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Optimal Bailouts in Banking and Sovereign Crises†

Sewon Hur

Federal Reserve Bank of Dallas
sewonhur@gmail.com

César Sosa-Padilla

University of Notre Dame
and NBER
csosapad@nd.edu

Zeynep Yom

Villanova University
zeynep.yom@villanova.edu

[PRELIMINARY AND INCOMPLETE]

Abstract

We study optimal bailout policies in the presence of banking and sovereign crises. First, we use European data to document that asset guarantees (i.e. conditional capital injections) are the most prevalent way in which sovereigns intervene during banking crises. Then, we build a model of sovereign borrowing with limited commitment where domestic banks hold government debt and also provide credit to the private sector. Shocks to the banks' capital can trigger banking crises and the government may find it optimal to extend guarantees over those assets. The key trade-off is the following: larger bailouts improve domestic financial markets and increase output, but they also imply larger fiscal needs for the government and can lead to increased default risk. We find that the optimal bailouts exhibit clear properties. Other things equal, the fraction of banking losses that the bailouts would cover are: (i) decreasing in the level of government debt, (ii) increasing in aggregate productivity, and (iii) increasing in the severity of the banking crisis.

Keywords: Bailouts, Sovereign Defaults, Banking Crises, Conditional Transfers, Sovereign-bank diabolic loop.
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1 Introduction

The European debt crisis that began following the 2007–2008 financial crisis highlighted the diabolic loop between sovereign risk and bank risk. Whereas the Irish bailout of 2008 illustrated how financial risk can be transferred to the government via bailouts and asset guarantees (Acharya et al., 2014), the Greek debt crisis of 2012 showed inversely how sovereign risk can weaken banks' balance sheets due to overexposure to government debt (Sosa-Padilla, 2018). In response to banking crises, governments resort to direct capital transfers as well as to contingent liabilities which function as sovereign guarantees. In this paper, we focus on the optimal structure of government interventions during banking crises, in the presence of both sovereign and banking crisis risks.

We start by reviewing some motivating facts related to the dynamic relationship between sovereign risk, bank risk, and bailouts. We leverage the vast existing empirical literature to document that *(i) defaults and banking crises tend to happen together*, and *(ii) the banking sectors are exposed to government debt and this exposure is higher during crisis times.* We then provide our own empirical evidence to document a third motivating fact, namely that *(iii) the issuance of sovereign guarantees is the most prevalent form of intervention.* Among European countries, the average share of government guarantees in GDP is four times as large as the average share of capital transfers in GDP during banking crises. This relationship does not hold during normal times. This suggests that the contingent liabilities strategy seems to be the more dominant policy for governments when trying to alleviate banking crises.

We then build a model to quantitatively assess the interaction between sovereign risk, bank risk, and government bailouts by extending Sosa-Padilla (2018)'s framework in two dimensions: firstly, we introduce banking crises that are driven by exogenous shocks to bank capital, and secondly, we study the optimal bailout decision of the government. This allows for a rich feedback between banking and sovereign risk. On the one hand, sovereign defaults lead to a deterioration of bank balance sheets, reducing the amount of credit that banks extend to the private sector, and thereby reducing output. On the other hand, governments optimally choose to bailout banks to ameliorate the adverse effects of banking crises, which tends to increase government debt, increasing sovereign risk. This feedback generates an endogenous clustering of banking and sovereign crises.

Our framework links these dynamics in a general equilibrium model of sovereign default, in which a government determines debt and taxes to finance the sum of (constant) government spending and contingent bailouts to banks. The economy is subject to two types of aggregate uncertainty; in addition to firm productivity shocks there are also shocks to bank's capital. In anticipation of an adverse banking shock, banks reduce lending to the private sector. The sovereign may find it optimal to announce guarantees (i.e. conditional transfers) to compensate for the banks' capital losses in the event of a crisis — these are the bailouts in our model. Defaults are costly because the government loses access to debt financing, it loses the ability to issue bailouts, banks' credit to the private sector declines, and eventually output falls. The benefit of default is that all existing debt is wiped out, relaxing the government's budget constraint, and allowing it to reduce distortionary taxes. Our framework is flexible enough to feature defaults triggering banking crises (as in Sosa-Padilla, 2018 or Perez, 2015), and banking crises triggering defaults (highlighted as empirically relevant by Reinhart and Rogoff, 2011a): a complete 'doom loop.'

After calibrating the model to match salient moments in the data such as the unconditional frequencies of banking crises and sovereign defaults as well as the average bailout size, we show that the occurrence of a banking crisis increases the default probability (from 0.5 to 0.7 percent annually), resulting sovereign spreads that are higher (from 0.7 to 0.9 percent) and more volatile (from 0.6 to 1.0 percent). Optimizing governments find it optimal to issue bailouts (i.e. contingent guarantees) that are on average 2 percent of GDP during banking crises. These contingent guarantees exhibit clear properties. Other things equal, the fraction of banking losses that the bailouts would cover are: (i) decreasing in the level of government debt, since the more debt the government has, the less fiscal space it has to prop up banking sector assets, (ii) increasing in aggregate productivity, since the better the aggregate state of the economy is, the higher the value of credit and the cheaper it is to borrow to provide the guarantees, and (iii) increasing with the severity of the banking crisis, and this is because the effects of financial shocks are nonlinear: small shocks have negligible impacts on loans to the private sector, whereas large shocks can lead to severe contractionary credit crunches in the absence of government interventions.

Related literature. Our paper builds on the sovereign default literature developed by Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008), among many others. Our paper differs from these early papers, in that it presents a model that entails a rich interaction between the government and the financial sector to study the transmission of the risks between these sectors and their implications on the real economy.

Our paper is at the intersection of two strands in the literature. The first looks at how the effects of sovereign risk are amplified through the banking channel. Sosa-Padilla (2018), Perez (2015), and Bocola (2016) are recent examples. In addition to bank balance sheet effects, our paper also incorporates the transmission of banking crises to sovereign crises, which these papers do not consider. The second focuses on how banking crises lead to sovereign crises through bailouts. See, for example, Lizarazo et al. (2014), Acharya et al. (2014), Cooper and Nikolov (2018), Farhi and Tirole (2018), and Correa and Sapriza (2014). The main contribution of our paper is to study the optimal banking sector intervention in the presence of both sovereign and banking crisis risks.

The rest of the paper is organized as follows: Section 2 summarizes the stylized facts that motivate the theoretical model presented in the rest of the paper. Section 3 introduces the model. Section 4 explains the numerical solution and the calibration of the model, presents the quantitative results, and discusses the properties of the optimal contingent bailouts. Section 5 concludes.

