Efficient Bailouts? *

Javier Bianchi

Wisconsin & NYU

January 2012

Abstract

This paper develops a non-linear DSGE model to assess the interaction between ex-post interventions in credit markets and the build-up of risk ex ante. During a systemic crisis, bailouts to the financial sector relax balance sheet constraints and accelerate the economic recovery. Ex ante, the anticipation of such bailouts leads to an increase in risk-taking, making the economy more vulnerable to a financial crisis. We find that the optimal intervention in the economy requires a bailout of around two percentage points of GDP during a credit crunch. We also show how bailouts may increase financial fragility in the absence of prudential policy.

Keywords: Bailouts, moral hazard, credit crunch, financial shocks
JEL classification: E32, E44, F40, G18

1 Introduction

A common feature of financial crises is massive government intervention in credit markets. For example, the initial Troubled Assets Relief Program (TARP) required 700 billion dollars to provide credit assistance to financial and non-financial institutions. These measures sparked an intense debate on the desirability of large scale government intervention. Supporters argue that the bailout was necessary to prevent a complete meltdown of the financial sector, which would have resulted in an extraordinary contraction in output and employment. Critics argue that bailouts create incentives for investors to take even more risk ex ante, sowing the seeds for future crises. These critics propose regulations to limit the central bank's ability to bailout the financial sector.

This paper addresses the following questions: How does the expectation of a bailout impact the stability of the financial sector? Is it desirable to prohibit the use of public funds to bailout the financial sector? How large should bailout packages be?

We answer these questions using on a non-linear DSGE model in which credit frictions generate scope for bailouts during a financial crisis, but where the anticipation of bailouts generate more risk-taking before the crisis actually hits. Recent research (e.g. Gertler and Kiyotaki, 2010) analyzes how credit policy can mitigate a credit crunch and the resulting recession ex-post. At the same time, a growing theoretical literature investigates the moral hazard implications of large scale government interventions (e.g. Farhi and Tirole, 2010). However, there has been little work assessing the quantitative implications of moral hazard. In this paper, we develop a quantitative DSGE model to assess the interaction between ex-post interventions in credit markets and the build-up of risk ex ante in a unified framework. We use this quantitative framework to derive the optimal intervention in the economy and evaluate the macroeconomic and social welfare effects.

The model features a representative corporate entity that faces two frictions in its capacity to finance investment. First, debt contracts are not fully enforceable, giving rise to a collateral constraint that limits the amount that firms can borrow. Second, there is a constraint on minimum dividends that firms must make each period. Therefore, firms balance the desire to increase borrowing and investment today with the risk of becoming

financially constrained in the future. When leverage is high and a sufficiently large adverse financial shock hits the economy, firms are forced to cut down on investment, which leads to a protracted recession.

In our model, credit crunches are socially inefficient because firms remain undercapitalized, hindering the economic recovery. From an individual point of view, households do not have an incentive to unilaterally transfer funds to firms, since this only entails costs for them. A bailout by the government, however, might represent a Pareto improvement because the collective transfer to firms allows all households to obtain higher dividends and higher labor income. We derive the optimal form of intervention by considering a social planner that is subject to the same constraints as the private economy. To capture efficiency costs from government intervention, we assume that there is an iceberg cost associated with transfers from households to firms. Therefore, the government only conducts bailouts when the credit crunch is sufficiently severe.

We emphasize that bailouts also improve social welfare from an ex-ante perspective. In our model, the government finds it optimal to have a bailout policy even if that means that firms and households anticipate bailouts may occur in the future. This occurs because bailouts provide a form of insurance against disruptions in financial markets. However, from an ex-ante perspective, bailouts might also create an externality because they reduce the cost of borrowing below the social cost. This externality, in turn, rationalizes the need for prudential policy.

We analyze different decentralizations for the optimal intervention. The key feature of ex-post interventions is that they imply a redistribution from households to firms. Accordingly, policies like debt guarantees and equity injections are effective during a systemic crisis. Importantly, the precise form of the bailout package has implications for the form of the ex-ante intervention. In general, there is a role for a prudential tax on debt, as long as bailouts reduce the perceived cost of borrowing. Finally, we illustrate how less targeted bailouts can reduce the need for prudential policy.

Quantitatively, we find that the optimal bailout is approximately two percentage points of GDP on average and it is increasing on the leverage ratio at the onset of the crisis. The bailout generate an increase in leverage, making financial constraints increasingly more

2

binding. This, in turn, leads to an increase in the incidence of a credit crunch of around 10 percent. On the other hand, the severity of these episodes is considerably reduced. In fact, we find that the the cumulative loss in output that results from a credit crunch falls from 10 percent to 6 percent when there is government intervention.

Bailout expectations play a key role in crisis dynamics. When bailouts are not anticipated, the fall in investment is reduced from 28 percent to 22 percent during an average credit crunch. As a result, the fall in output following the credit crunch is reduced from 1.7 percent to 1.3 percent. Moreover, the optimal bailout is reduced by half because risk-taking does not increase as much in the run-up to the crisis.

Our findings also highlight the importance of prudential policy to offset the excessive risk-taking behavior generated by bailouts. In fact, without prudential policy the economy experiences financial crisis which are as severe as in the absence of any bailout policy, and these episodes also become more frequent.

Related Literature — This paper draws on the extensive literature on the macroeconomic effects of financial frictions, shaped by the work of Bernanke and Gertler (1989) and Kiyotaki and Moore (1997). In particular, our model shares with Jermann and Quadrini (2010) the consideration of financial shocks and active dividend policy, and with Mendoza (2010) the emphasis on non-linear dynamics beyond the steady state. However, these papers do not address normative issues.

This paper is also related to a growing quantitative literature that studies the effects of credit policy during a credit crunch (e.g. Gertler and Karadi (2011), Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010)).[1] For reasons of tractability, most of this literature focuses on policy measures in response to unanticipated crises or on log-linear dynamics around the deterministic steady state and does not address risk considerations and the moral hazard effects of credit policy. Instead, a distinctive feature of this paper is the consideration of how expectations of future bailouts affect ex-ante risk-taking. This is crucial to assess the dynamic implications of credit intervention on financial stability and on social welfare.

---

[1]Other recent models of credit crunches include Guerrieri and Lorenzoni (2011) and Midrigan and Philippon (2011).

The recent work by Gertler, Kiyotaki, and Queralto (2011) is more closely related to our paper. Gertler et al. develop a model in which banks have access to debt and equity financing and investigate the moral hazard effects of credit policy. They focus on the macro dynamics around a "risk-adjusted" steady state in which financial constraints are always binding. Our paper differs in two important aspects. First, we characterize and solve for the optimal bailout policy and prudential policy to avoid excessive risk-taking. Second, we conduct our analysis using a global solution method and study full equilibrium dynamics in a stochastic steady state in which binding financial constraints are rare events. On the other hand, we also acknowledge that our framework is not as flexible as Gertler et al. to handle richer features considered in larger scale DSGE models.

This paper also builds on the theoretical literature that analyzes the incentive effects of bailouts on financial stability. Farhi and Tirole (2010) and Chari and Kehoe (2009) emphasize how bailouts can increase financial fragility and draw implications for ex-ante regulation. Schneider and Tornell (2004), Diamond and Rajan (2009) and Keister (2010) emphasize, as we do, that bailouts can be optimal ex-ante as a form of insurance, but their focus is mostly on self-fulfilling crises.[2] Our analysis mainly differs by developing a quantitative framework to assess the macroeconomic and welfare effects of bailouts.

This paper is also related to a growing quantitative literature on how macro-prudential policy can be used to reduce the level of financial fragility.[3] Our paper also gives a role to limits on leverage during good times, but, unlike this literature, it arises as a result of an externality created by bailouts. Moreover, their inefficiency relates to the effects between the intertemporal reallocation of wealth across leveraged borrowers and equilibrium prices, while here it is related to the effects between the intratemporal reallocations of wealth between shareholders and managers of corporations and investment capacity.

---

[2]See also Keister and Narasiman (2011) for recent work on how policy issues might be affected by whether a financial crisis is originated by fundamentals or self-fulfilling expectations.

[3]See e.g. Bianchi (2011), Bianchi and Mendoza (2010), and Jeanne and Korinek (2010). Benigno, Chen, Otrok, Rebucci, and Young (2010) also discuss ex-post policy measures to address a pecuniary externality (see also Jeanne and Korinek (2011)). For theoretical contributions see e.g. Lorenzoni (2008) and Caballero and Krishnamurthy (2001).

The remainder of the paper is organized as follows: Section 2 presents the analytical framework; Section 3 analyzes the optimal intervention; Sections 4 and 5 present the quantitative analysis; and Section 6 discusses the conclusions

2   Analytical Framework

Our model economy is a small open economy populated by firms and workers who are also the firms' shareholders. We begin by describing the decisions made by different agents in the economy, and then we discuss the general equilibrium.

2.1   Households

There is a continuum of identical households of measure one that maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t - G(n_t)) \tag{1}$$

where c_t is consumption, n_t is labor supply, β is the discount factor, and $G(\cdot)$ is a twice-continuously differentiable, increasing and convex function. The utility function $u(\cdot)$ has the constant-relative-risk-aversion (CRRA) form; the composite of the utility function has the GHH form, eliminating wealth effects on the labor supply. The advantage of these preferences is that they deliver realistic responses of employment during a credit crunch without introducing frictions in labor markets that would complicate the analysis.

Households do not have access to bond markets, and they are the firms' shareholders. This yields the following budget constraint:

$$s_{t+1}p_t + c_t \leq w_t n_t + s_t(d_t + p_t) \tag{2}$$

where s_t represents the holdings of firm shares and p_t represents the price of firm shares.

