

Cost-Efficient Mechanisms against Debt Overhang*

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Abstract

We analyze the relative efficiency of government interventions against debt overhang when the government is either unable or unwilling to hurt long term debt holders. We first consider three interventions that have actually been used or seriously considered: buying back risky assets, injecting capital, and providing guarantees for new debt issuances. With symmetric information or compulsory participation, all the interventions are equivalent. Asset buyback and debt guarantee programs are still equivalent with voluntary participation and asymmetric information about the quality of banks' balance sheets, but they are strictly dominated by equity injections. We also find that buying back assets is the worse solution when there is adverse selection across asset classes, and that taking deposit insurance into account reduces significantly the net cost of government interventions. Finally, we show how to construct a constrained-efficient mechanism where the government makes a junior loan at a subsidized rate in exchange for call options on equity.

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A well-functioning financial sector steers an economy's savings to its most productive investments. If the financial sector is impaired and cannot intermediate between investors and producers, savings may not go to its most productive use, which can lead to large welfare losses.

One reason why the financial sector may become impaired is if financial institutions suffer large losses on their assets. A decline in the market value of a financial institution's assets leads to a decline in the market value of its equity, and raises the risk of a financial institution's debt. Risky debt deters owners of financial institutions from investing (lending) because some of the expected profits of investment go to debt holders instead of equity holders. This is the classical debt overhang problem (Myers (1977)). If many financial institutions experience losses at the same time, then debt overhang may bring bank lending to a standstill.

Indeed, there is wide agreement among observers that debt overhang is one of the main barriers to bank lending during the financial crisis of 2007/08 (Zingales (2008b) and Fama (2009), among many others). Recent empirical evidence suggests that banks have indeed significantly reduced their lending since the start of the financial crisis. Ivashina and Scharfstein (2008) show that new lending was 68% lower in the three-month period around the Lehman bankruptcy relative to the three-month period before the financial crisis. Using cross-sectional variation in bank access to deposit financing, the authors show that the reduction in lending reflects a reduction in credit supply by banks rather than a reduction in credit demand by borrowers. These results suggest that banks are suffering from debt overhang.

Even though there is wide agreement on the diagnosis of debt overhang, there is considerable disagreement about whether and how the government should intervene in the financial system. The original bailout plan proposed by former Treasury Secretary Paulson favors asset buy backs over other forms of interventions. Stiglitz (2008) argues that equity injections are preferable to asset buy backs because the government can participate in the upside if financial institutions recover. Soros (2009a) also favors equity injections over asset buy backs because otherwise banks sell their least valuable assets to the government. Diamond, Kaplan, Kashyap, Rajan, and Thaler (2008) argue that the optimal government policy should be a combination of both asset buy backs and equity injections because asset

buy backs establish prices in illiquid markets and equity injections encourage new lending. Bernanke (2009) suggests that in addition to equity injections and debt guarantees the government should purchase hard-to-value assets to alleviate uncertainty about bank solvency.

Other observers have pointed out common elements among the different interventions without necessarily endorsing a specific government intervention. Ausubel and Cramton (2009) argue that both asset buy backs and equity injections require to put a price on hard-to-value assets. Bebchuk (2008) argues that both asset buy backs and equity injections have to be conducted at market values to avoid overpaying for bad assets. Soros (2009b) argues that bank recapitalization has to be compulsory rather than voluntary. Kashyap and Hoshi (2008) compare the current situation with the Japanese banking crisis and argue that in Japan both asset buy backs and capital injections failed because the programs were too small. Scharfstein and Stein (2008) argue that government interventions should restrict banks from paying dividends because, if there is debt overhang, equity holders favor immediate payouts over new investment. Acharya and Backus (2009) suggests that public lender of last resort interventions would be less costly if they borrowed some of the standard tools used in private contracts for lines of credit. Zingales (2008b) argues that the government should force a debt for equity swap or debt forgiveness over other forms of intervention.

Veronesi and Zingales (2008) conduct the only empirical analysis of the different interventions to recapitalize the banking system. They perform an event study using data on stock returns and credit default swaps around the announcement of the revised Paulson Plan. They find that the revised Paulson plan, which combines capital injections with debt guarantees, increased the value of bank financial claims by \$109 billion at a taxpayer's cost of \$112-135 billions. They argue that there is no evidence that the revised Paulson Plan alleviated the debt overhang problem because improved investment opportunities should have created a net benefit of the program. They evaluate alternative interventions assuming the government was to achieve the same reduction in credit default swap prices as the revised Paulson plan and find that pure equity injections yield a higher net benefit than the revised Paulson plan or asset buy backs. Their preferred solution is a debt for equity swap as proposed by Zingales (2008a) and Zingales (2009).

The goal of our paper is to compare the efficiency and welfare implications of different government interventions in a standard model with debt overhang. Although we use our model to think about banks, we should emphasize that the model itself also applies to industrial firms. We consider both the ‘optimal’ mechanism and the main interventions undertaken since the start of the financial crisis. Before describing our results, we want to emphasize three important caveats of our analysis.

The first caveat is that we focus on one particular market failure, namely debt overhang. We analyze how debt overhang leads to welfare losses and we analyze how and at what cost the government can reduce these welfare losses. We allow for asymmetric information between the government and the private sector because the private sector is certainly better informed about assets values than the government. However, we maintain the assumption that there is symmetric information about asset values within the private sector. We make this assumption because we believe that information asymmetry within the private sector is a separate market failure and we want to isolate the impact of debt overhang from other market distortions (see Philippon and Skreta (2009) for an analysis with adverse selection among private investors).

The second caveat is that we focus on government interventions that allow banks to choose whether to participate in the intervention. The bank’s participation constraint means that the government cannot arbitrarily force banks to participate in government programs and that the government cannot alter the priority structure of existing financial contracts. We believe these constraints are plausible because they are either imposed by the legal system or arise in practice, especially when the government has to act promptly. For example, we note that a debt default of a major banks is perceived, rightly or wrongly, as too risky. If we drop this constraint and allow the government to force banks to restructure in bankruptcy or impose debt for equity swaps, then the government can implement the first best directly. We certainly do not wish to dismiss these solutions but rather want to analyze the optimal intervention if these solutions are perceived as too costly for reasons outside of our model.