2 Motivating Facts

The nexus between sovereign and banking crises is not a new phenomenon and different aspects of it have been studied previously. In this section we highlight three features of banking and sovereign debt crises that motivate our study: *(i)* defaults and banking crises tend to happen together, *(ii)* the domestic banking sectors are highly exposed to government debt and this exposure tends to be higher during crises, and *(iii)* the most prevalent form of government intervention (during banking crises) is to issue asset guarantees.

- *Defaults and banking crises tend to happen together.* Balteanu et al. (2011) build a dataset with 121 sovereign defaults and 131 banking crises for 117 emerging and developing countries from 1975 to 2007. Among these, they identify 36 "twin crises" (defaults and banking crises): in 19 of them a sovereign default preceded the banking crisis and in 17 the reverse was true, which suggest that both directions of complementarity are likely at play.

- *Banks are exposed to sovereign debt and this exposure is higher during crises.* Gennaioli et al. (2018) report an average exposure ratio (net credit to the government as a fraction of bank assets) of 9.3 percent using data on banks from both advanced and developing countries. When they focus only on defaulting countries, they find an exposure ratio of roughly 15 percent. Similarly, Abad (2019) documents that the banking sectors in Spain and Italy increased their exposure to domestic sovereign debt during the recent European debt crisis (with exposure ratios increasing by 8 percentage points).

Our own empirical contribution is to document a third motivating fact, regarding how governments intervene during banking crises. Specifically,

- *The most prevalent form of government intervention to alleviate banking crises is the issuance of sovereign guarantees.* Governments in the European Union have intervened mostly in two ways: (i) via asset guarantees and (ii) via capital transfers. Using data from Eurostat, we construct the average net annual change in government guarantees and average capital transfers as a percentage of GDP in the 23 EU countries from 2007 to 2016.[1] Figure 1 shows that governments mostly rely on asset guarantees rather than capital transfers as the way to intervene during banking crises (defined following Laeven and Valencia, 2013). We find that the average change of government guarantees as a fraction of GDP is close to 1.8 percent during banking crises, whereas it is negative during normal times. We also find that the average share of capital transfers is not very different across two time periods, which suggests that they are not very prominent methods as government interventions to alleviate banking crises. In appendix A, we show that a similar pattern holds for a broader concept of contingent liabilities.

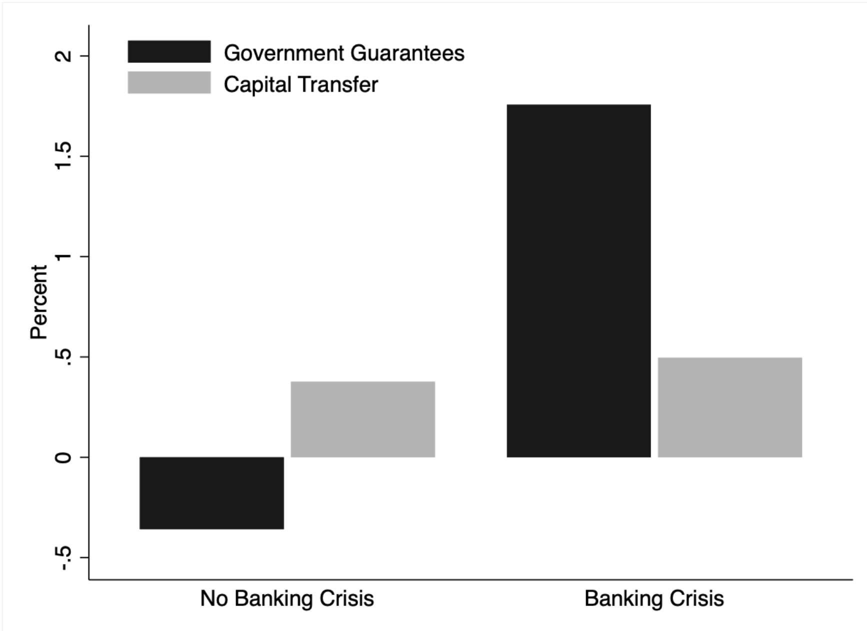
3 Model

We extend the banking and sovereign default model of Sosa-Padilla (2018) in two dimensions: *banking crises* that are driven by exogenous shocks to banking capital in addition to the bank balance sheet effects triggered by increased sovereign risk, and *government bailouts* which can mitigate the banking crisis but may trigger sovereign default crises.

Environment. We consider a closed economy populated by four agents: households, firms, banks, and a government. Households supply labor to firms, but do not face any intertemporal decisions. Firms hire labor and borrow working capital loans from the banks in order to produce the consumption good. Banks lend to both firms and the government, and are subject to a lending constraint. Additionally, banks are subject to shocks to the value of their capital. Finally, the government is a benevolent one (i.e., it maximizes the households' utility). It faces a stream of spending that must be financed and it can also provide contingent guarantees to the banks. To face its obligations the government has three instruments: labor income taxation, borrowing, and default.

[1]EU countries in our sample are Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg,Portugal, Slovenia, Spain, Sweden, The Czech Republic, The Netherlands, and the United Kingdom

Figure 1: Government guarantees and capital transfers



Debt contracts are not enforceable and the government may default on its debt. We assume defaults are total: all debt gets erased. If the government decides to default, it gets excluded from the credit market for a random number of periods.

There are three aggregate state variables in our model economy: one endogenous and two exogenous. The level of government debt, B, is the endogenous state variable. The first exogenous state variable is aggregate productivity z, which follows a Markov process. The second (and more novel) exogenous state variable, ε, captures the fraction of banks' capital that could be lost. We denote $s = \{z, \varepsilon\}$.

Timing of events. If the government enters the period in good credit standing, then the sequence of events is as follows:

1. The aggregate state s is realized
2. Considering the aggregate state (B, s), the government decides whether to repay ($d = 0$) or to default ($d = 1$)
3. If $d = 0$, then:
   (a) the government announces a bailout policy

(b) given the bailout policy, banks decide their loan supply

   i. with probability π, the bank's capital is reduced by ε, and the government disburses the promised bailouts

   ii. with probability $1-\pi$, the bank's capital is unaffected, and the government doesn't pay any bailouts

(c) all other private decisions take place

(d) the government chooses its borrowing policy $B'(B, s)$

4. If $d = 1$, then:

(a) the government cannot promise bailouts and is excluded from financial markets

(b) banks decide their loan supply

(c) with probability π, the bank's capital is reduced by ε

(d) all private decisions take place

In case the government enters the period in bad credit standing (i.e. it finished the previous period excluded from financial markets), the government regains market access with probability θ. If it regains market access, then the timing of events is as above, with an initial debt level of zero. Otherwise, if the government remains excluded, the timing of events amounts to the sequence of stages 1 and 4 above.