The first-order conditions are given by:

$$w_t = G'(n_t) \tag{3}$$

$$p_t u'(t) = \beta \mathbb{E}_t u'(t+1)(d_t + p_{t+1}) \tag{4}$$

Iterating forward on (4) and imposing a no-bubble condition yields that in equilibrium, the price of shares must be equal to:

$$p_t = \mathbb{E}_t \sum_{j=1}^{\infty} \beta^j m_{t+j} d_{t+j} \tag{5}$$

where $m_{t+j} \equiv (\beta^j u'(c_{t+j} - G'(n_{t+j})))/(u'(c_t - G'(n_t)))$ represents the stochastic discount factor.

2.2   Corporate entities

There is a measure one of identical firms with technology given by the production function $F(z_t, k_t, h_t)$ that combines capital denoted by k, and labor denoted by h to produce a final good. TFP denoted by z_t follows a first-order Markov process. Consistent with the typical timing convention, k_t is chosen at time $t-1$ and is therefore predetermined at time t. Instead, the input of labor h_t can be flexibly changed in period t.

Firms have the following technology to transform final goods into investment goods.

$$k_{t+1} = k_t(1 - \delta) + i_t \tag{6}$$

where i_t is the level of investment and δ is the depreciation rate. Capital accumulation is subject to convex adjustment costs, given by $\psi(k_t, k_{t+1})$. Adjustment costs are introduced to improve the quantitative performance of the model in terms of the volatility of investment and asset pricing implications.

Firms pay dividends, denoted by d_t, and issue non-state contingent debt, denoted by b_{t+1}. Firms finance investment, including capital adjustment costs $(i_t + \psi(k_t, k_{t+1}))$, debt repayments (b_t), dividend payments (d_t) with internal cash flows $(F(z_t, k_t, h_t) - w_t n_t)$, and new debt (b_{t+1}). The flow of funds constraint for firms is then given by:

$$b_t + d_t + i_t + \psi(k_t, k_{t+1}) \leq F(z_t, k_t, h_t) - w_t n_t + \frac{b_{t+1}}{R} \tag{7}$$

where w_t is the wage rate, and R is the gross interest rate determined in international markets. Implicit in this constraint is the fact that firms cannot issue new shares (we normalize the total number of shares to 1). However, they can adjust retained earnings by cutting dividend payments.

Firms face two types of liquidity constraints on their ability to finance investment. First, they are subject to a collateral constraint that limits the amount of borrowing to a fraction of their capital holdings:

$$b_{t+1} \leq \kappa_t k_{t+1} \tag{8}$$

This constraint is similar to those used in existing literature, and we interpret it as arising in an environment where creditors can only recover a fraction κ_t of the firms' assets.[4] Following Jermann and Quadrini (2010), κ_t represents a shock to the borrowing capacity of firms. For simplicity, this "financial shock" follows a two-state Markov chain with values given by κ^H and κ^L. In our quantitative analysis, the collateral constraint will never bind when $\kappa = \kappa^H$, so that when κ switches from high to low, this may lead to a binding constraint and a credit crunch. Note that whether the economy enters a credit crunch depends endogenously on the degree of leverage in the economy.

Without any constraints on equity financing, the shadow value of external funds would be equal to one. We assume that there is a lower bound on dividends given by $\bar{d}$, i.e., at each period firms are required to satisfy:

$$d_t \geq \bar{d} \tag{9}$$

A special case is the restriction that dividends need to be non-negative, which effectively implies that the issuance of new shares is not available. This constraint reflects the notion that dividend payments are required to reduce agency problems and information asymmetries between shareholders and managers.

---

[4] We implicitly assume that the liquidation value of capital is not affected by market prices, thereby turning off a fire-sale externality mechanism (see e.g. Bianchi and Mendoza (2010) for an analysis of this channel). We make this assumption to focus on an alternative mechanism which results from reallocation of funds between shareholders and firms.

We assume that firms maximize shareholder value as is standard in the dynamic corporate finance literature. Maximization of shareholder values implies that firms must discount profits at state $t + j$ the rate m_{t+j} defined above. That is, their problem is to maximize $\mathbb{E}_t \sum_{j=0}^{\infty} m_{t+j} d_{t+j}$.

2.3 Recursive Problem and Optimality Conditions

The aggregate state of the economy is given by the aggregate level of capital K,, bonds B, and the aggregate shocks κ and z. Denoting $V(k, b, X)$ the cum-dividend market value of the firm $X = \{K, B, \kappa, z\}$, and using prime to denote next period variables, the optimization problem for firms can be written recursively as:

$$V(k, b, X) = \max_{d, h, k', b'} d + \mathbb{E}m'(X, X')V(k', b', X') \tag{10}$$

$$s.t.$$

$$b + d + k' + \psi(k, k') \leq (1 - \delta)k + F(z, k, h) - wn + \frac{b'}{R}$$

$$b' \leq \kappa k'$$

$$d \geq \bar{d}$$

The optimality condition for labor demand yields a standard static condition:

$$F_h(z_t, k_t, h_t) = w_t \tag{11}$$

There are also two Euler intertemporal conditions that relate the marginal benefit from distributing one unit of dividends today with the marginal benefit of investing in the available assets and distributing the resulting dividends in the next period. Denoting by μ, the multiplier associated with the borrowing constraint, η the multiplier associated with the dividend payout constraint, the Euler equations and associated complementary slackness conditions are given by:

$$1 + \eta_t = R\mathbb{E}_t m_{t+1}(1 + \eta_{t+1}) + R\mu_t \tag{12}$$

$$(1 + \eta_t)(1 + \psi_{2,t}) = \mathbb{E}_t m_{t+1} \left[1 - \delta + F_{k,t+1} - \psi_{1,t+2}\right](1 + \eta_{t+1}) + \kappa_t \mu_t \tag{13}$$

$$\mu_t(\kappa_t k_{t+1} - b_{t+1}) = 0, \quad \mu_t \geq 0 \tag{14}$$

$$\eta_t(d_t - \bar{d}) = 0, \quad \eta_t \geq 0 \tag{15}$$

In the absence of financial constraints on borrowing and dividend payments, the cost of raising equity (by reducing dividends), i.e., $1/\mathbb{E}_t m_{t+1}$, would be equal to the cost of debt R, and firms would be indifferent at the margin between equity and debt financing. However, when the collateral constraint binds, there is a wedge between the marginal benefit of borrowing one more unit and distributing it as dividends in the current period and the marginal cost of cutting dividends in the next period to repay the debt increase. In addition, when the dividend payout constraint binds, a positive wedge arises between the marginal benefit from investing one more unit in capital or bonds and the marginal cost of cutting one unit of dividends.

As we will see in the quantitative analysis, the collateral constraint and the dividend payout constraint often bind at the same time. Intuitively, both constraints impose a limit on a firm's funding ability. A binding dividend payout constraint forces higher levels of borrowing for given investment choices. Similarly, a tighter constraint on borrowing puts pressure on the firms to finance with equity. Note that in equilibrium, reducing dividend payments increases the cost of equity because households have a concave utility function.

Discussion of Financial Frictions — Our normative analysis requires a model of incomplete markets that departs from Modigliani-Miller. We discuss now some of the assumptions that we have made to deviate from Modigiliani-Miller results. First, the fact that asset markets are restricted to one-period non-state contingent bonds is standard in the literature and represents a simplification of the limited insurance that firms have access to.

Second, borrowing by firms is limited by imperfect enforceability of contracts. In particular, we assume that creditors require firms to hold collateral to back promised repayments according to (8). In order to enrich the model, we have introduced shocks to how much collateral firms firms are required to pledge. In the model, a negative financial shock produces a credit crunch with similar features to the data when leverage is high enough. Jermann

and Quadrini (2010) recently pointed out that financial shocks improve the quantitative performance of a business cycle model.[5]

Third, firms face a lower bound on dividend payments. This is a relatively standard way of capturing agency problems and information asymmetries between a firm's shareholders and its managers, and it is in line with an extensive literature documenting the importance of agency frictions between shareholders and corporate managers (see .e.g. Shleifer and Vishny (1997) for a survey). Without this constraint on dividend payments, firms in our model would be able to raise enough equity to finance desired investments and would fail to reproduce the evolution of real and financial variables in the data.[6]

Fourth, households in our model do not have access to credit markets, although this constraint can be relaxed to some extent. What is important is that households face a tight borrowing limit when firms are credit constrained. In particular, if households had perfect access to credit markets, firms would not be borrowing constrained in the long run. To guarantee that firms occasionally experience a binding collateral constraint, we assume for the sake of simplicity that households cannot access credit markets. Note that households can smooth consumption through dividend payments, which in turn will affect firms' financial decisions.

Overall, these assumptions allow us to formulate a parsimonious analysis of optimal bailouts in a model that produces financial and real flows that are broadly consistent with key features of the data in terms of general co-movements and financial crises dynamics.

2.4   Competitive equilibrium

The competitive equilibrium for a small open economy that borrows from abroad at an exogenous interest rate can be constructed in the usual form. Market clearing in the labor

---

[5]A possible interpretation of this shock relates to disruptions in financial intermediaries, which become either less willing to lend or more concerned about the riskiness of the corporate sector, possibly due to fundamentals or "animal spirits".