The third caveat is that the government faces the same constraints in reducing debt overhang as the private sector. Debt overhang arises because equity holders cannot renegotiate with debt holders and because new investment opportunities cannot be separated

from existing assets. We think these assumptions are plausible because efficient renegotiation with dispersed debt holders is difficult and new investment projects usually require bank-specific inputs, especially if investment decisions are taken over a short time horizon. We thus assume that the government cannot renegotiate on behalf of shareholders or set up new banks to finance profitable investment opportunities. Again, we do not want to dismiss such solutions but rather analyze a setting in which the government faces the same constraints as the private sector.

In our benchmark model, banks differ across two dimensions. The first dimension is the quality of their investment opportunities. If the quality of investment opportunities is high, there is a welfare loss from not investing. The second dimension is the quality of assets in place. If asset quality is low, debt overhang is severe and banks under-invest. The information structure is such that, under symmetric information, the government and the banks only know the distribution of future investment opportunities and asset values. Under asymmetric information, the private sectors knows the asset values and investment opportunities of each bank but the government only knows the distribution.

We start by comparing the relative efficiency of three government interventions. The first intervention is the buy back of hard-to-value assets. This intervention corresponds to the original plan under the Troubled Asset Relief Act (TARP). The second intervention is capital injections in exchange for equity shares in banks. This intervention corresponds to the initiative effectively undertaken after the passage of TARP. The third intervention are government guarantees for new debt issues. This intervention corresponds to debt guarantees provided under TARP.

This comparison delivers two main results. First, if banks and the government have the same information, all interventions are equivalent. By equivalent, we mean that two interventions implement the same level of bank lending at the same expected cost for tax payers. Second, if banks have an informational advantage over the government, asset buy backs and debt guarantees are equivalent and capital injections dominate both asset buy backs and debt guarantees. By dominance, we mean that one intervention dominates another intervention if the former intervention has a lower expected cost than the latter intervention and both interventions implement the same level of investment.

The intuition for the symmetric information case is fairly straightforward. If banks and

the government have the same information, the participation constraint for banks is the same under all programs. Hence, the government can extract the expected payoff from future investment projects by keeping banks to their reservation utility of not participating in the program. This result is independent of the particular form of the government program.

The result under information asymmetry is more surprising and more difficult to prove. When banks can opt in government programs based on private information about asset quality, the government faces the problem of endogenous selection. This endogenous selection can be adverse since the banks whose assets are of poor quality are more likely to participate. The endogenous selection can also be beneficial, however, since banks with good investment opportunities are more also more likely to participate. Overall government programs might fail to increase net lending either because banks might prefer to keep the government's money on their balance sheet (inefficient participation), or because they would have been able to lend even without assistance (opportunistic participation). Tax payer money is wasted in both cases. To limit inefficient participation, all the programs must charge a strictly positive haircut. This means that only the banks whose internal rate of return exceeds the market return will opt in the program.

It is far from obvious whether asset buy backs, equity injections, and debt guarantees should face the same trade off between welfare gains from increasing lending on the one hand, and adverse selection and inefficient or opportunistic participation on the other hand.

It turns out that asset buy backs and debt guarantees are equivalent because both interventions charge a fixed price independent of the future bank equity value. For asset buy backs, the fixed price attracts banks with low quality assets because their assets would yield a lower price on private markets. Similarly, debt guarantees attracts banks with low quality assets because those banks are charged high interest rates to raise debt elsewhere. Since both interventions provide the same net benefit to banks, asset buy backs and debt guarantees attract the same set of participating banks, and thus yield the same investment at the same expected cost to the government.

Equity injections are different because the price of participation depends on the future bank equity value. The government takes an equity stake in the bank and thus participates in the upside of future investment opportunities. For a fixed size of the government program, the same low quality banks participate in equity injections as in the case of asset buy backs or

debt guarantees. However, some firms with good investment opportunities but low-quality assets do not participate because they do not want to share the upside with the government and rather invest alone. As a result, there is less inefficient participation in equity injections than other interventions and the expected cost of equity injections is lower.

We also study whether allowing banks to act upon their private information is beneficial or detrimental. The benefit of informed banks is that the government can use haircuts to discriminate among banks and avoid giving away tax payer money to the banks that do not have investment opportunities. The cost is of course that, with asymmetric information, banks earn informational rents. We find that interventions under symmetric information are more attractive if there are many profitable investment opportunities and if the government wants to implement an outcome close to the first best investment level. On the other hand, interventions under asymmetric information are more attractive if there are few profitable investment opportunities.

We believe that the results on symmetric information versus asymmetric information also shed light on the comparison of compulsory versus voluntary government interventions. The symmetric information case is equivalent to compulsory participation under the constraint that the program be *acceptable for the average bank*. We think this participation constraint is the right one for a meaningful comparison of voluntary versus compulsory programs because of political constraints or because of concerns for the welfare of a representative well diversified shareholder. Our results therefore show that compulsory programs are more attractive if there are many profitable investment opportunities and the chosen intervention is large.

We then study two extensions of the model. The first extension is to allow for heterogeneity of bank assets. This extension has no effect on equity injections or debt guarantees but raises the costs of asset buy backs. The reason is that banks choose to sell their lowest quality assets to the government. This result indicates that equity injections dominate asset buy backs for two separate reasons: adverse selection *across* banks due to inefficient participation and adverse selection *within* banks due to inefficient asset sales.

The second extension is the introduction of deposit insurance. Deposit insurance decreases the net costs of intervention, because the government is partially bailing out the FDIC, not only debt holders. In the case where deposits are never strictly safe, the costs of

intervention are actually negative and the government can and should implement the first best. In any case, deposit insurance does not alter our results on the relative efficiency of the different interventions.

Finally, we solve for the constrained optimum intervention. We construct an efficient mechanism where the government asks for call options on equity in exchange for providing a junior loan at a low interest rate.