3.1 Decision problems given government policy

Households. The only decisions of the households are the labor supply and consumption levels. Therefore, the problem faced by the households can be expressed as:

$$\max_{\{c,n\}} \quad U(c, n) \tag{1}$$

$$\text{s.t.} \ \ c = (1-\tau)wn + \Pi^F, \tag{2}$$

where $U(c, n)$ is the period utility function, c stands for consumption, n denotes labor supply, w is the wage rate, τ is the labor-income tax rate, and Π^F represents the firms' profits. The solution to the problem requires:

$$-\frac{U_n}{U_c} = (1-\tau)w, \tag{3}$$

which is the usual intra-temporal optimality condition equating the marginal rate of substitution between leisure and consumption to the after-tax wage rate. Therefore, the optimality conditions from the households' problem are equations (2) and (3).

Firms. The firms demand labor to produce the consumption good. They face a working capital constraint that requires them to pay up-front a certain fraction of the wage bill, which they do with intra-period loans from bankers. Hence, the problem is:

$$\max_{\{N,\ell^d\}} \quad \Pi^F = zF(N) - wN - r\ell^d \tag{4}$$

$$\text{s.t. } \gamma wN \leq \ell^d \tag{5}$$

where z is aggregate productivity, $F(N)$ is the production function, ℓ^d is the demand for working capital loans, r is the interest rate charged for these loans, and γ is the fraction of the wage bill that must be paid up-front.

Equation (5) is the working capital constraint. This equation will always hold with equality because firms do not need loans for anything else but paying γwN; thus any borrowing over and above γwN would be sub-optimal. Taking this into account we obtain the following first-order condition:

$$zF_N(N) = (1 + \gamma r)w, \tag{6}$$

which equates the marginal product of labor to the marginal cost of hiring labor once the financing cost is factored in. Therefore, the optimality conditions from the firms' problem are represented by equation (5), evaluated with equality, and equation (6).

Bankers. Bankers play a vital role in the economy by providing loans to both the government and the firms. They face a lending constraint which requires that loans to firms do not exceed the value of banks' resources. These resources amount to the sum of three components: b, A, and T. The first component is the banks' holdings of sovereign bonds, b. The second component is banks' capital, $A(\varepsilon)$, which is subject to aggregate shocks. The third component are government guarantees, $T(B, s, A)$ (i.e. the state-contingent bailouts that the government may implement).

The dynamics of bank capital are as follows: every period, bank capital has a reference value of $\bar{A}$, but it is subject to shocks ε, which represent the fraction of bank capital that could be lost. The magnitude of the shock ε is realized at the beginning of the period, but the uncertainty regarding whether the shock hits the banks is only resolved at the end of the period: with probability π, the bank's capital is reduced by ε, and with probability $1-\pi$, the bank's capital is unaffected. These dynamics can be summarized as

$$A = \begin{cases} \overline{A} & \text{with probabilty } 1-\pi \\ \overline{A}(1-\varepsilon) & \text{with probabilty } \pi. \end{cases} \tag{7}$$

Let $\underline{A}(\varepsilon) = \overline{A}(1-\varepsilon)$. We refer to the event that $A = \underline{A}(\varepsilon)$ and $\varepsilon > 0$ as a banking crisis.

The lending constraint faced by the banker is such that it needs to be satisfied state-by-state. This implies that every period the supply of loans is limited by the worst-case scenario of the bankers' loanable funds:

$$\ell^s \leq \min_A \{A + b + T(B, s, A)\}\,. \tag{8}$$

When the government has access to credit, the banker's value is given by

$$\begin{aligned} W^R(b; B, s) = \max_{\ell^s} \mathbb{E}_A & \begin{Bmatrix} \max\limits_{x, b'} & x + \delta \mathbb{E}_{s'|s}\left[(1-d')W^R(b'; B', s') + d'W^D(s')\right] \\ \text{s.t.} & x \leq T(B, s, A) + b - q(B', s)b' + r(B, s, A)\ell^s \end{Bmatrix} \\ \text{s.t. } & \ell^s \leq \min_A \{A + b + T(B, s, A)\} \end{aligned} \tag{9}$$

where x is consumption, δ is the banker's discount factor, $r(B, s)$ is the interest rate on private loans, $q(B', s)$ is the price of government bonds, and B', T, and d are government policies for debt, bailouts, and default, which the banker takes as given. W^d is the banker's value when the government does not have access to credit, which is given by

$$\begin{aligned} W^D(s) = \max_{\ell^s, x}\ & x + \delta \mathbb{E}_{s'|s}\left[\theta W^R(0; 0, s') + (1-\theta) W^D(s')\right] \\ \text{s.t. } & x \leq r_{\text{def}}(s)\ell^s \\ & \ell^s \leq \underline{A}(\varepsilon) \end{aligned} \tag{10}$$

where θ is the probability that the government regains access to credit and $r_{\text{def}}(s)$ in the interest rate on private loans when the government does not have access to credit.

3.1.1 Characterization of equilibrium given government policies

Hereafter, we focus on bailout policies that take the form:

$$T = 0 \qquad \text{if } A = \overline{A} \tag{11}$$

$$0 \le T \le \varepsilon\overline{A} \quad \text{if } A = \overline{A}(1-\varepsilon). \tag{12}$$

In other words, the government cannot provide bailouts if the adverse financial shock does not materialize, and it can only cover the amount of the loss to bank capital if the shock does materialize. In that sense, we also refer to the bailout policy as a government guarantee.

Loan market. When the government does not have access to credit, bankers supply

$$\ell^s_{\text{def}}(s) = \underline{A}(\varepsilon). \tag{13}$$

When the government has access to credit, bankers supply

$$\ell^s(B, s) = B + \underline{A}(\varepsilon) + T(B, s, \underline{A}(\varepsilon)). \tag{14}$$

Note that the loan supply does not depend on the realization of A. Instead, given our restrictions on government bailout policies, total loan supply is determined by the level of government debt (B), the reduced bank capital $\underline{A}(\varepsilon)$, and government transfers T.