[6]Several papers, including Jermann and Quadrini (2010) and Gilchrist, Sim, and Zakrajšek (2010), follow similar assumptions. More generally, it is necessary to assume that equity becomes relatively costly to issue in some states of nature. One way to demonstrate this point is to model the lack of incentives to issue equity when managers have private information about investment opportunities. For example, in Myers and Majluf (1984), good firms may find it optimal not to issue equity when they are pooled with those of lower quality (see also Bigio, 2011 for recent work linking adverse selection in credit markets with banks' equity financing).

market requires:

$$h_t = n_t \tag{16}$$

Market clearing in equity markets requires:

$$s_t = 1 \tag{17}$$

Using the two equations above and combining the household budget constraint and the firms' flow of funds constraint, we obtain the resource constraint for the economy:

$$b_t + c_t + k_{t+1} + \psi(k_t, k_{t+1}) = (1 - \delta)k_t + F(z, k_t, h_t) + \frac{b_{t+1}}{R} \tag{18}$$

The recursive competitive equilibrium can be defined as follows:

Definition 1 *A recursive competitive equilibrium is given by (i) firms' policies* $\left\{ \hat{d}(k, b, X), \hat{h}(k, b, X), \hat{k}(k, b, X), \hat{b}(k, b, X) \right\}$*; households's policies* $\hat{s}(s, X), \hat{c}(s, X), \hat{n}(s, X)$*; a stochastic discount factor* $m(X, X')$*; firm's value* $V(k, b, X)$*; prices* $w(X), p(X)$*; and a law of motion of aggregate variables* $X' = \Gamma(X)$*, so that: (i) households solve their optimization problem; (ii) firms' policies and firms' value solve (10); (iii) markets clear in equity market* $(\hat{s}(1, X) = 1)$ *and labor market* $(\hat{h}(K, B, X) = \hat{n}(1, X))$*, (iv) the stochastic discount factor for firms is given by* $m(X, X') = \beta u_c(1, X')/u_c(1, X)$ *(v) the law of motion* $\Gamma(\cdot)$ *is consistent with individual policy functions and stochastic processes for* κ *and* z*.*

Proposition 1 *Given an interest rate* R *and stochastic processes for* z_t *and* κ_t*, a set of stochastic sequences* $\{c_t, k_{t+1}, i_t, b_{t+1}, d_t, h_t, n_t, w_t, p_t, \mu_t, \eta_t, s_t\}_{t \geq 0}$ *is a competitive equilibrium if and only if equations (2)-(4), (6)-(17) are satisfied.*

Proof: See Appendix.

In order to illustrate the properties of the model, it is useful to first analyze the case without uncertainty. In a deterministic steady state with $\beta R < 1$, (i) the collateral constraint is always binding, and (ii) there exists $\hat{d}$ such that the dividend payout constraint binds if $\bar{d} > \hat{d}$. For (i), note that in a deterministic steady state, $m_t = 1$ and (12) is simplified to $1 = \beta R + \mu$. Since $\beta R < 1$, this implies that $\mu > 0$. For (ii), one can obtain the steady

11

state values $[k^{ss}, h^{ss}, b^{ss}, \mu^{ss}]$ from (3),(8),(12), and (13). Substituting these expressions, (8) and (3) in the flow of funds constraint (22) yields the value of dividends at steady state

$$d^{ss} = F(z^{ss}, k^{ss}, h^{ss}) - k^{ss}(\delta + \bar{\kappa}(R-1)/R) - h^{ss}G'(h^{ss}).$$

In general, in a stochastic steady state, these financial constraints may or may not bind depending primarily on the magnitude of the shocks, βR, and the tightness of the constraints.

3 Normative Analysis

3.1 Social Planner's Solution

The key externality in our setup is related to the undercapitalization of firms. Households are not willing to unilaterally transfer funds to firms because they only incur costs. Instead, a social planner recognizes that transferring resources to the firm increases labor payments and dividend payments in future periods for all households in the economy.

The normative analysis proceeds in two steps. First, we consider a social planner with limited planning abilities. In particular, we consider a benevolent social planner who (a) directly chooses the sequence of debt, capital, and equity payout subject to the liquidity constraints and the resource constraint; (b) chooses a sequence of transfers Υ_t between firms and households at a linear cost φ; (c) lets labor markets and goods markets clear competitively. Second, we will identify possible instruments that can decentralize this planner's problem.

It is necessary to mention a few factors in our formulation of the planner's problem. First, by making the planner subject to the same financial constraints as the decentralized equilibrium, the economy is also subject to the deleveraging effects of financial shocks. Second, to reflect the fact that these transfers are costly in practice, we assume that there is an iceberg cost φ on the volume of transfers. This cost could arise from distortions in taxation or the financing of inefficient projects. However, we do not model the causes of the cost explicitly.[7] Finally, while the social planner cannot directly affect labor market outcomes,

---

[7]For the sake of simplicity, we assume that the cost is linear on the transfer to each firm, but we could allow for a more general cost. For example, we could introduce a fixed cost to bail out a single firm, implying that the government would provide a bailout when there is a sufficient number of firms in distress (see Farhi and Tirole (2010) for a theoretical analysis and Kelly, Lustig, and Van Nieuwerburgh (2011) for empirical evidence on the anticipation of systemic bailouts). Since all firms are identical, the implications for the social planner solution would be very similar. We will discuss this point further when we address implementability.

he may affect the labor market indirectly through the choice of capital as it affects wages in the next period. However, we assume that the planner does not consider these indirect effects in order to keep the decentralization relatively simple.[8]

Admissible Allocations — The admissible allocations are given by equations (3),(4),(8), (11),(16),(17) and

$$b_t + c_t + k_{t+1} + \psi(k_t, k_{t+1}) + \Upsilon_t \varphi = (1 - \delta)k_t + F(z, k_t, h_t) + \frac{b_{t+1}}{R} \tag{19a}$$

$$(1 - \delta)k_t + F(z, k_t, h_t) - w_t h_t + \frac{b_{t+1}}{R} + \Upsilon_t - b_t - k_{t+1} - \psi(k_t, k_{t+1}) \geq \bar{d} \tag{19b}$$

Proposition 2 The solution to the constrained social planner's problem allocations satisfy feasibility, equations (12)-(15), and

$$\varphi u'(c_t - G(h_t)) \geq \eta_t \text{ with equality if } \Upsilon_t > 0 \tag{20}$$

Proof: See Appendix

Condition (20) is crucial to identifying the tradeoffs involved in the bailout policy. This condition establishes that the planner will transfer resources from households to firms until the marginal cost given by $\varphi \lambda_t$ equals the marginal benefits, given by η_t, the shadow value from relaxing (19b). It also follows that $\Upsilon_t = 0$ if the dividend payout constraint is not binding or if the shadow value from relaxing the dividend payout constraint is small enough. Note that it is not optimal to fully relax the dividend payout constraint, i.e. if $\Upsilon_t > 0$ for some t, it also follows that $\eta_t > 0$. We also have the following two results:

Corollary 1 If $\varphi = 0$, constraint (19b) does not bind for the social planner.

Proof: Setting $\Upsilon_t > \bar{d} + b_t + i_t + \psi(k_t, k_{t+1}) - F(z_t, k_t, n_t) - w_t h_t + \frac{b_{t+1}}{R}$, the planner can completely relax (19b) without affecting the objective function or the rest of the constraints. Intuitively, if taxes are not distortive, the planner can use cost-free transfers as a substitute for lower dividend payments when the dividend payout constraint becomes binding.

---

[8]The planner would choose less capital in those states in which the dividend constraint might bind in the next period in order to reduce wages and make the dividend payout constraint less binding. Quantitatively, however, the effect of this pecuniary externality is not significant.

Corollary 2 *If $\bar{d} = -\infty$, the competitive equilibrium and the social planner's solution coincide.*

Proof: The proof notes that $\bar{d} = -\infty$ implies $\Upsilon_t = 0$ and $\eta_t = 0$, which yields that the conditions characterizing the competitive equilibrium are identical to those characterizing the social planner.

Since firms have unrestricted access to equity, implementing a transfer from households to firms has no effect. Note, however, that since the economy remains distorted by the collateral constraint, financial shocks have real effects.[9] It also follows that if $\bar{d} = -\infty$ and $\varphi > 0$, bailouts are welfare reducing.

In the policy experiment below, we consider the general case where $\varphi > 0$, which implies that the government faces strictly positive efficiency costs from transferring resources from firms and households. Under these conditions, bailouts involve ex-post a trade-off between relaxing firms' balance sheet constraints and the iceberg costs associated with the transfer.

3.2 Decentralization

This section analyzes various ways to decentralize the planner's allocations. As we will see, the decentralization requires in general both ex-ante prudential measures and ex-post policy measures. -textbfDebt guarantees — We first analyze the role of debt guarantees. We consider a policy in which the government pays a fraction γ_t of private debts and finances this transfer of funds and its iceberg cost with lump sum taxes T_t to households. In addition, the government sets a tax τ_t on borrowing that is rebated by a lump-sum tax to firms, given by T_t^f. With these policies, the households' budget constraint and the firms's flow of funds constraint become respectively:

$$s_{t+1}p_t + c_t \leq w_t n_t + s_t(d_t + p_t) - T_t \tag{21}$$

---

[9]With $\bar{d} = -\infty$, the economy becomes a model of a small open economy with a representative firm-household facing a collateral constraint from external borrowing (see Mendoza (2010) and Bianchi and Mendoza (2010)). For the case of $\bar{d} = -\infty$, if we assumed instead that households have *unrestricted* access to international credit markets by borrowing and saving at the interest rate R, the competitive equilibrium would be unaffected by financial shocks. Therefore, the Modigiliani Miller theorem would hold, and the model would become a standard RBC model. Note that from a household's first-order condition, it would be the case that $REm' = 1$. Using the firm's first-order condition, $REm' + \mu = 1$ would yield $\mu = 0$.

$$(1 - \gamma_t)b_t + d_t + i_t + \psi(k_t, k_{t+1}) \le F(z_t, k_t, h_t) - w_t n_t + \frac{b_{t+1}}{R}(1 - \tau_t) + T_t^f \quad (22)$$

First-order condition with respect to b_{t+1} yields:

$$1 + \eta_t = R(1 + \tau_t)\mathbb{E}_t m_{t+1}(1 + \eta_{t+1})(1 - \gamma_{t+1}) + R(1 + \tau_t)\mu_t \quad (23)$$

The rest of the optimality conditions remain the same. Note that from (23), the private costs of borrowing at time t are reduced by a factor of $(1 - \gamma_{t+1})$ in a state t+1 in which the government provides debt guarantees. An examination of these first-order conditions leads to the following proposition:

Proposition 3 *The government can implement the constrained optimal allocations through a combination of debt guarantees, taxes on debt, and lump sum taxes. These polices are given by:*

$$\gamma_t = \frac{\Upsilon_t}{b_t}, \quad T_t = \Upsilon_t(1 + \varphi), \quad \tau_t = \frac{\mathbb{E}_t m_{t+1}(1 + \eta_{t+1}) + \mu_t}{\mathbb{E}_t m_{t+1}(1 + \eta_{t+1})(1 - \gamma_{t+1}) + \mu_t} - 1, \quad T_t^f = \frac{b_{t+1}}{R}\tau_t \quad (24)$$

where all variables are evaluated at the constrained optimal allocations.