We view our work as following the tradition of Modigliani and Miller (1958) on the irrelevance of capital structure. We seek to distinguish the economic forces that matter from the ones that do not, by providing a benchmark in which the form of government interventions is irrelevant. In particular, we show that under symmetric information all interventions implement the same allocation at the same expected costs. However, under asymmetric information equity injections dominate over other forms of interventions because equity injection provide better incentives for program participation and thus alleviate adverse selection.

This paper relates to the existing literature on bank bailouts. Gorton and Huang (1999) argue that there is a potential role for the government to bail out banks in distress because the government can provide liquidity more effectively than the private market. Diamond and Rajan (2005) show that bank bailouts can increase excess demand for liquidity, which can cause further insolvency and lead to a meltdown of the financial system. Diamond (2001) emphasizes that governments should only bail out banks that have specialized knowledge about their borrowers. Aghion, Bolton, and Fries (1999) show that bank bailout policies can be designed such that they do not distort ex-ante lending incentives relative to strict bank closure policies. Our paper is different from the literature because we focus on the optimal form of the bank bailout instead of the effect of bank bailouts on lending incentives. The main question in our paper – how to recapitalize banks in the presence of debt overhang and adverse selection – is not addressed in the literature.

The paper proceeds as follows. Section 1 sets up the model. Section 2 solves for the decentralized equilibrium with and without debt overhang. Section 3 describes the government interventions. Section 4 compares the interventions. Section 5 extends the model to heterogenous assets and deposit insurance. Section 6 discusses optimal mechanisms. Section 7 concludes.

1 Model

The model has a continuum of firms of measure 1. Our abstract model is applicable to industrial and financial firms alike, but, for concreteness, we will focus on financial firms

We have in mind commercial banks, investment banks, insurance companies, or finance companies. For simplicity, we refer to all of them as banks.

Figure 1 summarizes the timing, technology and information structure of the model. The model has three dates $t = 0, 1, 2$. There is no discounting. Banks start time 0 with given initial assets and liabilities. At time 1 banks receive new investment opportunities, and they lend to and borrow from each other and from outside investors. To avoid confusion with inter-bank lending, we use the word “investments” to refer to the new loans that banks make to the non-financial sector at time 1. All returns are realized at time 2, and profits are paid out to investors.

The government announces its interventions at time 0, but the implementation can happen either at date 0 or at date 1. The difference matters because banks learn about the value of their existing assets and about their new investment opportunities at date 1. Interventions at date 1 are therefore subject to adverse selection, while interventions at date 0 are not. The two cases are empirically relevant, and we therefore analyze both.

1.1 Initial assets and liabilities

At time 0 banks have both assets and liabilities in place. All banks are ex-ante identical. On the liabilities side, banks have long term debt. Long term debt is due at time 2. Let D be the face value of long-term debt outstanding.

On the asset side, banks have two types of assets: cash and long term assets. Cash is liquid and can be used for investments or for lending at date 1. Let c_t be cash holdings at the beginning of time t . All banks start time 0 with c_0 in cash. Cash holdings cannot be negative:

$$c_t \geq 0 \text{ for all } t.$$

Long-term assets deliver random payoff $a = A$ or $a = 0$ at time 2. We define the probability of a good outcome as

$$p \equiv \Pr(a = A).$$

At time 1 private investors learn the value of p for each bank.

1.2 Investment opportunities

At time 1 banks receive investment opportunities. Investments cost the fixed amount x at time 1 and deliver safe income v at time 2. The value of v is between 0 and V learned at time 1. The joint distribution of p and v is

$$F(p, v) \text{ for } p \in [0, 1] \text{ and } v \in [0, V]$$

And we use the notation

$$\bar{p} \equiv E[p]$$

To make the problem interesting, we assume that individual banks do not have enough cash to finance investment projects but the aggregate system has sufficient cash to finance all investments. To study debt overhang, we assume that debt is risky such that long term debt D is in default when $a = 0$, but not when $a = A$. We also assume that the payoff V from new investment is not sufficient to cover long term debt D .

Assumption A1: $c_0 < x < V < D < A$

Assumptions A1 is maintained throughout the paper. Borrowing and lending at time 1 can be among banks, or between banks and outside investors. We assume risk neutral investors and we normalize the risk free rate to 0.

2 Equilibrium without intervention

In this section, we study the equilibrium without government intervention. We characterize the first best outcome, and the debt overhang equilibrium.

2.1 Investor payoffs

Figure 2 summarizes the payoffs to equity holders. In order to finance investment, banks can lend to and borrow from each other. Let l be the face value of borrowing at time 1 and let r be the gross interest rate for interbank lending. At time 2 total bank income y is:

$$y = a + c_2 + v \cdot i,$$

where i is dummy for the decision to invest at time 1. Let y^D , y^l and y^e be the payoffs at time 2 of long term debt, interbank lending and equity, respectively. Long term debt is senior to interbank lending l . Equity is junior to debt. There are no direct deadweight losses from bankruptcy. Under the usual seniority rules, the payoffs to investors are:

$$y^D = \min(y, D); \quad y^l = \min(y - y^D, rl); \quad y^e = y - y^D - y^l.$$

Under assumption A1, the payoffs to investors depend on the realization of asset value in the following way. If $a = A$, all liabilities are fully repaid ($y^D = D$ and $y^l = rl$) and equity holders receive $y^e = y - D - rl$. If $a = 0$, then long term debt holders receive all income ($y^D = y$) and other investors receive nothing: $y^l = y^e = 0$.

2.2 First best

Figure 3 depicts the investment region in the first best equilibrium. Without intervention, the banks simply carry their cash holdings from period 0 to period 1, so $c_1 = c_0$. The interbank lending market opens at time 1. The first best assumption is that banks choose investments at time 1 to maximize total value $V_1 = E_1[a] + c_2 + v \cdot i - E_1[y^l]$, subject to the time 1 budget constraint

$$c_2 = c_1 + l - x \cdot i. \tag{1}$$

The break even constraint for outside lenders is:

$$E_1[y^l] \geq l. \tag{2}$$

Using condition A1, there is excess aggregate liquidity to finance the investment, and the break even constraint (2) binds: $E_1[y^l] = l$. Using (1), this implies that

$$V_1 = E_1[a] + c_1 + (v - x) \cdot i.$$

Therefore, investment takes place in the domain:

$$I^* \equiv \{(p, v) \mid v > x\}.$$

Proposition 1 *The first best solution is for investment to take place at time 1 if and only if $v > x$, irrespective of the value of p .*

A few properties of the first best solution are worth mentioning. First, the interest rate is bank specific since equation (2) is simply $r = 1/p$. The other important property is the connection between shareholder value and total value. We can always write $V_1 = E_1 [y - y^l] = E_1 [y^e + y^D]$. The maximization program for total value is equivalent to the maximization of shareholder value $E_1 [y^e]$ as long as we allow renegotiation and transfer payments between shareholders and debt holders.

