]$	[0.2,0.5]	[0.2,0.5]
Short debt/Output	$\bar{\nu}$	17	16
Govt spread mean	σ^{ν}	1.8	2.6
Govt spread volatility	β^{g}	1.4	2.3
Recovery	R	0.6	0.8
Int coeff$\times[\overline{\lambda}_{75,t} - \overline{\lambda}_{25,t}]$	β	-0.83	-0.54
Autocorrelation ν	ρ^{ν}		0.50

4.5 Business Cycles

Series for GDP, employment, public consumption, and short term debt are annual from 1980 to 2015, logged, and linearly detrended from the OECD database. The series for government spread and firm spread start in 2000. Government spread is the difference between the 10-year yield on Italian government bonds relative to a similar German bond yield. Firm spread is taken from the database of **?** and is the difference in average corporate yields relative to German yield.

Table 3: Business Cycle Statistics - Italy

ITALY	St. Dev.	Corr (x, spr^g)	Corr (x, GDP)
Govt Spread	1.4	1.00	-0.54
Firm Spread	1.2	0.82	-0.40
GDP	6.1	-0.54	1.0
Public Consumption	5.0	-0.48	0.75
Govt Debt	15.4	0.63	-0.31
Firm Debt	6.6	-0.26	0.52
Means			
Govt Spread	1.8	Firm Spread	2.0
Public Debt / GDP	17		
MODEL	St. Dev.	Corr (x, spr)	Corr (x, GDP)
Govt Spread	2.3	1.00	-0.96
Firm Spread	2.1	0.99	-0.97
GDP	6.3	-0.96	1.0
Public Consumption	18	-0.58	0.55
Govt Debt	27	0.59	-0.62
Firm Debt	7.6	-0.97	0.99
Means			
Govt Spread	2.6	Firm Spread	2.5
Public Debt / GDP	16		

4.6 Recent Crisis

We now use the model to interpret the recent crisis in Europe. We want to measure to what extent our model can rationalize the decline in GDP in Italy and decompose the decline as responding to deterioration in productivity versus enforcement.

Event Analysis: Productivity Shocks

We first feed in the observed aggregate productivity shocks and evaluate its implications for output and government spreads. Figure 3 shows these results:

- Feed p_t shock, big increase in 2009
- Minor increase in spreads
- Big GDP decline in 2009, no further decline

Event Analysis: Productivity and Enforcement Shocks

We now feed in the default cost shocks to replicate the series of government spreads. Figure 4 shows these results.

- Feed in public shock to match spread: decrease in debt enforcement
- Can match large increase in spreads in 2011-2012
- Both shocks account for large fraction of GDP decline

The model calls for a continuous decline in enforcement since 2006 to replicate the dynamics of government spreads.

Event Analysis: Counterfactual No Passthrough

If no feedback from govt to private, would there had been a crisis?

- Use model with no feedback $\beta = 0$
- Feed in recovered p_t and ν_t shocks
- Evaluate prediction on GDP and govt spread

Figure 5 shows these results:

- Moderate decline in output
- Spread higher, schedule less tight and govt more aggressive

Decomposition Summary

We now summarize these finding by showing the decomposition of the movements in output and government spreads in the sample. Table 4 presents the decomposition.

The decomposition shows that:

- Model accounts for decline in GDP and increase in spread

Table 4: Even Decomposition

	GDP Total	GDP Average	GDP % Data	Spread Total	Spread Average	Spread % Data
Data	-69	-5.7		13.5	1.1	
Model						
p shock only	-52	-4.4	76	5.7	.5	42
Both shocks	-78	-6.5	113	13.5	1.1	100
$\beta = 0$	-48	-4	69	35	3.0	262

- Private shock account for 75% of the GDP decline
- Public shock accounts for most of the spread increase
- Passthrough essential for decline in GDP
- Govt debt crisis divorced from output

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Figure 3: Event Analysis: Productivity Shocks