The proof notes that the specified policy instruments demonstrate that the conditions characterizing the competitive equilibrium are identical to those of the constrained optimal allocations (see Propositions 1 and 2).

The role of the tax on debt is Pigouvian, as it aims to correct the private cost of borrowing, which is distorted by debt guarantees. Note that the tax on debt is only strictly positive when debt guarantees are activated with strictly positive probability in the next period, an event that occurs when the dividend payout constraint becomes binding in the economy. Hence, the tax on debt is prudential.

Equity injections — An alternative policy to the debt guarantees is the injection of equity. In order to facilitate a comparison with debt guarantees, we consider an equity injection that is a fraction of the amount of individual debt held by the firm, i.e., the number of new shares issued is such that the value of equity injections equals $e_t b_t$. In particular, the government mandates firms to issue new shares and transfer those shares to the households, which then receive the future dividend payments.

The firms' objective can be expressed as maximize $\mathbb{E}_t \sum_{j=0}^{\infty} m_{t+j}(d_{t+j} - e_t b_t)$ subject to the flow of funds constraint $b_t + d_t + i_t + \psi(k_t, k_{t+1}) \leq F(z_t, k_t, h_t) - w_t n_t + \frac{b_{t+1}}{R} + e_t b_t(1 - \tau_t) + T_t^f$ and the same financial constraints in problem (10). The first-order condition with respect to debt yields:

$$1 + \eta_t = R\mathbb{E}_t m_{t+1}(1 + \eta_{t+1}(1 - e_{t+1})) + R\mu_t \qquad (25)$$

At the beginning of each period, the total number of shares can be renormalized to one. Hence, the rest of the equilibrium conditions remain the same yielding a similar proposition to the one stated for debt guarantees.

Proposition 4 *The government can implement the constrained optimal allocations through a combination of equity injections, taxes on debt, and lump sum taxes. In particular:*

$$e_t = \frac{\Upsilon_t}{b_t}, \quad T_t = \Upsilon_t(1 + \varphi), \quad \tau_t = \frac{\mathbb{E}_t m_{t+1}(1 + \eta_{t+1}) + \mu_t}{\mathbb{E}_t m_{t+1}(1 + \eta_{t+1}(1 - e_{t+1})) + \mu_t} - 1, \quad T_t^f = \frac{b_{t+1}}{R}\tau_t \quad (26)$$

where all variables are evaluated at the constrained optimal allocations.

The proof follows the same steps as Proposition 3. Note from (25) that the shadow cost of tightening the dividend payout constraint in a state $t + 1$, in which the government is recapitalizing firms, is reduced by a factor of $(1 - e_{t+1})$. Comparing this condition with (23) yields that the tax on debt is smaller than the one required for bailout guarantees. Intuitively, equity injections also involve a cost for shareholders because they perceive a reduction in their ownership of the firm. In addition, the tax on debt is strictly positive only if $\varphi > 0$. Intuitively, firms do not internalize that when they are bailed-out, the social costs of the bailout are paid by other agents in the economy. As a result, they would take too much debt in the absence of a tax on debt.

Lump-sum transfers — The final policy instrument we consider is a lump-sum transfer that is independent of any individual choice made by the firms. In contrast to the above polices, first-order conditions are unaffected when the government bails out firms with a lump-sum transfer, which implies that no prudential policy is required. Intuitively, the government provides insurance in such a way that firms see the benefits from the bailout as entirely exogenous from their financial decisions. As a result, the government can implement the

constrained optimal allocations without resorting to additional instruments. It is important to keep in mind that lump-sum transfers are extremely impractical for reasons that are not modeled in this paper In this respect, we see the implementation of lump-sum transfers as purely illustrative.

Financial Intermediaries — In practice, central banks implement a variety of policies with the aim of facilitating the corporate sector's access to credit, some of which involve bailouts to financial institutions. We would like to point out that both the prudential and ex-post policy measures we have described can also be applied to financial intermediaries in a simple extension of our model.[10] To simplify the analysis, we do not model financial intermediaries and consider only direct bailouts to firms. The crucial factor for our analysis is that this intervention relaxes balance sheets across the economy and mitigates the fall in credit and investment that occurs during crises.

4   Quantitative Analysis

Numerical Solution — The numerical solution to the model involves several challenges. First, there are the well-known complications of non-linearities introduced by the absence of complete markets and, in particular, the occasionally binding financial constraints. In addition, the state variables in the model are not confined to a narrow region of the state space. We use a policy function iteration algorithm whereby we approximate the equilibrium functions over the entire state space and check that the equilibrium conditions are satisfied at all grid points. A key feature of this algorithm is that the two financial constraints are allowed to bind only in some states of nature. The algorithm also captures the high non-linearities close to these constraints.

Calibration and Functional Forms — We calibrate the model to an annual frequency using data from the U.S. economy. Parameter values are summarized in Table 1.

We make the following assumptions regarding forms for preferences and technology:

---

[10]In particular, one could modify the problem of the corporate entities so that instead of carrying out production activities on their own, they provide intra-period loans to firms in the form of capital goods. It is easy to see that this modified setup would be isomorphic to our baseline model. As a result, one could reinterpret the model as applied to the banking sector. See also Bianchi (2011) for a mapping between taxes on debt, capital requirements, and margin requirements.

$$u(c - G(n)) = \frac{\left[c - \chi \frac{n^{1+\frac{1}{\omega}}}{1+\frac{1}{\omega}}\right]^{1-\sigma} - 1}{1 - \sigma}$$

$$F(z, k, h) = z k^{\alpha} h^{1-\alpha}$$

$$\psi(k_t, k_{t+1}) = \frac{\phi_k}{2} \left(\frac{k_{t+1} - k_t}{k_t}\right)^2 k_t$$

We assume that TFP shocks and financial shocks are independent processes. TFP follows a first order autoregressive process:

$$log(z_t) = \mu_z + \rho \, log(z_{t-1}) + \epsilon_t, \qquad \epsilon_t \sim N(0, \sigma_\epsilon)$$

Financial shocks follow a two-state Markov chain with values given by $\left\{\kappa^L, \kappa^H\right\}$ and transition matrix:

$$P = \begin{bmatrix} P_{L,L} & 1 - P_{L,L} \\ 1 - P_{H,H} & P_{H,H} \end{bmatrix}$$

We need to assign values to 16 parameters that we classify in two sets. The first subset includes parameters that are chosen independently of equilibrium conditions or are calibrated using steady state targets, some of which are typical in the business cycle literature. This subset is given by $\{\alpha, \delta, \sigma, \omega, \beta, R, \varphi, \chi, \mu_z\}$. The capital share α is set to 0.33; the depreciation rate is set at 10 percent; the risk aversion σ is set to 1.5; the Frisch elasticity of labor supply ω is set to 2. The value of β is pinned down by setting the capital-output ratio equal to 2.5 in a deterministic steady state with $\kappa = 0$, which results in a value of 0.964.[11] R is set to 1.02 to capture the low interest rate in mid 2000. Note that $\beta R < 1$ guarantees that there is a well-defined stochastic steady state. For φ, which is more specific to our framework, we choose a benchmark value of 10 bps.[12] Clearly, this parameter is important for the welfare results, so we will conduct extensive sensitivity analysis. Finally, we normalize the labor

---

[11]Due to precautionary savings, average capital is 2.6, which is still within the range of empirical estimations.

[12]We also note that given the rest of the parameter values, we find that financing the bailout with a distortionary tax on labor and setting $\varphi = 0$ yield very similar results that our benchmark value for φ.

disutility coefficient χ and the average value of the TFP shock so that employment and output equal one in the deterministic steady state.

The remaining parameters are $\left\{\rho, \sigma_\epsilon, \phi_k, \kappa^L, \kappa^H, \bar{d}, P_{L,L} \, P_{H,H}\right\}$ and are set to jointly match a set of long-run moments from the economy where bailouts are absent.[13] These moments are: (1) a standard deviation of output of 2 percent; (2) an autocorrelation of output of 0.50; (3) a standard deviation of investment of 10 percent; (6) an average leverage ratio of 45 percent; (5) four credit crunches occurring every 100 years; (7) an average duration of a credit crunch of 3 years; (8) a probability of a binding dividend constraint equal to the probability of a binding collateral constraint; and (9) a probability of a binding collateral constraint conditional on $\kappa = \kappa^H$ equal to zero. While all these parameters affect all the target moments, each parameter has a more significant impact on one particular moment, as we explain below.

The TFP shock is discretized into 3 states using the Tauchen and Hussey procedure. We set ρ and σ_ϵ to match the volatility and autocorrelation of output between 1950-2010, which yields $\rho = 0.24$ and $\sigma_\epsilon = 0.01$. As in the macro-international literature, the adjustment cost on capital is calibrated to match the standard deviation of investment between 1950-2010. This calibration yields $\phi_k = 3$, a standard value.

We set the value of κ^H high enough so that the collateral constraint never binds when κ takes this value. The value of κ^L is set to target an average leverage of 45 percent. The choice of a leverage ratio of 45 percent corresponds the ratio of credit market instruments to net worth in the years preceding the 2007 financial crisis (see Table B102 in the Flow of Funds database).

The dividend threshold $\bar{d}$ is more difficult to pin down from the data because it is difficult to identify whether constraints on equity financing or on borrowing are more pervasive. For simplicity, we set $\bar{d}$, so that the borrowing constraint and the dividend payout constraint bind with the same probability in the long run. This yields $\bar{d} = 0.05$ and probabilities of binding constraints equal to 8 percent.

---

[13]To the extent that optimal bailouts in our model have similar features to the data, one could argue that it would be more appropriate to target the moments of the economy with the optimal bailout policy. Since we will experiment with different values of φ,, it is more practical to calibrate the economy without bailouts. In any case, this choice does not have a significant impact on the results.