2.3 Debt overhang

We assume that banks maximize shareholder value instead of total value. Under the risky debt assumption A1, shareholder value maximization leads to the classic debt overhang problem.

Figure 4 depicts the investment region in the debt overhang equilibrium. Consider the market at time 1. Shareholders get nothing if the bad state realizes at time 2, and if the good state is realized they get $c_2 + A + v \cdot i - D - rl$. The bank maximizes shareholder value subject to budget constraint (1) and break even constraint for new investors (2). The condition for investment becomes

$$v - x > (r - 1)l \tag{3}$$

This is the investment condition under debt overhang.

Recall that the first best investment rule was simply $v - x > 0$. The difference with the First Best investment rule comes from two critical properties. First, the outside investors ask for a risk premium because they know that lending is risky. Hence $r > 1$. Second, shareholders perceive a high cost of funds because they do not get the returns of the investment project in the bad state. In the first best world, they would renegotiate with the debt holders. Debt overhang follows from the assumption that debt contracts cannot be renegotiated, or at least not quickly enough to seize the investment opportunity.

A constrained firm would always choose to invest its own cash first, so $c_2 = 0$, and $l = x - c_1$. Since $c_1 = c_0$, Equation (3) becomes $pv + (1 - p)c_0 > x$ and we get the investment domain:

$$I^o \equiv \{(p, v) \mid L^o(p, v) > 0\}, \tag{4}$$

where we define

$$L^o(p, v) \equiv pv + (1 - p)c_0 - x. \quad (5)$$

If $L^o(p, v) < 0$, no investment takes place. If $L^o(p, v) > 0$, investment takes place using the free cash c_0 and the additional borrowing $x - c_0$. The function $L^o(p, v)$ measures the value for shareholders of undertaking a new investment under debt overhang, given the quality of the existing assets p , the available liquidity c_0 , and the fundamental value of new investment v . From the perspective of shareholders, the NPV of the investment is $pv - x$. Internal cash c_0 has a low opportunity cost since it would be given away to debt holders with probability $(1 - p)$.

2.4 Shareholder value and welfare losses

We repeatedly use ex-ante calculations of shareholder below. So it is worth understanding the determinants of shareholder value. Shareholder value at time 1 is

$$E_1 [y^e | p, v] = p(N + c_0) + L^o(p, v) 1_{(p,v) \in I^o} \quad (6)$$

Shareholder value at time 1 is the sum of two component. The value of old assets is the probability of solvency times the net payment in the good state N , defined by:

$$N \equiv A - D$$

The second component is the shareholder value of new projects $L^o(p, v)$ defined above. Taking expectations at time 0, ex-ante shareholder value is:

$$E_0 [y^e] = \bar{p}(N + c_0) + \iint_{I^o} L^o(p, v) dF(p, v) \quad (7)$$

The first term on the RHS is the expected value of cash and assets in place minus outstanding liabilities. The second term on the RHS is the expected value of new investment opportunities. The domain I^o is defined in Equation (4). Of course, $L^o(p, v)$ is zero on the border of I^o .

Welfare under debt overhang depends on the set of implement new projects I^o . We define $W(\cdot)$ as the social welfare function, so that welfare under debt overhang is:

$$W(I^o). \quad (8)$$

As long as I^o is strictly smaller than I^* , there is a welfare loss. In the banking context, these deadweight losses capture missed trading and lending opportunities. We assume the social welfare function incorporates deadweight losses to both banks and borrowers. Hence, the welfare function is independent of how the benefits of investment projects are shared among banks and borrowers.

Note that equation (8) assumes that investment projects are bank specific. This formulation captures the idea that banks have proprietary information about their borrowers and it is costly for borrowers to switch to other banks. This assumption is based on a large literature in banking which argues that one of the main functions of financial intermediaries is to generate private information about their borrowers (see for instance Diamond (1984))

3 Description of government interventions

We consider three government interventions: capital against equity, asset buy backs, and debt guarantees. We first discuss the government's objective function and then briefly describe each intervention.

3.1 Government objective function and constraints

The objective of the government is to minimize the welfare losses from missed investment opportunities and the costs of intervention. Let Ψ be the expected cost of a government intervention. Let χ be the marginal deadweight losses associated with raising taxes and administering the bank bailout program. The objective function of the government is then

$$\max_{\Gamma} W(I(\Gamma)) - \chi\Psi(\Gamma)$$

where Γ are the parameters chosen by a specific government intervention. For simplicity, we assume that the marginal cost χ is constant. This means that the government cares about expected costs, but not about the distribution of these costs.

The expected costs of the program depend on the date of participation. At time 0, all banks are identical and information is symmetric. At time 1, the banks receive investment opportunities and learn about the value of their existing assets. The type of a bank is a 2-dimensional random variable (p, v) realized at time 1.

We place constraints on the interventions of the government. First, we do not allow the government to change the priority rules of financial contracts, and we assume that the government is unwilling to increase the losses incurred by debt holders. These restriction rule out forced bankruptcy, forced asses sales, debt equity swaps, etc. We also assume that the government cannot make payments directly contingent on the banks' new investments. This rules out directed lending. Finally, we assume that the government can restrict dividend payments to shareholders. This makes capital injection feasible.

3.2 Description of asset buy back program

The government announces at time 0 that it is willing to purchase assets up to an amount Z at a per unit price of q in exchange for cash. If a bank decides to participate and sell $z < Z$, long term assets become $A_1 = A - z$ and cash $c_1 = c_0 + zq$. The government can offer banks to participate in this program at time 0, at time 1, or both times. The date for participation is important because at time 1 banks learn about their investment opportunities and receive a signal about the value of their assets in place. Due to the option value of new information, banks always choose to wait with their decision until time 1 if possible. Without loss of generality, we thus only consider government programs with participation at either time 0 or at time 1, not at both times.