The demand for intra-period loans comes from the firms. Combining conditions (6) and (5) (with equality) gives rise to the following loan demand function:

$$\ell^d(B, s, A) = \gamma\left[\frac{znF_n}{1+\gamma r}\right]. \tag{15}$$

Note that loan demand depends on the realization of A. This is because during a banking crisis ($A = \underline{A}(\varepsilon)$ with $\varepsilon > 0$), the government may need to raise ditortionary labor income taxes to pay for the bailouts, affecting equilibrium labor.

It is then straightforward to derive the equilibrium conditions for the loan rate under repay and default:

$$r(B, s, A) = \max\left\{\frac{zn(B, s, A)F_n}{B + \underline{A}(\varepsilon) + T\left(\underline{A}(\varepsilon)\right)} - \frac{1}{\gamma}, 0\right\} \tag{16}$$

and

$$r_{\text{def}}(s) = \max\left\{\frac{znF_n}{\underline{A}(\varepsilon)} - \frac{1}{\gamma}, 0\right\}. \tag{17}$$

As was the case in Sosa-Padilla (2018), there is the possibility that the interest rate that clears the loan market in (16) is not strictly positive. In that case, the equilibrium loan amount is demand determined. Notice that a default shrinks the supply of loanable funds and, other things equal, increases the rate on the working capital loans. This increase in the loan rate comes from two reasons: bonds are not repaid and the government is unable to extend bailouts during defaults.

Government bond market. The bond pricing function satisfies

$$q(B';\ s) = \delta\mathbb{E}_{s'|s}\left\{\left[1 - \underbrace{d(B', s')}_{\text{default premium}}\right]\mathbb{E}_{A'}\left[1 + \underbrace{r\left(B', s', A'\right)}_{\text{lending discount}}\right]\right\} \tag{18}$$

This expression shows that in the case of a default in the next period, $(d(B', s') = 1)$ the lender loses not only its original investment in sovereign bonds but also the future gains that those bonds would have created had they been repaid. These gains are captured by $\mathbb{E}_{A'}\left[r(B', s', A')\right]$.

3.2 Determination of government policies

The government's optimization problem can be written recursively as:

$$V(B, s) = \max_{d\in\{0,1\}}\left\{(1-d)V^R(B, s) + d\,V^D(s)\right\} \tag{19}$$

where V^R and V^D is the value of repaying and defaulting, respectively. Let $\kappa \equiv (B, s, A)$ denote the complete aggregate state and $\Phi \equiv \{\tau, T, B'\}$ summarize the fiscal policies under repay. The value of repaying is:

$$V^R(B, s) = \max_{\tau, B', T}\mathbb{E}_A\Big\{U\big(c\left(\Phi;\kappa\right), n\left(\Phi;\kappa\right)\big) + \beta\,\mathbb{E}_{s'|s}V\left(B', s'\right)\Big\} \tag{20}$$

subject to:

$$\tau\, w(\Phi;\kappa)\, n(\Phi;\kappa) + B'\, q(B',s) = g + B + T \qquad \text{(gov't b.c.)}$$
$$c(\Phi;\kappa) + x(\Phi;\kappa) + g = zF\left(n(\Phi;\kappa)\right) \qquad \text{(resource constraint)}$$

$$\left.\begin{array}{ll} \quad T = 0 & \text{if } A = \overline{A} \\ 0 \le T \le \varepsilon \overline{A} & \text{if } A = \overline{A}(1-\varepsilon) \end{array}\right\} \qquad \text{(constraint on } T\text{)}$$

$$\left.\begin{array}{l} q(B',s) = \delta\, \mathbb{E}_{s'|s}\Big\{ \left[1 - d(B',s')\right] \mathbb{E}_{A'}\big[1 + r(\Phi';\kappa')\big] \Big\} \\ r(\Phi;\kappa) = \max\left\{ \frac{zn(\Phi;\kappa)F_n}{B+\underline{A}(\varepsilon)+T(\underline{A}(\varepsilon))} - \frac{1}{\gamma}, 0 \right\} \\ -\frac{U_n}{U_c} = (1-\tau)\, w\left(\Phi;\kappa\right) \\ zF_n = \left(1 + \gamma\, r\left(\Phi;\kappa\right)\right) w\left(\Phi;\kappa\right) \\ \ell\left(\Phi;\kappa\right) = \gamma w(\Phi;\kappa) n(\Phi;\kappa) \\ x(\Phi,\kappa) = T + B - q(B',s)B' + r(\Phi;\kappa)\ell\left(\Phi;\kappa\right) \end{array}\right\} \qquad \text{(comp. eq. conditions)}$$

where $c(\Phi;\kappa)$, $n(\Phi;\kappa)$, $x(\Phi;\kappa)$, $\ell(\Phi;\kappa)$, $w(\Phi;\kappa)$, $r(\Phi;\kappa)$, and $q(B',s)$ represent the equilibrium quantities and prices for the private sector given public policy (under repayment).

The value of default is:

$$V^D(s) = \max_{\tau}\; U\big(c_{\text{def}}\left(\tau;s\right), n_{\text{def}}\left(\tau;s\right)\big) + \beta\, \mathbb{E}_{s'|s}\big[\theta V\left(0,s'\right) + (1-\theta) V^D\left(s'\right)\big] \tag{21}$$

subject to:

$$\tau\, w_{\text{def}}(\tau;s)\, n_{\text{def}}(\tau;s) = g \qquad \text{(gov't b.c.)}$$
$$c_{\text{def}}(\tau;s) + x_{\text{def}}(\tau;s) + g = zF\left(n_{\text{def}}(\tau;s)\right) \qquad \text{(resource constraint)}$$

$$\left.\begin{array}{l} r_{\text{def}}(\tau;s) = \max\left\{ \frac{zn_{\text{def}}(\tau;s)F_n}{\underline{A}(\varepsilon)} - \frac{1}{\gamma}, 0 \right\} \\ -\frac{U_n}{U_c} = (1-\tau)\, w_{\text{def}}\left(\tau;s\right) \\ zF_n = \left(1 + \gamma\, r_{\text{def}}\left(\tau;s\right)\right) w_{\text{def}}\left(\tau;s\right) \\ \ell_{\text{def}}\left(\tau;s\right) = \gamma w_{\text{def}}(\tau;s) n_{\text{def}}(\tau;s) \\ x_{\text{def}}(\tau;s) = r_{\text{def}}(\tau;s)\ell_{\text{def}}\left(\tau;s\right) \end{array}\right\} \qquad \text{(comp. eq. conditions)}$$

where $c_{\text{def}}(\tau;s)$, $n_{\text{def}}(\tau;s)$, $x_{\text{def}}(\tau;s)$, $\ell_{\text{def}}(\tau;s)$, $w_{\text{def}}(\tau;s)$, and $r_{\text{def}}(\tau;s)$ represent the equilibrium quantities and prices for the private sector given public policy (under default).