Table 1: Calibration

	Value	
Interest rate	$R - 1 = 0.02$	
Discount factor	$\beta = 0.97$	
Depreciation rate	$\delta = 0.1$	
Share of capital	$\alpha = 0.34$	
Labor disutility coefficient	$\chi = 0.66$	
Risk aversion	$\sigma = 1.5$	
Frisch elasticity parameter	$\omega = 2.0$	
Efficiency cost	$\varphi = 10bps$	
Parameters set by simulation	**Value**	**Target**
TFP shock		
	$\sigma_\epsilon = 0.01$	SD of GDP=2.0
	$\rho = 0.24$	Autocorrelation of GDP=0.45
Financial shock		
	$\kappa_L = 0.43$	Average leverage =45 percent
	$\kappa_H = 0.54$	Non-binding collateral constraint
	$P_{HH} = 0.9$	Probability of credit crunch=4 percent
	$P_{LL} = 0.1$	Duration of credit crunch=3 years
Adjustment cost	$\phi_k = 2.0$	SD of investment =9 percent
Dividend threshold	$\bar{d} = 0.05$	Equalize prob. binding constraints

We calibrate the transition matrix for the financial shock to target the frequency and the duration of financial crises. We define a financial crisis as an episode in which credit falls below two standard deviations. The financial crisis begins in the period in which credit falls below one standard deviation, providing that some point within the next two years, the level of credit falls at least two standard deviations below its mean. The crisis ends when the level of credit exceeds one standard deviation below its mean. Consistent with the empirical literature (e.g. Reinhart and Rogoff, 2009), we target an incidence of crises of 4 every 100 years and an average duration of 3 years. This procedure yields that $P_{L,L}$, which mostly affects the duration of crises, equals 0.1. $P_{H,H}$, which primarily affects the long-run probability of a crisis, equals 0.9. With these values, the economy spends only 11 percent of the time with negative financial shocks.

5   Results

We begin by showing the equilibrium policy functions of the model. We then proceed to simulate the model and assess the macroeconomic and welfare implications of bailouts.

Our quantitative analysis delivers 5 main findings: (1) the optimal bailout is approximately 2 percentage points of GDP and it is increasing in leverage; (2) the resulting increase in leverage exposes the economy to more frequent credit crunches; (3) output collapses significantly more in the absence of bailouts; (4) when bailouts are unanticipated the optimal intervention is reduced by half and the recession also becomes less severe; (5) a bailout policy which is not complemented with prudential policy might leave the economy more exposed to more frequent and more severe financial crises.

5.1   Laws of Motion

Figure 4 shows the laws of motion for debt, capital, and leverage in the economy as a function of the current level of debt, for a value of capital approximately equal to the average value and an average TFP shock. Since mean output is approximately one, all variables can be interpreted as ratios with respect to the average output. The superior (inferior) panel corresponds to a positive (adverse) financial shock. The straight lines correspond to the competitive equilibrium without bailouts (NBP), and the dashed lines correspond to the economy with the optimal bailout policy (OBP). Let us first describe the behavior of NBP before analyzing the effects of credit intervention.

As Figure 4 shows, the occasionally binding constraints produce a non-monotonic law of motion for debt. For low values of current debt, the collateral constraint is not binding. As the value of current debt increases, the demand for debt increases. When the current level of debt reaches 1.2, the collateral constraint becomes binding. Since firms need to cut down on investment, the borrowing capacity shrinks. As a result, for $b > 1.2$ in the inferior panel, the next period debt holdings decrease in current debt holdings. For this law of motion, the dividend payout constraint becomes binding approximately at the same value of debt.

In order to understand how bailouts affect the competitive equilibrium, it is useful to first analyze its effects during periods in which the financial constraint becomes binding. As

Figure 4 shows, bailouts allow firms to borrow more during these periods because as firms receive the transfers, they can allocate these funds to invest more in capital, which boosts their capacity to borrow.

In the region where the financial constraints are not binding, firms also borrow more in the competitive equilibrium with bailouts because there is a lower incentive to accumulate precautionary savings during normal times since crises become less severe as a result of bailouts. Higher borrowing will lead in turn to a higher probability that the economy becomes financially constrained in the future. This effect is markedly stronger when the economy is in a positive financial shock and has a relatively large amount of debt.

As Figure 4 shows, OBP features more capital accumulation when financial constraints become binding because bailouts provide more funds, which allows firms to invest more. The effects before the constraint bind are generally ambiguous due to two opposing forces. On one hand, the fact that OBP effectively has more insurance available increases the demand for risky assets, in this case, capital. On the other hand, since capital is also a form of savings, the demand for capital decreases. Overall, we find that there is less demand for capital in OBP, except for relatively low values of the capital stock.

5.2   Non-linear Impulse Responses

This section conducts simulations of the economy with and without bailouts to demonstrate how the time-series are affected by the presence of bailouts.
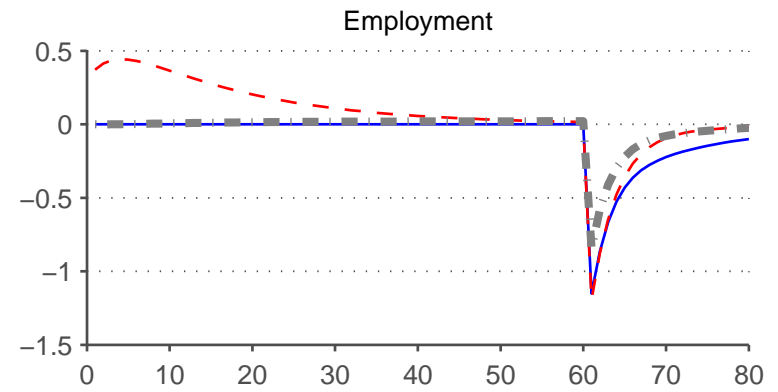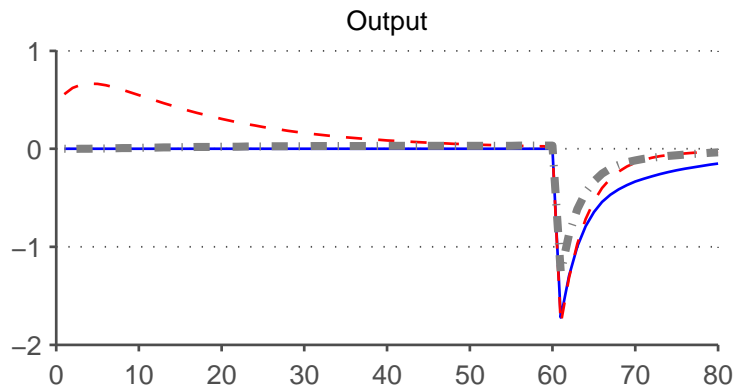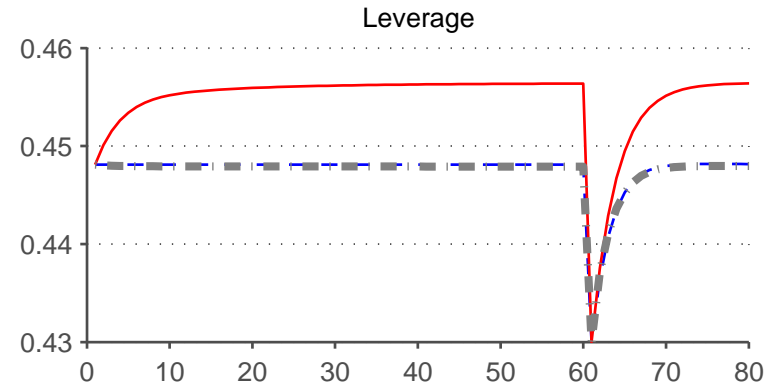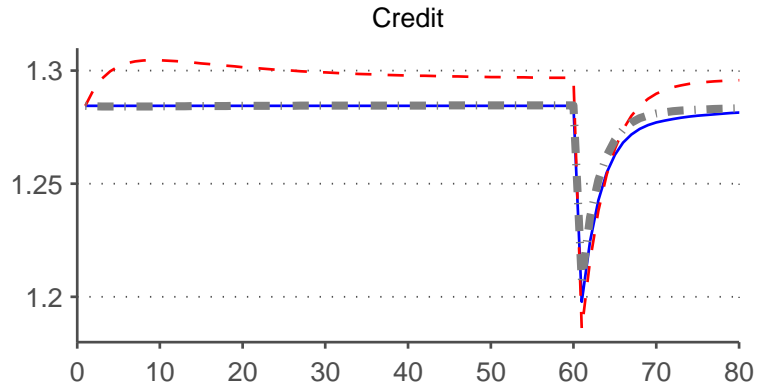
Our first experiment is a non-linear impulse response. In particular, we simulate the economy with a constant TFP equal to the average and a financial shock that has a high value at the beginning of the simulations, then falls in what we refer to as the credit crunch, and then again achieves a high value. For illustrative purposes, we start the economy at a level of bonds and capital at which the competitive equilibrium converges after a long sequence of κ^H and a TFP shock equal to the average. In this experiment, the shock hits after 40 periods (years) so that the economy with the optimal bailout remains approximately constant in the absence of any other shock. We also compute the simulations of the economy where government intervention is unanticipated when the negative financial shock hits. After the initial "surprise," we assume for simplicity that the economy returns in the following

period to a situation in which there is a policy of no bailouts. That is, the government switches from NBP to OBP in period 40 and then returns to NBP the following period. Each of these switches is unanticipated.

Figures 1 and 2 show the simulations for the economy with the optimal bailout policy (OBP), for the economy without bailouts (NBP), and for the economy where the bailout is unanticipated (UBP). The variables we consider in Figure 1 are credit, leverage, output, employment, investment, and the exogenous shocks. Figure 2 plots the sequence of dividends, risk premium, bailouts, and taxes on debt as defined in Proposition 2.