Since the government can always set $Z = 0$ and since all banks are ex-ante identical, we can without loss of generality consider programs at time 0 where all banks participate. The expected cost of the time 0 asset buy back is:

$$\Psi_0^a(Z, q) = z_0 (q - \bar{p}) \text{ with } z_0 < Z$$

The government pays out zq at time 0 and receives z in the high-payoff state whose ex-ante probability is \bar{p} . Constraint (??) implies $A + c_0 - Z > D$.

At date 1, banks learn about their investment opportunity and receive signal p before deciding whether to participate. The expected cost is therefore

$$\Psi_1^a(Z, q) = \int \int_{(v,p)} z_1(v, p; Z, q) \cdot (q - p) dF(v, p)$$

where F is defined in Section 3.1. Note that this formulation allows for adverse selection because banks opt in and out depending on their type (v, p) .

3.3 Description of capital injection program

Equity injection programs are parameterized by m and α . The government announces at time 0 that it is willing to offer cash m against a fraction α of equity returns. Similar to the asset buy back program, the government can offer banks to participate in this program at time 0 or time 1. If a bank decides to participate, its cash position becomes $c_1 = c_0 + m$. The expected cost of the program at date 0 is

$$\Psi_0^e(m, \alpha) = m - \alpha E_0[y^e(m)]$$

where $E_0[y^e(m)]$ is the expected equity return at time 0 conditional on cash injection m . In words, the government pays out m at time 0 and receives a share α of equity returns y^e at time 2. There are no constraints on that program, except $m \geq 0$ and $\alpha \in [0, 1]$. The expected cost of the date 1 program is

$$\Psi_1^e(m, \alpha) = \int \int_{(v,p)} \delta^e(m, \alpha; v, p) \cdot (m - \alpha E_1[y^e(m) | v, p]) dF(v, p)$$

where δ^e is a dummy whether a bank participates in the program, and $E_1[y^e(m) | v, p]$ is the expected equity return at time 1 given the cash injection m , and conditional on the bank's type. Similar to asset buy back, this formulation allows for adverse selection depending on bank type (v, p) .

3.4 Description of debt guarantee program

Debt guarantee programs are parameterized by S and ϕ . The government announces at time 0 that it is willing to guarantee new bank debt up to a face value of S and charges banks a fee ϕ per unit of lending. There are many equivalent ways to define the parameters S and ϕ . In our notations, the fee is paid up-front and the upper bound applies to the face value of the borrowing. Let s be the face value of secured debt actually borrowed and let r_s be the interest rate. The amount of money raised at time is therefore $s/r_s - \phi s$ and the constraint is $s < S$ (of course we will see shortly that $r_s = 1$ in equilibrium). The expected cost to the government if banks must issue the debt at time 0 is

$$\Psi_0^g(S, \phi) = s_0(1 - \phi - \bar{p})$$

$$\Psi_1^g(S, \phi) = \int \int_{(v,p)} s_1(v, p; S, \phi) (1 - p - \phi) dF(v, p)$$

The debt guarantee allows for adverse selection depending on bank type (v, p) .

4 Comparison of government interventions

Our main result is that all interventions are equivalent date 0, but capital injections dominate both asset buy backs and debt guarantees at date 1. Equivalence of two interventions means that both interventions implement the same level of investment at the same expected cost to the government. Dominance of two interventions means that the dominant intervention implements the same level of investment at lower costs compared to the dominated intervention. To build the intuition for our result we first present two useful lemmas, one for cash injections and one for debt guarantees.

The following investment domain $I(m)$ will play a key role in our discussions. It is depicted on Figure 5.

Definition 1 *Let the domain $I(m)$ be defined by*

$$I(m) \equiv \{(p, v) \mid L^m(p, v) > 0\} \tag{9}$$

where the lower schedule is defined by

$$L^m(p, v) \equiv L^o(p, v) + (1 - p)m$$

4.1 Equilibrium with free cash injections at time 0

Let us first discuss the particular case of a pure cash injection at time 0. That is, the government simply gives m to each bank, without asking for anything in return. This is the particular case of an equity injection with $\alpha = 0$, or a buy back with $Z \rightarrow 0$ and $qZ = m$, or a debt guarantee program with $S = m$ and $\phi = 0$. The following lemma characterizes cash injections.

Lemma 1 *A pure cash injection leads to the following welfare function for the government*

$$W(I(m)) - \chi m$$

Proof. Suppose the government injects m in each bank so that initial liquidity becomes $c_1 = c_0 + m$. From equation (4) and (5), we see that the investment domain becomes $I(m)$ and the total cost is $\Psi_0^e(m, 0) = m$ since the number of banks is normalized to one. ■

If the cash injection is large enough to cover the entire financing need for investment, then debt overhand is entirely eliminated. In other words, $I(x - c_0) = I^*$. Shareholder value will play a critical role in our analysis. Interim shareholder values at date 1 are easily obtained by replacing c_0 by $c_0 + m$ and I^o by $I(m)$ in equations (6) and (7).

4.2 Equilibrium with debt guarantee at time 1

Figure 6 depicts the equilibrium under debt guarantee. Debt guarantee programs are parameterized by S and ϕ . Secured borrowing is risk free while unsecured borrowing is risky. The equilibrium rates are therefore $r_s = 1$ and $r_u = 1/p$. The date-1 budget constraint (1) becomes

$$c_2 = c_0 + l_u + (1 - \phi)s - x, \quad (10)$$

and the investment condition (3) becomes

$$L^o(p, v) + s(1 - \phi - p) > 0. \quad (11)$$

It is clear that the government never wants to set S above $x - c_0$ since this could not possibly help the financing of new projects.

Another issue is whether banks who do not plan to invest would like to participate. This would be highly inefficient since the government would be providing a pure subsidy to bond and equity holders without affecting new investments. It is therefore important to impose a ‘no inefficient participation’ constraint (NIP from now on). Payoffs to shareholders in the good state are $A - D + c_2 - s$, so from equation (10), it is clear that the NIP constraint is:

$$\phi > 0. \quad (12)$$

We summarize this brief discussion in the following lemma.