3.2.1 Recursive Equilibrium

A Markov-perfect equilibrium is then defined as follows:

Definition 3.1. A *Markov-perfect equilibrium* for this economy is (i) a set of value functions for the government $\{V(B,s), V^R(B,s), V^D(s)\}$, (ii) a set of government policy rules for borrowing $B'(\kappa)$, taxation $\tau(\kappa)$, bailouts $T(\kappa)$, and default $d(B, s)$, (iii) a set of decision rules and prices from the private sector under repay $\{c(\Phi;\kappa), n(\Phi;\kappa), x(\Phi;\kappa), \ell(\Phi;\kappa), w(\Phi;\kappa), r(\Phi;\kappa)\}$, and under default $\{c_{\text{def}}(\tau;s), n_{\text{def}}(\tau;s), x_{\text{def}}(\tau;s), \ell_{\text{def}}(\tau;s), w_{\text{def}}(\tau;s), r_{\text{def}}(\tau;s)\}$, and (iv) an equilibrium pricing function for the sovereign bond $q(B', s)$, such that:

1. Given prices and private sector decision rules; the borrowing, tax, bailout and default rules solve the government's maximization problem in (19) – (21).
2. Given the price $q(B', s)$ and government policies, the decision rules and prices of the private sector are consistent with the competitive equilibrium.
3. The equilibrium price function satisfies equation (18).

4 Quantitative results

In this section, we first describe how we set the parameters of the model. Second, we examine the ability of our model to account for salient features of the data in GIIPS countries. Third, we show how default incentives interact with shocks to the banking sector and bailouts. Fourth, we study the properties of the optimal bailout policies. Finally, we analyze the welfare impact of having access to bailouts.

4.1 Functional forms and stochastic processes

The period utility function of the households is given by

$$U(c, n) = \frac{\left(c - \frac{n^\omega}{\omega}\right)^{1-\sigma}}{1-\sigma} \tag{22}$$

where σ and ω govern risk aversion and the wage elasticity of labor supply, respectively.

The production function is given by

$$zF(n) \quad \text{with} \quad F(n) = n^\alpha. \tag{23}$$

We assume that TFP shocks (z) follow an AR(1) process given by:

$$\log(z_{t+1}) = \rho_z \log(z_t) + \nu_{z,t+1} \tag{24}$$

where $\nu_z \sim N(0, \sigma_z)$. We use the Tauchen method to discretize the TFP shocks in 25 states.

Table 1: Calibration

Parameters	Values	Target/Source
Household discount factor, β	0.81	Default probability: 0.5 percent
Risk aversion, σ	2	Sosa-Padilla (2018)
Frisch elasticity, $\frac{1}{\omega-1}$	0.67	Sosa-Padilla (2018)
Government spending, g	0.15	Gov't consumption (percent GDP): 19.3
Prob. of financial redemption, θ	0.50	Expected exclusion: 2 years
Bankers' discount factor, δ	0.96	Real interest rate: 4 percent
Baseline bank capital, $\bar{A}$	0.28	Bailouts in banking crises (percent GDP): 1.8
Financial shock shape, σ_ε	4.26	Standard deviation of output: 3.4 percent
Prob. of banking crisis, π	0.03	Banking crisis frequency: 1.8 percent
Labor share, α	0.70	Sosa-Padilla (2018)
Working capital constraint, γ	0.52	Sosa-Padilla (2018)
TFP shock persistence, ρ_z	0.80	Standard value
TFP shock std, σ_z	0.02	Standard value

The potential bank capital shocks are assumed to take values that are between 0 and $\bar{\varepsilon}$, and have a cumulative distribution function,

$$F_{\sigma_\varepsilon}(\varepsilon) = \frac{1 - \exp(\varepsilon)^{-\sigma_\varepsilon}}{1 - \exp(\bar{\varepsilon})^{-\sigma_\varepsilon}} \tag{25}$$

which is a transformation of the bounded Pareto distribution. We discretize the ε shocks in to four states in a one-sided application of the Tauchen method. The shape parameter, σ_ε, determines the variance of the ε shocks.

4.2 Calibration

A period in the model is assumed to be a year. Table 1 summarizes the parameter values used.

The household and government's discount factor is set to 0.81 to match a default probability of 0.5 percent. Since our analysis mainly focuses on the European periphery, our target default probability is lower than that used for emerging economies (Aguiar et al. 2016) and higher than that for advanced economies (Hur et al. 2018). Government spending g is set to 0.15 to match the government consumption share of GDP of 19.3 percent documented for OECD economies in Hur et al. (2018). The probability of financial redemption, θ, is set to

0.5, which implies an average exclusion of 2 years.[2]

The banker's discount factor is set to 0.96 to generate a real interest rate of 4 percent. The level of the baseline bank capital, $\bar{A}$, is set to 0.28 so that the model matches the size of bailouts during banking crises, which is around 1.8 percent of GDP as shown in the empirical section. The financial shock shape parameter, σ_ε, is set to 4.26 to generate a standard deviation of output that matches the median of 3.4 percent for GIIPS. The parameter that governs the probability of banking crisis, π, is set to 0.03 so that the model matches the banking crisis frequency of 1.8 percent in a panel of 38 advanced and emerging economies from 1970 to 2017.[3]

There are six parameters that we do not calibrate. Following Sosa-Padilla (2018), we set risk aversion, $\sigma = 2$, and set the value of ω to correspond to a Frisch elasticity of 0.67, both standard values in the literature. Also as in Sosa-Padilla (2018), we set the labor income share $\alpha = 0.7$ and the working capital constraint $\gamma = 0.52$. Finally, we set the persistence $\rho_z = 0.8$ and standard deviation $\sigma_z = 0.02$, which is in the range of the typical values used in the literature.

4.3 Simulated moments

Table 2 shows representative moments from our model simulations. As it is usual in this literature, we report statistics for periods in which the government has access to financial markets and no defaults are declared (the only exception is the default frequency, for which we use all simulation periods).

We can see that, conditional on experiencing a banking crisis in the previous year, the default probability is 0.2 percentage points higher than our targeted unconditional default frequency of 0.5 percent. This increase in the default probability is the "diabolic loop" at work: banking crises trigger payments of contingent bailouts, and therefore imply that governments need to borrow more. This higher level of indebtedness pushes governments into the default risk zone, leading to more frequent defaults.

[2] This is a middle ground estimate given the long exclusion spells typically observed after defaults in emerging economies and the relative quick resolution of recent sovereign crises in peripheral Europe.