When the bailout is unanticipated, the economy does not experience as sharp a decline in credit flows, investment, and output, as shown in Figure 1. Instead, when the bailout policy is anticipated, there is a trade-off: on one hand, the economy increases the amount of debt in response to the insurance provided by the government's intervention; on the other hand, the bailout relaxes balance sheet constraints ex-post. In fact, as the negative financial shock hits in period 40, both economies experience sharp deleveraging effects. For the optimal bailout policy, however, the effects of the credit crunch are less protracted. In fact, it takes 2 more years to recover approximately 75 percent of the output loss when there is no government intervention. Moreover, the cumulative loss in output for NBP is 11.2 percent, whereas it is 6.6 percent for OBP.

Figure 2 also shows that the magnitude of the bailout in the simulated credit crunch is approximately two percentage points of GDP. Considering that the cumulative loss in output is reduced by 4 percent, the multiplier effect of the bailout over output is approximately 2.2. Finally, figure 2 also shows the impact of bailouts on risk premium measured as the difference between the expected return on capital for firms and the return on bonds. Interestingly, at t=0, risk premium is smaller for the economy with bailouts. However, as leverage increases over the experiment, risk premium increases slightly for the economy for OBP.
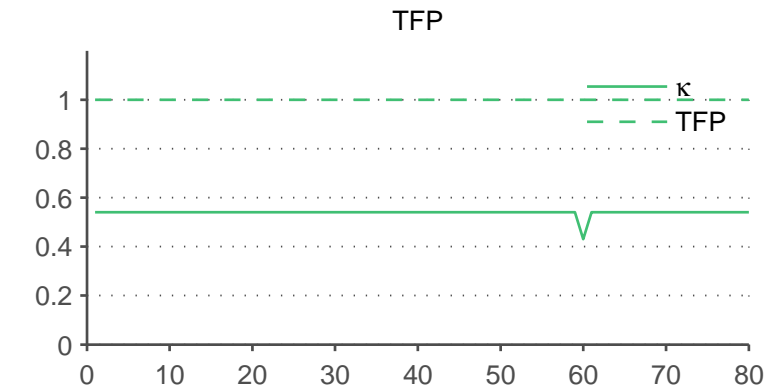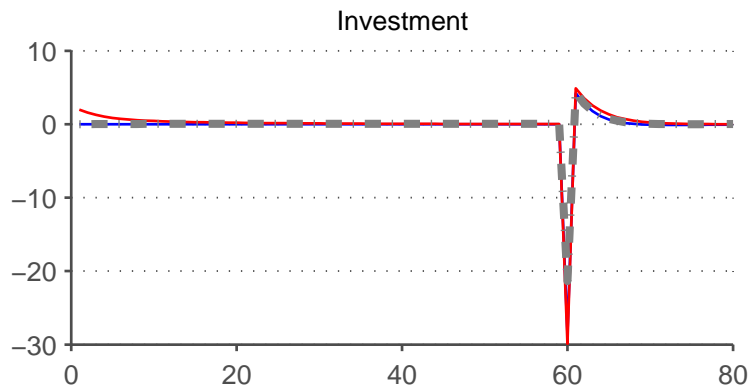
Figure 1: Non-linear Impulse Responses
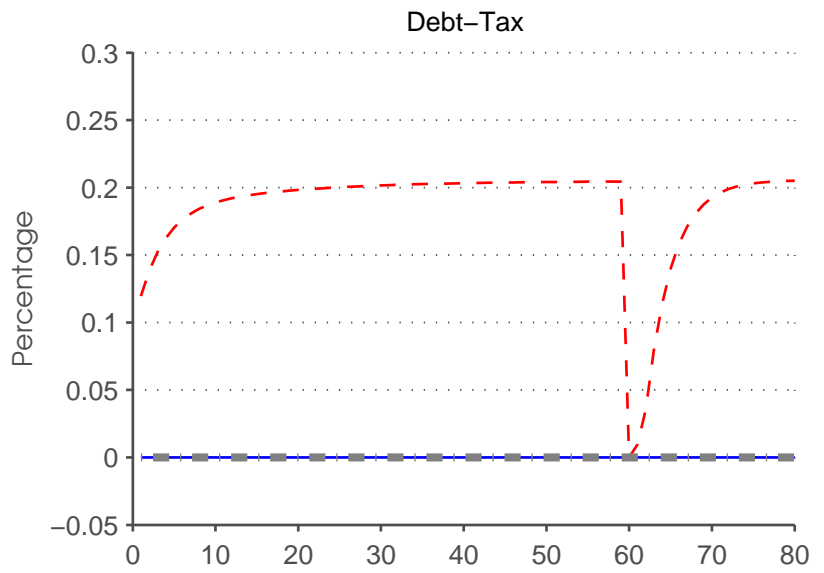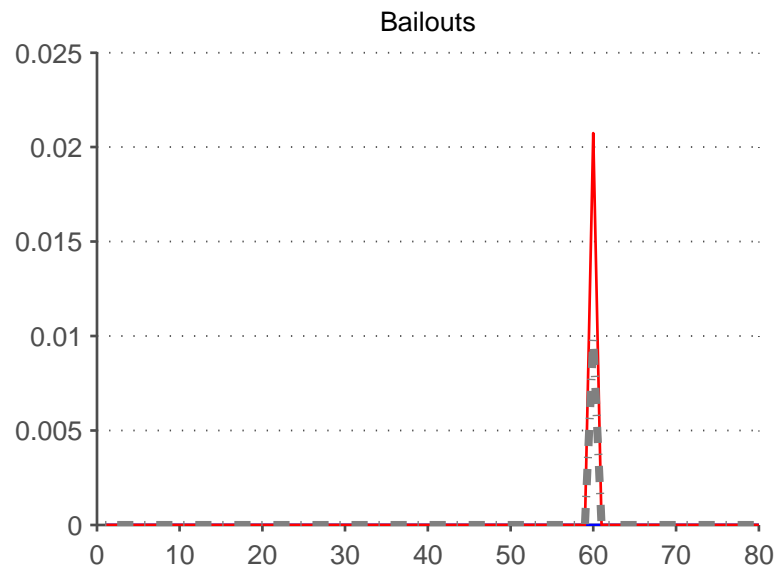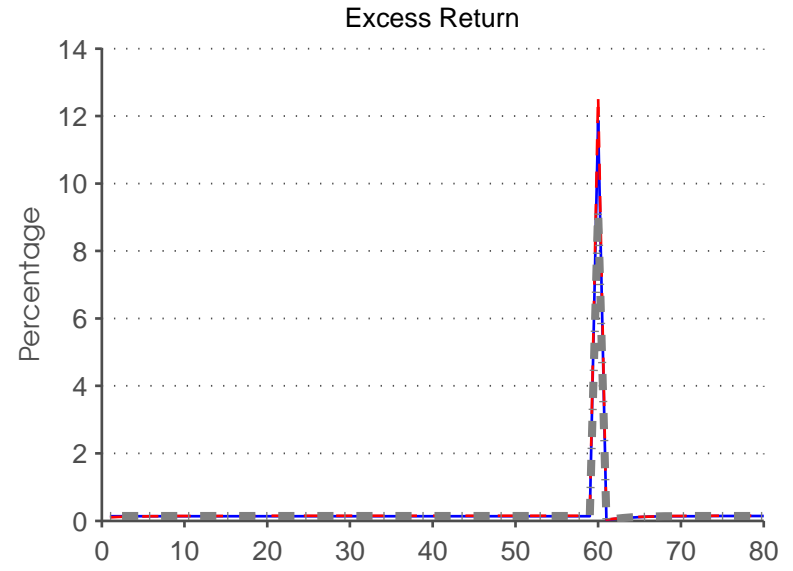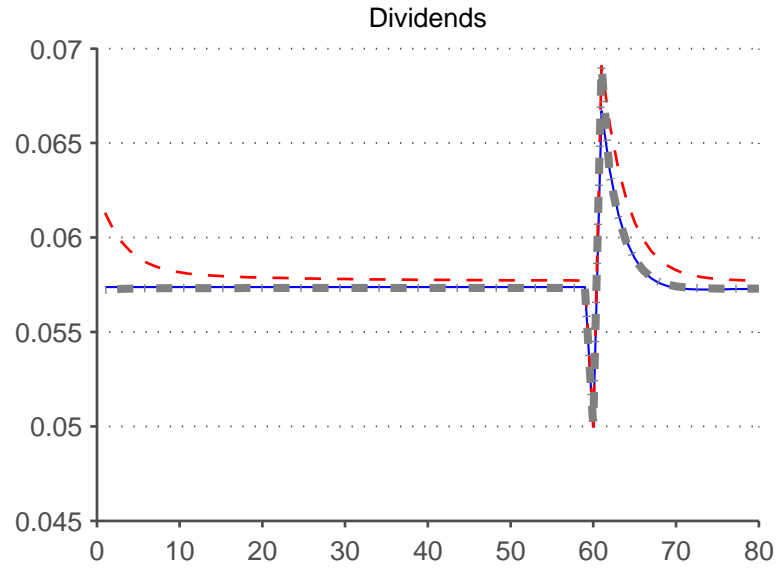
Figure 2: Non-linear Impulse Responses

5.3   Prudential Policy

We now examine the importance of the prudential instruments to complement the bailout policy. As Figure 1 shows, OBP features a tax on debt during the tranquil times preceding the credit crunch. The tax is initially around 0.12 percent and rises to 0.2 percent as the amount of leverage increases in the run up to the crisis.

To see the importance of the prudential tax on debt, consider an economy where the bailout policy is implemented with the use of debt guarantees as defined in Proposition 3, but where the tax on debt is set to zero. We reconstruct the non-linear impulse response from Figure 1, but now we compare the economy without bailouts (NBP) with the economy with bailouts but without a prudential tax on debt. Figure 5 shows the results of this experiment.