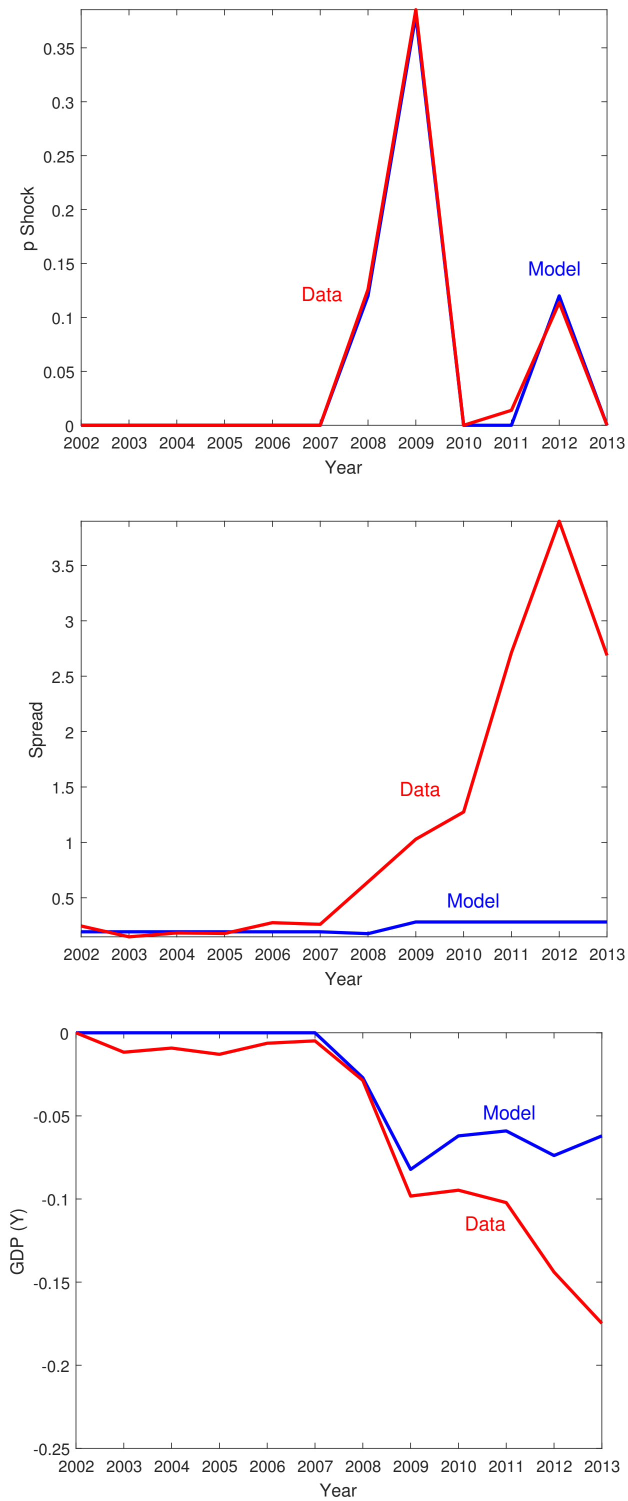

Figure 4: Event Analysis: Productivity and Enforcement Shocks

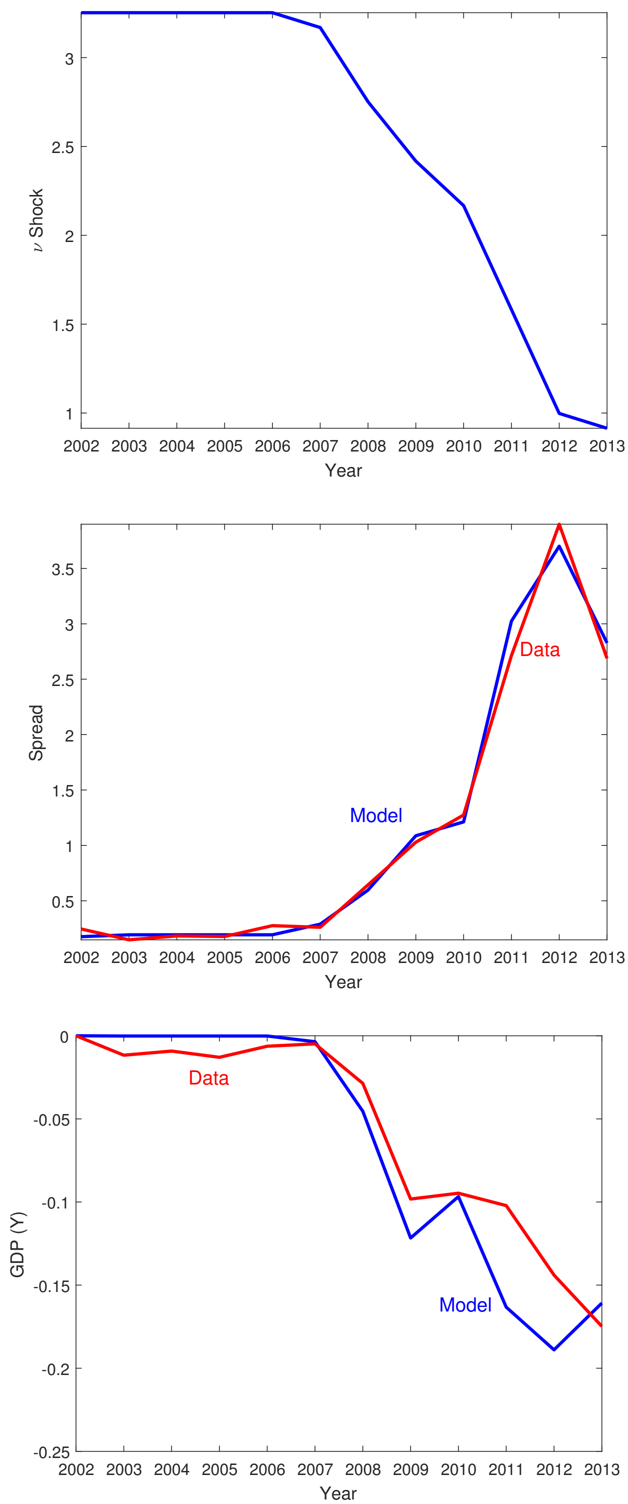

Figure 5: Event Analysis: Counterfactual No Passthrough