[3] In the data, we use the classification in Laeven and Valencia (2013), who use banking sector losses and other indicators to identify banking crises. The list of 38 advanced and emerging economies is as in Davis et al. (2016). In the model, we define a banking crisis as a non-zero reduction of bank's capital. This occurs with probability $\pi(1 - F_{\sigma_\varepsilon}(\underline{\varepsilon}))$ where $\underline{\varepsilon}$ refers to the lowest non-zero value in our discrete grid for ε.

Table 2: Simulated moments

	Unconditional	Banking crisis
Default frequency	0.5^{*}	0.7
Sovereign spread		
mean	0.7	0.9
standard deviation	0.6	1.0
Debt/GDP	15.5	16.0
Bailout/GDP	-	1.7^{*}

Units: percent. * denotes targeted moments.

These "diabolic loop" dynamics naturally translate into sovereign spreads.[4] The unconditional mean spread is 0.7 percent, but conditional on observing a banking crisis, the mean spread increases by 0.2 percentage points. This increase reflects not only the higher likelihood of default, but also a decline in the 'lending discount'. If there is a banking crisis in period t, then a default is more likely in period $t+1$ and hence the banker charges a higher default premium. Additionally, if in $t+1$ the default is averted, then the interest rate on loans is lower: there is higher debt, and therefore higher liquidity in the loan market. So, the sovereign bond becomes a less attractive investment for these two reasons: lower probability of repayment and, in case of repayment, lower overall return. Our simulations also generate higher spread volatility conditional on banking crisis because the risk of default increases.

The mean debt level in the model simulations is 15.5 percent of GDP.[5] Consistent with the intuition provided in the previous paragraphs, we observe that the debt level increases when conditioning on banking crises: these are periods of higher fiscal needs (the government needs to pay the contingent bailouts). This increase in debt as a result of banking crises can also be seen in Figure 2, which shows the histograms of debt-to-GDP ratios both unconditionally and conditional on banking crises.

[4]We compute sovereign spreads by comparing the sovereign bond price to the price of a default-free bond of similar characteristics. The price of such a default-free bond is given by

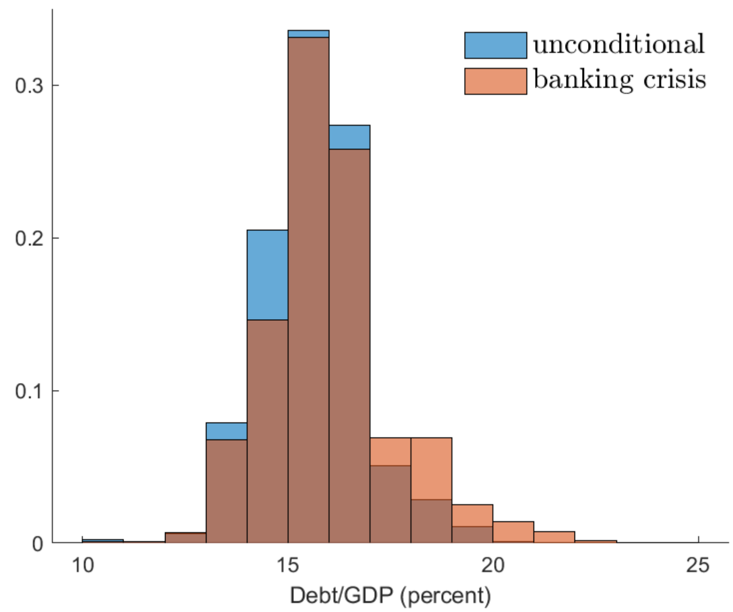
$$q^{nodef}(B';\ s) = \delta \mathbb{E}_{A',s'|s} \left\{ 1 + r_{\ell}^{nodef}(B', s', A') \right\}$$

where r_{ℓ}^{nodef} is the loans' interest rate with no default. The sovereign spread can then be defined as

$$spr(B', s) = \frac{q^{nodef}(B', s)}{q(B', s)} - 1.$$

[5] Data from Eurostat shows that GIIPS' short-term government debt ranged in between 4% and 9% of GDP (2000Q1 – 2020Q2). The total debt-to-GDP averaged between 40% and 98% for the same period.

Figure 2: Conditional and unconditional debt distributions

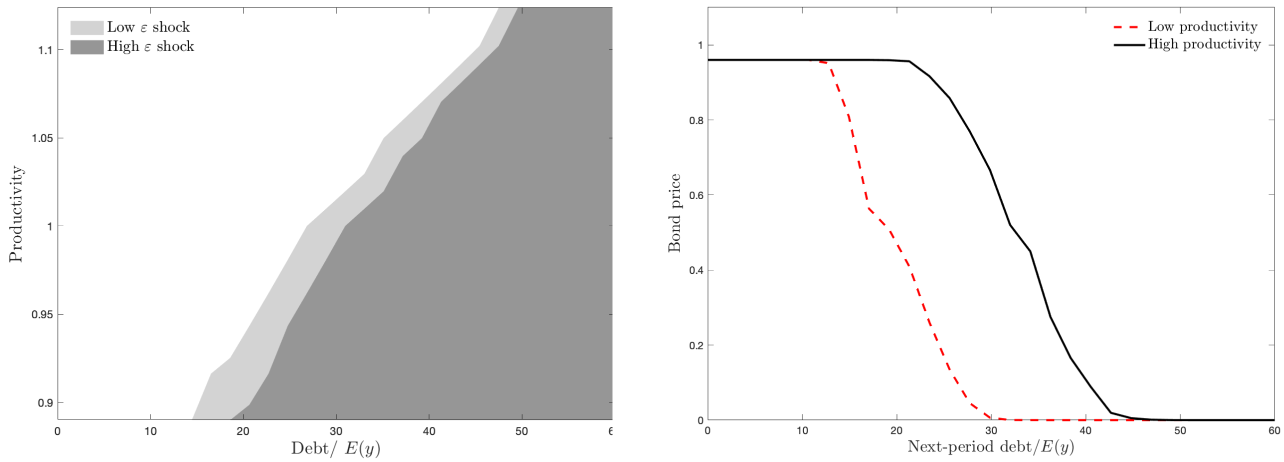


4.4 Default incentives, spreads and debt dynamics

Our model features a rich interaction between debt levels, default incentives, banking crises, and optimal bailout guarantees. Consistent with the standard endogenous default literature, our model also generates default incentives that decrease with the aggregate level of productivity and increase with debt, which can be verified in the left-panel of Figure 3. In addition to this standard finding, we also see that default sets shrink with high potential losses in banking capital. This is because severe banking crises can lead to severe contractions in the absence of government bailouts, thus increasing the cost of default.