As Figure 5 shows, the lack of prudential policy results in an even larger amount debt relative to the economy where prudential policy is used together with a bailout policy. This increase in debt leads to a sudden crash in period 40, which generates a recession that is now comparable to the economy without credit intervention. In fact, the cumulative loss in output is now about the same for the economy with bailouts and for the economy without bailouts. Moreover, the economy without prudential policy remains exposed to more frequent credit crunches.

5.4   Welfare

Next, we compute the welfare gains from policy intervention. Following the Lucas calculation, we compute for every possible state the percentage increase in consumption that leaves a household indifferent between living in an economy with the optimal government policy and remaining in an economy without government intervention. The results from these calculations are plotted in Figure 3 for an average TFP shock and an adverse financial shock. Note that the welfare gains are positive in all states and reach the maximum levels when the economy is highly leveraged.[14] Overall, the welfare gains from implementing OBP are on average close to 0.1 percentage points of permanent consumption and are compara-

---

[14]For graphical purposes, we attach a value of zero for those states that are non feasible, i.e. those with very high levels of debt.

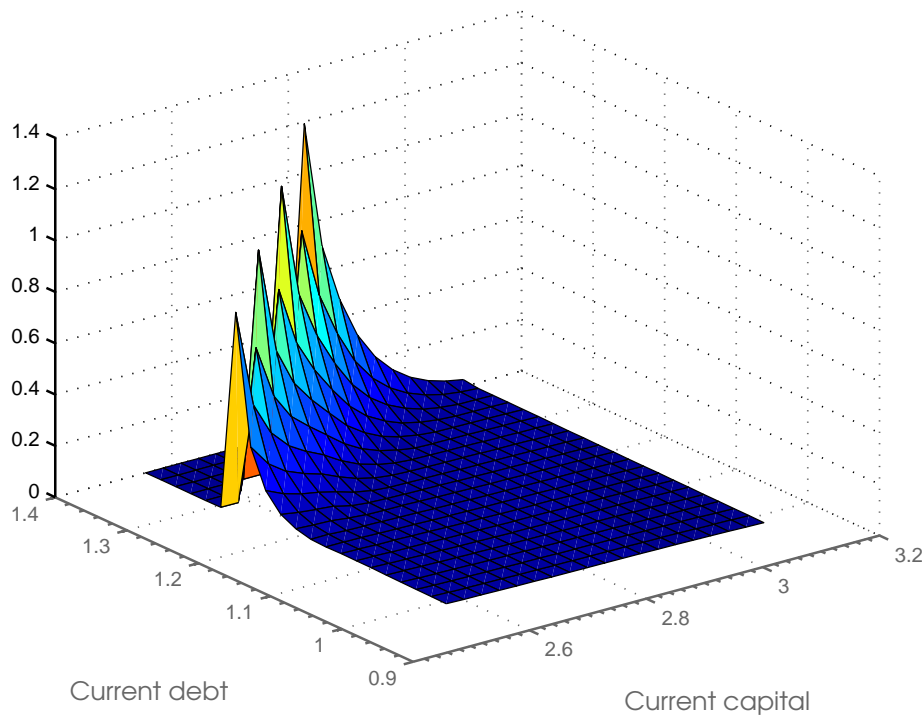ble to the gains obtained in the macro-prudential policy literature based on systemic risk externalities.[15]

Figure 3: Welfare Gains from Optimal Intervention for $\kappa = \kappa^L$ and average TFP shock

6 Conclusion

In this paper, we developed a quantitative framework to examine the effects of bailouts. The key novelty of our work is that we investigate what is the optimal bailout policy considering both the effects of relaxing balance sheet constraints ex-post and the increase in leverage that occurs ex-ante.

Overall, we find that the optimal intervention requires a bailout of approximately two percentage points of GDP during a credit crunch. While this policy slightly increases the

---

[15]However, maximum welfare gains across the ergodic distribution are larger here because bailouts have a large current impact on welfare. On the other hand, the welfare gains from prudential policy peak during good times because they reduce expected future volatility (see Bianchi and Mendoza (2010), Bianchi (2011))

exposure to a credit crunch, it generates larger gains by significantly reducing the effects of a credit crunch on the real sector. In particular, the loss in output falls by more than 40 percent when the government implements the optimal bailout policy.

Our findings are particularly relevant to the ongoing debates about the appropriate role of central banks during financial crises. Our analysis suggests that systemic insurance provided by the government should be part of the financial system's safety net. The design of this systemic insurance, however, should be complemented by macro-prudential policy during good times to offset incentives for excessive risk-taking.

References

BENIGNO, G., H. CHEN, C. OTROK, A. REBUCCI, AND E. YOUNG (2010): "Financial Crises and Macro-Prudential Policy," Mimeo, University of Virginia.

BERNANKE, B., AND M. GERTLER (1989): "Agency costs, net worth, and business fluctuations," *American Economic Review*, (1), 14–31.

BIANCHI, J. (2011): "Overborrowing and Systemic Externalities in the Business Cycle," *American Economic Review*, 101(7), 3400–3426.

BIANCHI, J., AND E. G. MENDOZA (2010): "Overborrowing, Financial Crises and 'Macroprudential' Policy," NBER Working Paper No. 16091.

BIGIO, S. (2011): "Financial Risk Capacity," Mimeo, NYU.

CABALLERO, R., AND A. KRISHNAMURTHY (2001): "International and domestic collateral constraints in a model of emerging market crises," *Journal of Monetary Economics*, 48(3), 513–548.

CHARI, V., AND P. KEHOE (2009): "Bailouts, time inconsistency and optimal regulation," Federal Reserve Bank of Minneapolis Staff Report, November.

DEL NEGRO, M., G. EGGERTSSON, A. FERRERO, AND N. KIYOTAKI (2010): "The great escape? A quantitative evaluation of the Feds non-standard policies," Mimeo, Federal Reserve Bank of New York.

DIAMOND, D., AND R. RAJAN (2009): "Illiquidity and interest rate policy," NBER Working Paper.

DURDU, B., AND E. G. MENDOZA (2006): "Are asset price guarantees useful for preventing Sudden Stops?: A quantitative investigation of the globalization hazard–moral hazard tradeoff," *Journal of International Economics*, 69(1), 84–119.

FARHI, E., AND J. TIROLE (2010): "Collective Moral Hazard, Maturity Mismatch and Systemic Bailouts," Forthcoming, American Economic Review.

GERTLER, M., AND P. KARADI (2011): "A model of unconventional monetary policy," *Journal of Monetary Economics*, 58(1), 17–34.

GERTLER, M., AND N. KIYOTAKI (2010): "Financial intermediation and credit policy in business cycle analysis," Handbook of Monetary Economics, forthcoming.

GERTLER, M., N. KIYOTAKI, AND A. QUERALTO (2011): "Financial Crises, Bank Risk Exposure and Government Financial Policy," Mimeo, NYU.

GILCHRIST, S., J. SIM, AND E. ZAKRAJŠEK (2010): "Uncertainty, Financial Frictions, and Investment Dynamics," .

GUERRIERI, V., AND G. LORENZONI (2011): "Credit Crises, Precautionary Savings and the Liquidity Trap!," University of Chicago mimeo.

JEANNE, O., AND A. KORINEK (2010): "Managing Credit Booms and Busts: A Pigouvian Taxation Approach," NBER Working Paper.

——— (2011): "Macroprudential Regulation Versus Mopping Up After the Crash," Mimeo, University of Maryland.

JERMANN, U., AND V. QUADRINI (2010): "Macroeconomic effects of financial shocks," Forthcoming, American Economic Review.

KEISTER, T. (2010): "Bailouts and financial fragility," Mimeo, Federal Reserve Bank of New York.

KEISTER, T., AND V. NARASIMAN (2011): "Expectations versus fundamentals: does the cause of banking panics matter for prudential policy?," note=Mimeo, Federal Reserve Bank of New York.

KELLY, B., H. LUSTIG, AND S. VAN NIEUWERBURGH (2011): "Too-Systemic-To-Fail: What Option Markets Imply About Sector-wide Government Guarantees," NBER Working Paper.

KIYOTAKI, N., AND J. MOORE (1997): "Credit Cycles," *Journal of Political Economy*, 105, 211–248.

LORENZONI, G. (2008): "Inefficient Credit Booms," *Review of Economic Studies*, 75, 809–833.

MENDOZA, E. G. (2010): "Sudden Stops, Financial Crises, and Leverage," *The American Economic Review*, 100(5), 1941–1966.

MIDRIGAN, V., AND T. PHILIPPON (2011): "Household Leverage and the Recession," CEPR Discussion Paper No. DP8381.

MILLER, M., AND F. MODIGLIANI (1961): "Dividend policy, growth, and the valuation of shares," *the Journal of Business*, 34(4), 411–433.

MYERS, S., AND N. MAJLUF (1984): "Corporate financing and investment decisions when firms have information that investors do not have," *Journal of financial economics*, 13(2), 187–221.

REINHART, C., AND K. ROGOFF (2009): *This time is different: Eight centuries of financial folly.* Princeton Univ Pr.

SCHNEIDER, M., AND A. TORNELL (2004): "Balance sheet effects, bailout guarantees and financial crises," *Review of Economic Studies*, 71(3), 883–913.

SHLEIFER, A., AND R. VISHNY (1997): "A Survey of Corporate Governance," *The Journal of Finance*, 52(2), 737–783.

7 Appendix

Proof of Proposition 1

The household and firms problems are a convex program. Conditions (2)-(4), (6)-(8) and (10)-(17) are necessary and sufficient for household and firm optimization respectively. By Walras Law, (18) is satisfied.