Lemma 2 *It is enough to consider debt guarantees such that $S \in [0, x - c_0]$ and $\phi > 0$.*

Next we consider the choice between secured and unsecured borrowing. It is clear from (11) that banks take up the debt guarantee rather than the unsecured lending if and only if $p < 1 - \phi$. Otherwise, banks prefer borrowing on the unsecured interbank lending market. This defines an upper-bound schedule for participation, $U_1^g(p, v; S, \phi) < 0$, where:

$$U_1^g(p, v; S, \phi) \equiv p + \phi - 1. \quad (13)$$

So when $p \in [1 - \phi, 1]$ we have $s = 0$. If in addition, $(p, v) \in I^o$, investment occurs without guarantee.

When $p < 1 - \phi$, the banks prefer to use the guarantee and since the payoffs are linear in s , the bank chooses the maximum guarantee: $s = S$. This implies $l_u = x - (1 - \phi)S - c_0$ if they invest. Equation (11) leads to the lower bound schedule for investment, $L_1^g(p, v; S, \phi) > 0$, where:

$$L_1^g(p, v; S, \phi) \equiv L^o(p, v) + (1 - \phi - p)S \quad (14)$$

We now have a complete description of the participation and investment decisions. The overall structure will be the same in all programs. There is an NIP constraint (12) which means that the program cannot be too generous. The NIP constraint will typically look like a haircut. There is an upper-schedule (13) above which banks decide not to participate in the government's program. In the case of the debt guarantee program, the upper-schedule is vertical (it does not depend on v), but in general it will be a function of p and v (as in the case of equity, see below). Finally, there is a lower-schedule (14) under which banks are unwilling or unable to invest even with the assistance of the government.

The participation set is therefore.

$$\Omega_1^g(S, \phi) = \{(p, v) \mid L_1^g(p, v; S, \phi) > 0 \wedge U_1^g(p, v; S, \phi) < 0\} \quad (15)$$

This participation set will determine the cost of the program.

Finally, the investment domain is made of the initial debt overhang set I^o (banks that would invest even without the government's intervention) and the new participation set Ω :

$$I_1^g(S, \phi) = I^o \cup \Omega_1^g(S, \phi) \quad (16)$$

Note that the overlap between the two sets, $I^o \cap \Omega_1^g(S, \phi)$, represents opportunistic participation. It is inefficient because it uses public money without increasing investment.

We can summarize our discussion in the following lemma:

Lemma 3 *A debt guarantee program (S, ϕ) delivers welfare function $W(\Omega_1^g(S, \phi))$ and has the expected cost $\Lambda_1^g(S, \phi)$ where*

$$\Lambda_1^g(S, \phi) \equiv S \int \int_{\Omega_1^g(S, \phi)} (1 - p - \phi) dF(p, v). \quad (17)$$

We can compare the debt guarantee with the pure cash injection:

Proposition 2 *Debt guarantees at time 1 always dominate free cash injections at time 0.*

Proof. The proof is simple. Consider a debt guarantee with $\phi = 0$ and $S = m$. They achieve the same investment domain since $I_1^g(m, 0) = I(m)$. On the cost side, it is clear from equation (17) that $\Lambda_1^g(m, 0) \leq m$. ■

In general, we see that debt guarantees are cheaper than pure cash injections for four separate reasons. First, the debt guarantee applies only to banks that invest. Second, the government only pays in case of default, and is compensated by fee ϕ otherwise. Third, banks that do not want to invest choose not to take the guarantee, while in the ex-ante cash injection banks receive the cash and keep it on their balance sheet. Fourth, healthy banks opt out of the guarantee program, while in the ex-ante cash injection they would receive cash nonetheless.

4.3 Comparison of date 0 programs

Let us first compare the date 0 programs. In these programs, the banks must opt in or out at time 0, when information is symmetric. We have the following proposition:

Theorem 1 *Equivalence of all date 0 programs.* *An asset buy back program (Z, q) with participation at time 0 is equivalent to a debt guarantee program with $S = Z$ and $q = 1 - \phi$. It is also equivalent to an equity injection (m, α) with participation at time 0, where $m = Zq$ and q and α are chosen such that at time 0 all banks are indifferent between participating and not participating in the program. All programs deliver the investment set $I(m)$ and have expected costs $Z(q - \bar{p})$.*

Proof. See Appendix. ■

The key to this equivalence result is that banks are forced to decide to participate in the programs before they receive information about investment opportunities and asset values. Banks are thus identical and the government optimally chooses the program parameters such that banks are indifferent between participating and not participating. For a fixed program amount, the government extracts all rents from the intervention. The cost to the government is thus independent of whether banks are charged through assets sales, guarantee fees, or equity shares.

It is important to emphasize that we are comparing pure date 0 interventions here, where no further interaction between the banks and the government occurs at date 1. We are not claiming that these pure date 0 interventions are optimal. In fact, they are not. It is always better for the government to sell at date 0 an option to participate in a date 1 program. We return to this idea later.

4.4 Comparison of date 1 programs

Let us now compare the date 1 programs. In these programs, the banks must opt in or out at time 1, when information is asymmetric. We have the following proposition:

Theorem 2 *Equivalence of asset buy-backs and debt guarantees at time 1. An asset buy back program (Z, q) with participation at time 1 is equivalent to a debt guarantee program with $S = Z$ and $q = 1 - \phi$.*

Proof. See Appendix. ■

Note that the allocation features adverse selection, such that banks only participate in the program if the expected value of their assets p is less than the price q offered by the government. This feature of the solution is a natural outcome of a setup in which banks know more about asset values than the government. The frequently made argument that asset buy backs or capital against equity have to occur at fair market value is not feasible because banks only participate in the program if the the program recapitalizes at rates above market value.