The price schedule (right-panel of Figure 3) reflects these default incentives. As usual, higher realizations of productivity are associated with better prices (and higher debt capacity). The price schedule demonstrates that borrowing is essentially risk-free for debt ratios below 12 percent. Consequently, starting from zero debt the economy's debt-to-GDP ratio quickly increases until it reaches 12 percent and then it 'lives' in the region where default risk is small but positive. Figure 2 shows the histograms of debt-to-GDP ratios both unconditionally and conditioning on banking crises. Since the left tails of these histograms are very long, we choose to truncate them in our plots. The debt-to-GDP distribution conditional on a banking crisis is more skewed to the left compared to the unconditional distribution. Together with the results from the simulated moments, we can conclude that banking crises not only lead to higher debt-to-GDP ratios on average, but also generate an increase in the

Figure 3: Default sets and bond prices



Note: The left panel shows the default sets with the shaded areas indicating default and the white area indicating repayment. The right panel shows the equilibrium bond price schedule.

probability of observing 'very high' debt-to-GDP realizations in our simulations.

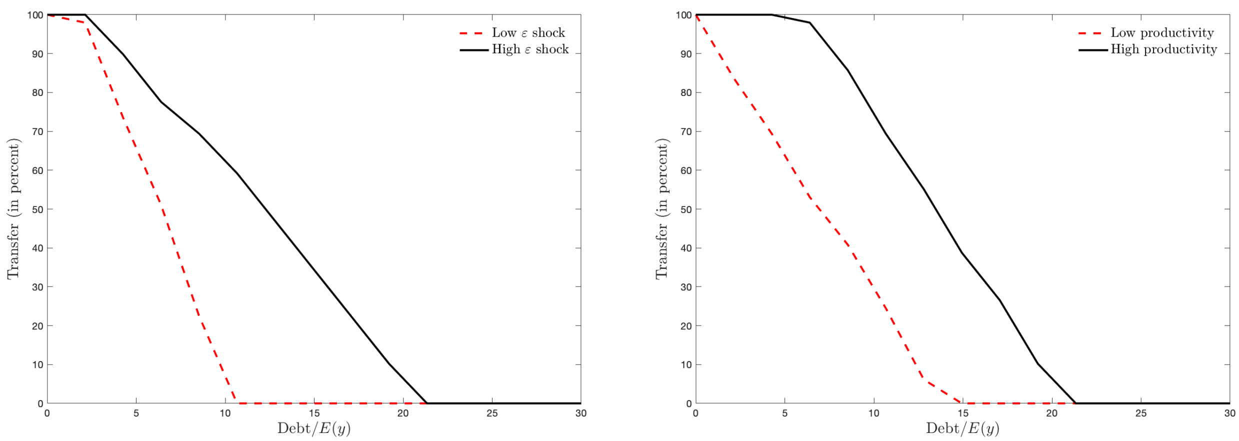
4.5 Properties of the optimal bailout policies

The ability of the government to give transfers to the bankers depends on the state of the economy in terms of productivity (z) and potential losses to bank capital (ε), in addition to the existing level of debt (B). As argued above, during the banking crises, the government has a higher incentive to borrow in order to finance the bailout transfers. As a result, we see thicker tails in the debt distribution conditional on banking crisis.

Since optimal transfers depend on many factors, it is helpful to look at the bailout policy functions generated by our model in order to highlight the role of each of those factors. Figure 4 shows the bailout policy functions expressed as the percent of the potential loss that the government promises to guarantee. Inspecting both panels of this figure we find the following properties for the bailouts:

1. **Increasing in ε.** The larger is the potential damage to the bankers' capital, the larger is the proportional bailout the government chooses. This is because the impact of financial shocks on the economy are non-linear. As can be seen in equation (16), in the absence of government bailouts, increases in ε rise the interest rate charged on loans to firms in a convex manner. Thus, the government uses bailout transfers to affect the supply side of the loan markets and keeps the equilibrium interest rate low,

Figure 4: Bailout policy



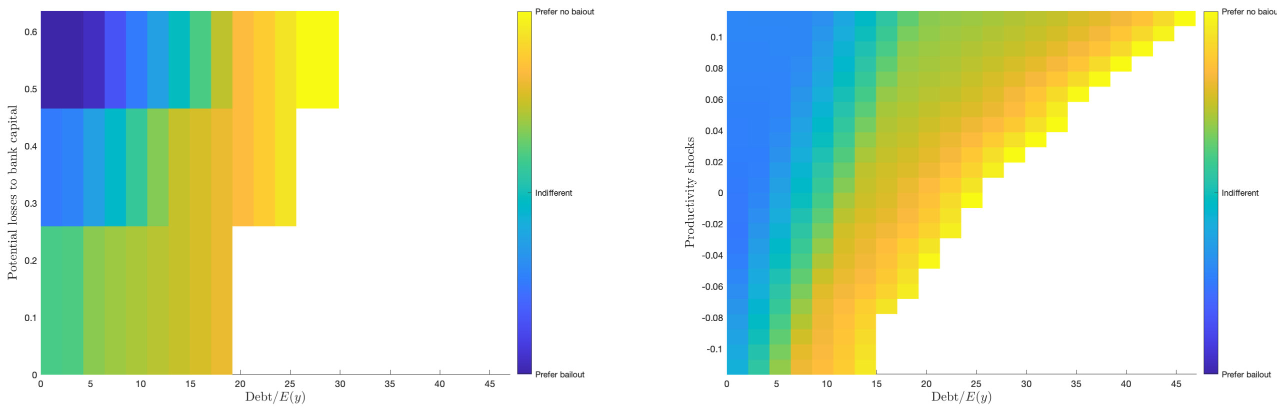
Note: The panels show the bailout policy functions expressed as the percent of the potential loss that the government promises to guarantee (i.e. $100 \times T(B, s, A) / \left(\bar{A}\varepsilon\right)$).

especially when the financial shocks are large.

2. **Decreasing in** B**.** While bailout guarantees play an essential role in alleviating the effects of banking crises on the real sector through the provision of higher liquidity, it is harder for the government to give transfers as the debt level increases due to the increased default risk. This is because even though the bankers benefit from bailout transfers, they also know that those bailouts will need to be financed with more borrowing. Since the bond prices drop sharply as debt increases the government will not be able to roll over its debt at high levels of debt and default becomes a more likely outcome.