Proof of Proposition 2

Formally, denoting by Υ_t^* the level of transfers implemented by the planner, the optimal solution is a set of sequences $\left\{k_{t+1}^*, b_{t+1}^*, d_t^*, c_t^*, \Upsilon_t^*, h_t^*, w_t^*, p_t\right\}_{t \geq 0}$ that solves the following problem:

$$\max_{k_{t+1}, b_{t+1}, d_t, c_t, \Upsilon_t, h_t, p_t} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t - G(h_t))$$

$$b_t + c_t + k_{t+1} + \psi(k_t, k_{t+1}) \Upsilon_t \varphi = (1-\delta)k_t + F(z_t, k_t, h_t) + \frac{b_{t+1}}{R}$$

$$(1-\delta)k_t + F(z, k_t, h_t) - w_t^* h_t^* + \frac{b_{t+1}}{R} + \Upsilon_t - b_t - k_{t+1} - \psi(k_t, k_{t+1}) \geq \bar{d}$$

$$b_{t+1} \leq \kappa k_{t+1}$$

$$\text{where } h_t^*, w_t^* \quad w_t^* = G'(h_t^*) = F_L(z_t, k_t^*, h_t^*)$$

$$p_t u'(t) = \beta \mathbb{E}_t u'(t+1)(d_t + p_{t+1})$$

Given that the problem is convex, first-order conditions are necessary and sufficient. We attach again η_t and μ_t to the financial constraints (notice that the last condition does not bind):

$$\varphi u'(c_t - G(h_t)) \geq \eta_t \text{ with equality if } \Upsilon_t > 0$$

$$(1+\eta_t) u_{c,t} = R \mathbb{E}_t u_{c,t+1}(1+\eta_{t+1}) + R \mu_t$$

$$(1+\eta_t)(1+\psi_{2,t}) u_{c,t} = \mathbb{E}_t u_{c,t+1}\left[1 - \delta + F_{k,t+1} - \psi_{1,t+2}\right](1+\eta_{t+1}) + \kappa_t \mu_t$$

$$\begin{aligned}
G'(h_t) &= F_h(z_t, k_t^*, h_t^*) \\
\mu_t(\kappa_t k_{t+1} - b_{t+1}) &= 0, \quad \mu_t \geq 0 \\
\eta_t(d_t - \bar{d}) &= 0, \quad \eta_t \geq 0
\end{aligned}$$

which correspond to the equations listed in Proposition 2.

Figure 4: Laws of Motion for average value of capital and average TFP shock. The superior (inferior) row corresponds to $\kappa^H(\kappa^L)$
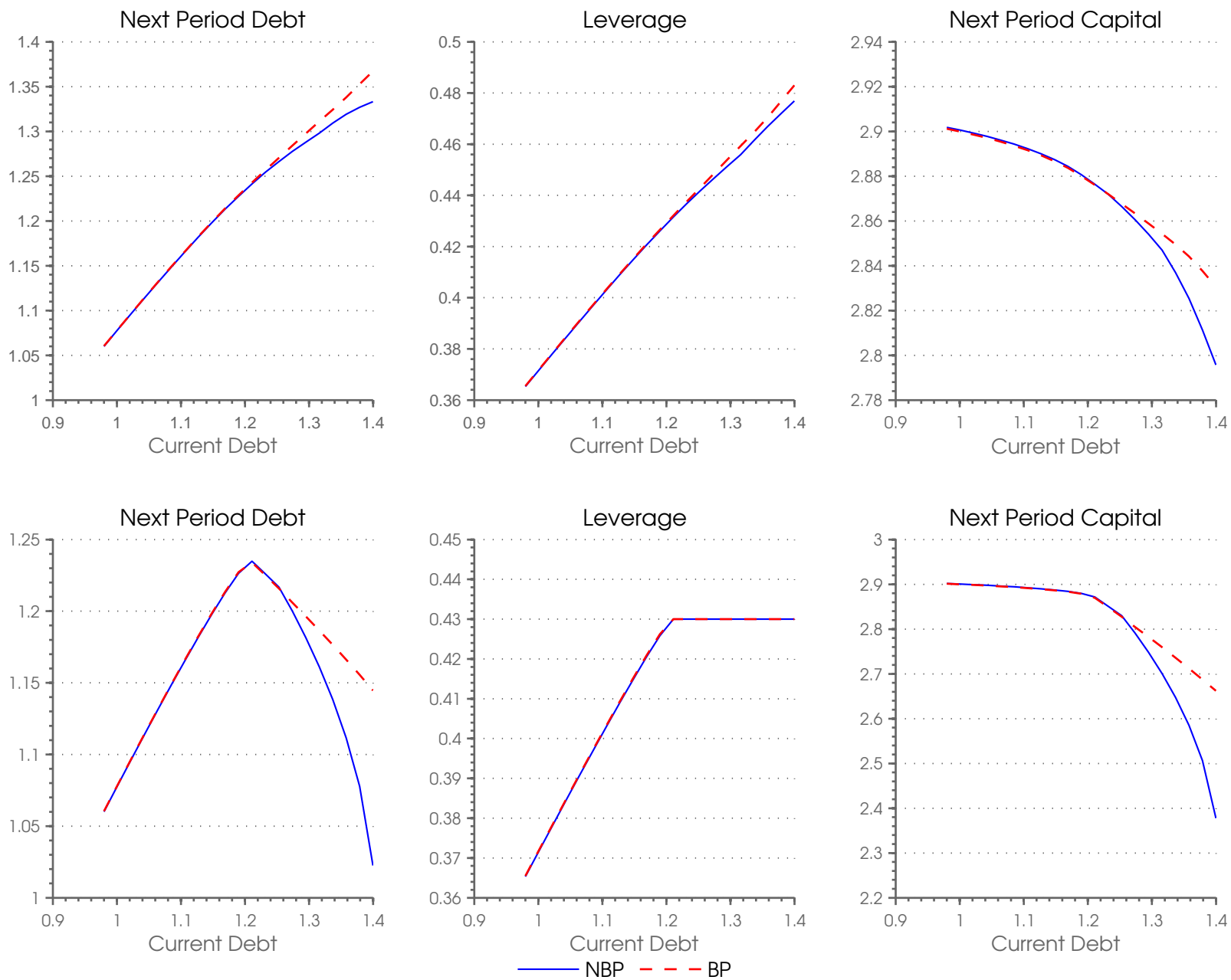
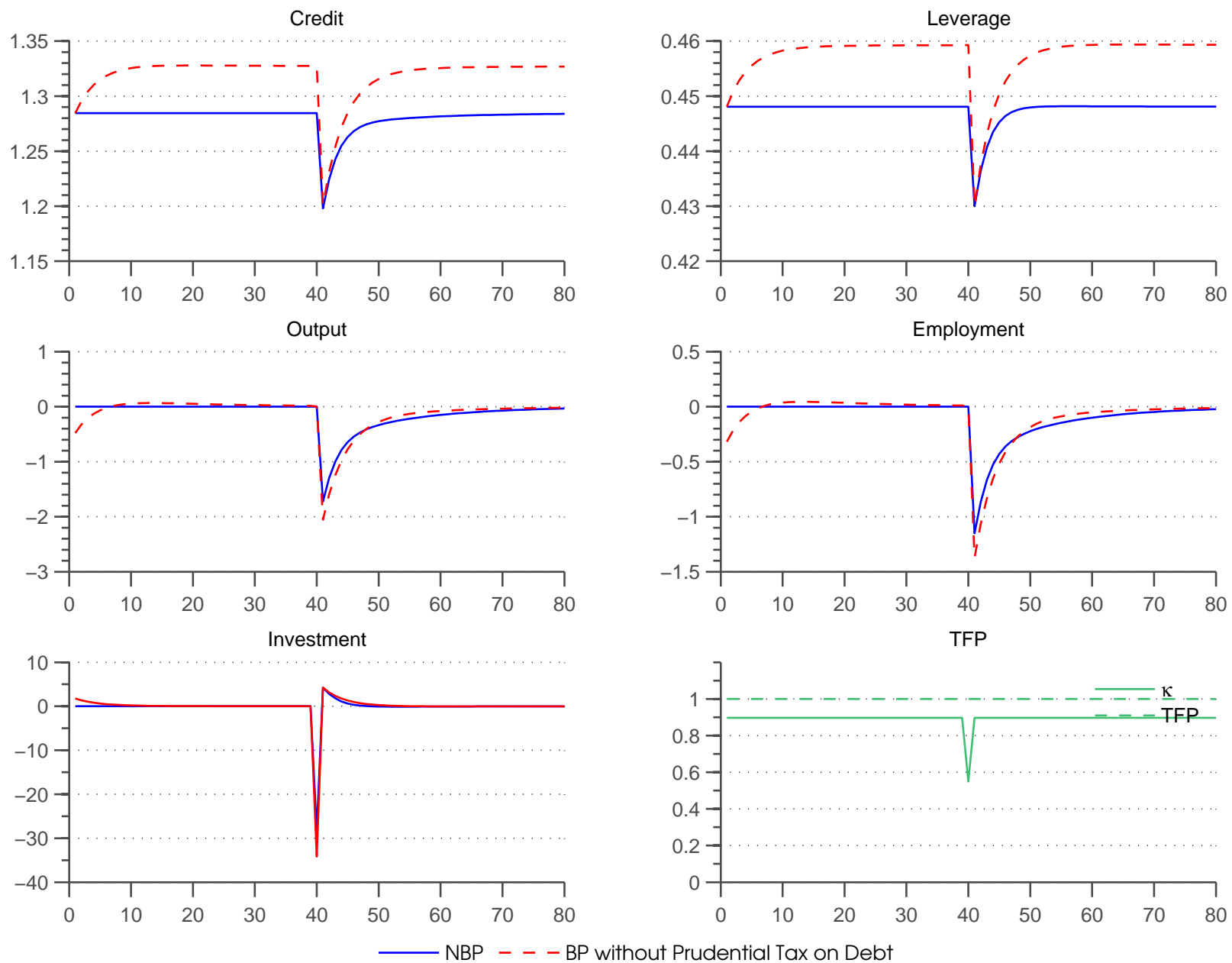**Figure 5:** Non-linear Impulse Responses without Prudential Policy

Table 2: Second Moments

	No Bailout Policy	Optimal Bailout Policy	Data
Output	2.3	2.2	2.3
Consumption	2.0	2.1	1.6
Employment	1.5	1.5	0.8
Investment	9.9	9.6	9.0

Note: Moments in the model correspond to the stochastic steady state. Moments in the data correspond to annual data from 1950-2010.