Theorem 3 *Dominance of equity injection at time 1.* *For any asset buy back program (Z, q) with participation at time 1, there is an equity program that achieves the same allocation at a lower cost for the government.*

Proof. See Appendix. ■

Figure 7 depicts the equilibrium with equity injection at date 1. The intuition is the following. First, we must understand the net effects of dilution. They are captured by the function:

$$X(p; m, \alpha) \equiv (1 - \alpha)m - \alpha p(N + c_0)$$

This function is intuitive: $(1 - \alpha)m$ is the net value of cash injected by the government, and $\alpha p(N + c_0)$ is the dilution of the claims on old assets. So X measures the cash value of government transfers under the program. The participation set in the equity program takes the generic form:

$$\Omega_1^e(m, \alpha) = \{(p, v) \mid L_1^e(p, v; m, \alpha) > 0 \wedge U_1^e(p, v; m, \alpha) < 0\}$$

This can be compared to the participation set in equation (15). The lower bound is defined by

$$L_1^e(p, v; m, \alpha) \equiv (1 - \alpha)L^o(p, v) + X(p; m, \alpha)$$

The intuition is clear. X are the transfers, and $(1 - \alpha)L^o(p, v)$ the diluted value of new investments. It is optimal to opt in and invest if $L_1^e(p, v; m, \alpha) > 0$. The upper bound for participation is

$$U_1^e(p, v; m, \alpha) \equiv \alpha L^o(p, v) - X(p; m, \alpha)$$

The intuition is also clear. By not participating, the firm foregoes the transfers $X(p; m, \alpha)$ but avoids the dilution of its new project. Hence, it is optimal to invest without the assistance of the government when $U_1^e(p, v; m, \alpha) > 0$. Finally, the NIP constraint is

$$X(1; m, \alpha) < 0$$

The intuition is once again clear. The government must avoid giving away money to banks that do not plan to invest. In this case, the comparison cash is transferred one for one between the good and the bad state, so the condition is $(1 - \alpha)m < \alpha(N + c_0)$. This

condition is the same as $X < 0$ for banks whose assets are risk free, i.e., the banks for which $p = 1$. It also means that $X(p; m, \alpha) \leq (1 - \alpha)(1 - p)m$ and therefore the investment domain is strictly smaller than in the pure cash injection: $I_1^e(m, \alpha) \subset I(m)$. The reason is that firms with high p and low v opt out to avoid dilution.

Now why is equity the better program? To understand, imagine a given asset buy back program. It has a lower schedule that determines the investment set, and thus the welfare function W . Now choose the equity program to have exactly the same lower schedule and thus the same investment set for an equity program.

The first point to understand is that equity induce less opportunistic participation. This is because it is costly for good banks to dilute their valuable equity. Hence the upper schedule is tighter. Of course, the two programs have different cost functions, so the fact that the participation set is smaller is not enough to show that equity is cheaper. However, the same reasons that make the upper schedule tighter also limit the rents earned as (p, v) move away from the lower frontier $L_1^e(p, v; m, \alpha) = 0$. Finally, it is easy to show that, once the lower schedule are the same, the NIP constraints are also equivalent. This shows that, for any asset buy back, or any debt guarantee program, there exists an equity injection program that delivers exactly the same investment set, but for a lower cost to the government. The lower cost comes from two sources: less opportunistic participation, and smaller rents conditional on participation.

4.5 Date 0 versus date 1

Let us now compare the programs at dates 0 and 1. From the perspective of the government, at date 0 there is adverse selection with respect to p since banks with bad assets are more likely to participate. There is also beneficial selection with respect to v since banks without investment projects are less likely to participate. We consider a change in the distribution of both p and v .

Proposition 3 *Comparison of date 0 and date 1 programs.*

- *Consider two distribution functions F and \tilde{F} for the parameters (p, v) . If \tilde{F} dominates F in the sense of first order stochastic dominance, then, for any investment domain I , the cost of the date 0 program is lower with \tilde{F} than with F .*

- *Date 1 programs always dominate date 0 programs when almost no bank has a positive NPV project (i.e., $\Pr(v > x) \rightarrow 0$).*
- *Date 0 programs always dominate date 1 programs when almost all banks have a positive NPV project (i.e., $\Pr(v > x) \rightarrow 1$) and the government wants to implement the first best ($I \rightarrow I^*$)*

Proof. See Appendix. ■

To understand this result, note that for every date 0 asset buy back program, we can construct a date 1 asset buy back program that generates the same investment region by setting the date 1 asset price q equal to one and choosing date 1 program size Z such that it generates the same cash injection as the date 0 asset buy back program.

If $\Pr(v > x) \rightarrow 0$ no bank receives an investment opportunity. Hence, there is no investment under any program. However, a date 0 asset buy back program yields a positive cost (because all banks participate) and a date 1 program yields zero cost (because nobody participates).

As more banks receive good investment opportunities, the cost of the date 0 program decreases because it extracts all rents from better investment opportunities. In contrast, the cost of date 1 asset buy back program increases because more banks participate.

A natural interpretation of date 0 versus date 1 is in terms of compulsory versus voluntary participation. Of course, compulsory participation without constraint does not make sense, so we impose the constraint that government offers be acceptable on average (for instance, a well diversified equity investor would accept the offer on behalf of all the banks). Our results can then be interpreted as follows: when interventions are large, and the government expect that most banks have positive NPV projects (positive franchise value), then it is better to do it early with compulsory participation. On the other hand, if the intervention is small, or if most banks do not have valuable new projects, then it is better to do it ex-post based on voluntary participation.

4.6 Discussion of the theorems

Let us briefly discuss our results. Some analysts advocate government interventions at market prices. In our model, this makes no sense since there would be no participation. The

frequently made argument that asset buy backs or capital against equity have to occur at fair market value is not feasible because banks only participate in the program if the program recapitalizes at rates above market value. A subsidy is needed, the only question is how to do it.

We do not consider ex-ante incentives of banks, and we agree that bailouts create moral hazard. However, if bailouts are going to happen, they might as well be efficient. Our mechanisms are about minimizing the cost to tax payers, so they remain relevant as soon as the government decides to intervene. In addition, our mechanisms minimize the rents to old shareholders and old debt holders (short of bankruptcy), so they also minimize moral hazard concerns conditional on any decision to bail out private investors.