3. **Increasing in** z**.** This intuitive property is due to two forces that go in the same direction. First, the more productive is the economy, the more valuable credit is. Therefore, it makes sense for the government to extend larger guarantees in good times. Second, the cost of borrowing that is necessary to finance the bailout is lower in periods of high productivity. Given the persistence of productivity shocks, a high productivity shock this period also implies a high productivity shock in the next period, which leads to a lower default risk, better prices for the government, and a higher borrowing capacity to finance the bailout transfers.

Figure 5: Preference for bailouts



Note: The left (right) panel shows the welfare gains for different values of financial shocks (productivity shocks). The white area represent points in the state space where default is chosen (in the economy with bailouts).

4.6 Preference for bailouts

In this section we examine the ex ante benefits and costs of having the option to issue bailouts. To do so, we additionally solve for the model without the bailout option. This is a simple exercise to study when the country prefers to have the option to bailout its banks.

The first observation is that the preference for bailouts depends on the level of existing debt, the size of potential losses to banks' capital, and productivity shocks. The left panel of Figure 5 shows the results for different values of potential losses to banks' capital, keeping productivity shock equal to its mean value and the right panel shows the results for different values of productivity shocks, keeping potential losses to banks' capital at its mean value. The darker regions show the state space in which bailout is preferred to no bailout. We find that at zero debt, governments prefer having the option of bailouts when the economy experiences a high potential loss to bank capital because bailouts ameliorate the reduction in lending to firms. As a consequence of bailouts, there is a rise in the supply of credit which reduces the cost of financing working capital and leads to higher output. However, this gain from bailouts disappears at higher levels of debt because the government relies on debt to finance bailouts, which escalates the default risk in the model with bailouts. As a result, for high levels of debt, the costs of facing higher debt yields outweighs the benefits, causing the government to prefer not having the option to bail out the banking sector.

Similarly, the right panel shows that the government prefers the option of bailouts as debt levels decrease and productivity shocks increase. At zero debt, the model with bailouts is preferred because the government can compensate a larger share of the loss in banking capital at a risk free rate as the productivity shock increases. Similar to the above case, we see the for high levels of debt, the increased cost of borrowing dominates, causing the government to prefer to not have the bailout option.

5 Conclusion

We study the dynamic relationship between sovereign defaults, banking crises, and government bailouts. We first document that when governments intervene to help distressed banking sectors, their most prevalent form of intervention is to extend contingent guarantees.

We then write down and solve a general equilibrium model of sovereign default, in which there is a benevolent government that maximizes household welfare by choosing debt, defaults, distortionary taxes, and bank bailouts. The economy is subject to two types of aggregate uncertainty: (standard) shocks to firm productivity and shocks to bank's capital. In anticipation of an adverse banking shock, banks reduce lending to the private sector. The sovereign may choose to announces guarantees (i.e. conditional transfers) to compensate for the banks' capital losses in the event of a crisis — these are the bailouts in our model. Defaults are costly because the government loses access to debt financing, it loses the ability to issue bailouts, banks' credit to the private sector declines and eventually output and consumption fall. The benefit of a default is that all existing debt is wiped-out, relaxing the government's budget constraint and allowing it to reduce distortionary taxes. Our framework is flexible enough to feature defaults triggering banking crises and banking crises triggering defaults: a complete 'doom loop.'

Using the calibrated model, we show that the occurrence of a banking crisis increases the default probability by 0.2 percentage points (from 0.5 to 0.7 percent annually) and raises the level and volatility of sovereign spreads (the latter increases from 0.6 to 1.0 percent). In the model, the government issues contingent guarantees, which exhibit clear properties. Other things equal they are: (i) decreasing in the level of government debt, since the more debt the government has, the less fiscal space it has to prop up banking sector assets, (ii) increasing in aggregate productivity, since the better the aggregate state of the economy is, the higher the value of credit and the cheaper it is to borrow to provide the guarantees, and (iii) increasing with the severity of the banking crisis, and this is because the effects of financial shocks are nonlinear: small shocks have negligible impacts on loans to the private sector, whereas large shocks can lead to severe contractionary credit crunches in the absence of government interventions.

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A Contingent Liabilities

In this section, we consider a broader notion of contingent government interventions by looking at the changes in government contingent liabilities instead of government guarantees. In addition to government asset guarantees, government contingent liabilities include public–private partnerships (PPP) recorded off-balance sheet of government, liabilities of government controlled entities classified outside of general government. For most countries, government guarantees have the largest share in government contingent liabilities. Because contingent liabilities are also stocks, we calculate the annual change in contingent liabilities as a share of GDP, and take the average of that ratio across all countries.

Government contingent liabilities and capital transfers

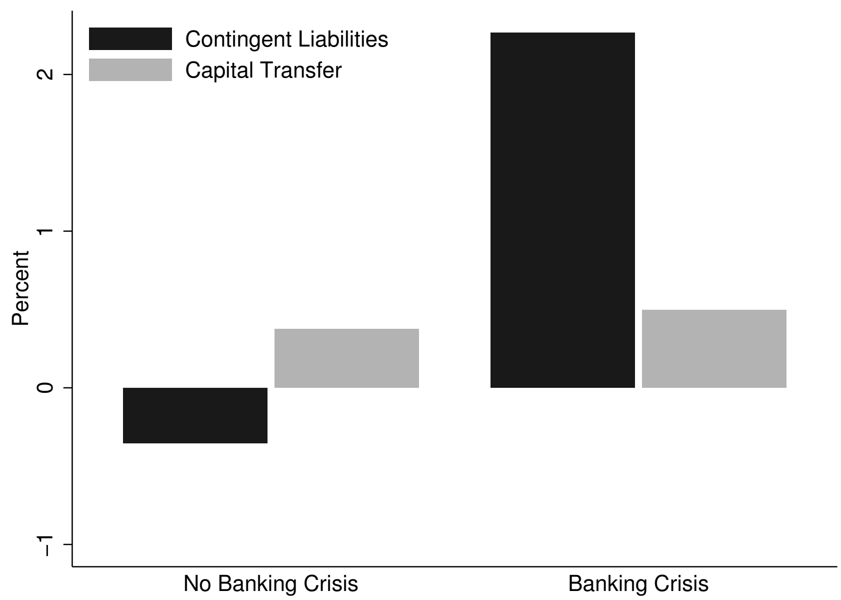

Figure ?? shows a side-by-side comparison of contingent liabilities and capital transfers during periods with and without banking crises. We obtain a similar pattern as before in that contingent liabilities exceed 2 percent during banking crises and they become negative other times.