We also need to discuss briefly the issue of risk shifting. Even though we assume that v is known at date 1, risk shifting is not absent from our model. Indeed, from the perspective of shareholders, selling risky assets is akin to anti-risk-shifting, and refusing to sell assets is like risk shifting. This is a very relevant issue. During his testimony to congress, Vikram Pandit, CEO of Citigroup, protested that he was not going to sell the assets at a dollar because it would not be right for shareholders: “When we look at some of the assets that we hold, we have a duty to our shareholders. The duty is that if it turns out they’re marked so far below what our lifetime expected credit losses are, we can’t sell them.” Our model captures this issue and explains why it has been so hard to convince the banks to sell their risky assets.

5 Extensions

5.1 Heterogenous assets within banks

Suppose that the face value of assets at time 0 is $A + A'$. All these assets are ex-ante identical. At time 1, the bank learns which assets are A' and which ones are A . The A assets are just like before, with probability p of A and $1 - p$ of 0. The A' assets are worth nothing. The ex-ante problems are unchanged, so all programs are still equivalent at date 0.

The equity and debt guarantee programs are unchanged at date 1. So equity still dominates debt guarantee. But the asset buy back program at date 1 is changed. For any

price $q > 0$ the banks will always want to sell their A' assets. This will be true in particular of the banks outside the range of positive NPV investments

Proposition 4 *With heterogenous assets inside banks, there is a strict ranking of programs: equity is best, debt guarantee is intermediate, buy back program is worse.*

The key point here is that adverse selection across banks is very different from adverse selection across assets within each bank. This is exactly the point of the opponents of the asset buy back program.

Corollary 1 *For asset buy back to be optimal, the market failure must come from private information among private agents.*

Of course this is only necessary. It remains to be seen if and how an asset buy back program can be optimal in the case of adverse selection in the private sector (Philippon and Skreta (2009)).¹

5.2 Deposit Insurance

Suppose long term debt consists of two types of debt: deposits Δ and unsecured long term debt B such that

$$D = \Delta + B.$$

Suppose that the government provides insurance for deposit holders and that deposit holders have priority over unsecured debt holders. Then the payoffs are are:

$$y^\Delta = \min(y, \Delta); y^B = \min(y - y^\Delta, B)$$

Suppose that the long term assets pay off \underline{A} in the low-payoff state. We consider two separate case. The first case is safe deposits if $\Delta < \underline{A} + c_0$. The second case is risky deposits if $\Delta \geq \underline{A} + c_0$

¹It is worth pointing out that adverse selection can be mitigated by debt overhang. In our simple model, the maximization of shareholder value does not create adverse selection because a fixed rate would not attract the low type (low p). By contrast, total firm value maximization would lead to adverse selection. Hence it is clear that the two market failures are best studied in separate papers.

Proposition 5 *With safe deposits, the cost and benefits of both date 0 and date 1 programs remain unchanged.*

Proof. See Appendix. ■

If deposits are safe, banks always have sufficient date 2 income to repay deposit holders. Hence, the expected cost of deposit insurance is zero independent of whether there is a government intervention. Note that deposits and unsecured long term debt are equivalent from the equity holder's perspective. Therefore all results remain unchanged.

Proposition 6 *With risky deposits, the costs of date 0 and date 1 programs decrease. The equivalence results and ranking of both date 0 and date 1 programs remain unchanged. If deposits are sufficiently large, date 0 programs dominate date 1 programs and the government can implement the first best at negative cost.*

Proof. See Appendix. ■

With risky deposits, the government has to pay out deposit insurance in the low-payoff state. Hence, every cash injection at date 0 lowers the expected cost of deposit insurance in the low-payoff state one-for-one. As a result, the government recoups its entire investment both in the high- and low-payoff state. Put differently, the date 0 cash injection represents a wealth transfer to depositors and, because of deposit insurance, a wealth transfer to the government. Also note that the government extracts all benefits of increased lending ex-ante by keeping equity holders to their reservation utility. As a result, the government receives the expected net benefit of increased lending and thus the expected cost is negative.

6 Optimal programs

6.1 Date 0

Proposition 7 *Any date 0 program can be improved by making participation at date 1 voluntary and selling at date 0 the option to participate at date 1.*

Proof. See Appendix. ■

A practical example is the debt guarantee program. It is inefficient to force banks to issue S at time 0. It is better to sell them at date 0 the right to issue secured debt at time 1. In this way, banks who end up without investment options do not participate, banks who can invest alone also do not participate, and everyone pays ex-ante the NPV of the option to participate.

Corollary 2 *An optimal date 0 program is to sell at date 0 the option to participate in an optimal date 1 program.*

6.2 Date 1

The following proposition extends the result of Theorem 3

Proposition 8 *Equity programs at date 1 cannot be improved by mixing them with a debt guarantee or asset buy back program. Pure equity programs always dominate.*

Proof. See Appendix. ■

Let us now consider optimal programs. The constraints we impose are that the debt holders cannot be worse off and that the government cannot alter the priority of claims. So all the government can do is to inject cash m at time 1 in exchange for state contingent payoffs at time 2. Date 1 junior creditor must be repaid, so as long as the government can commit, we can without loss of generality restrict our attention to the case where the government payoffs depend on the residual payoffs $y - y^D - y^l$.

In general, however, the government could offer a menu of contracts to the banks. Menus of contract can be used to obtain various investment sets. The optimal choice depends on the distribution of types $F(p, v)$ and the welfare function W so we cannot say in general which set is optimal. But we can say a lot about cost minimization for any given investment set. This is what we do now.

Lemma 4 *Any program with voluntary participation of shareholders over the set Ω and no renegotiation with debt holders has a minimum cost of*

$$\Psi^{\min}(\Omega) = - \int \int_{\Omega} L^o(p, v) dF(p, v)$$

Proof. Voluntary participation means that shareholders must get at least $p(N + c_0)$. With no renegotiation with debt holders, the government and old equity must share the residual surplus whose value is

$$p(N + c_0) + L^o(p, v)$$

Hence the expected net payments to the government must be $\iint_{\Omega} L^o(p, v) dF(p, v)$. These are negative as long as Ω extends the debt overhang investment set, hence the positive minimum cost. ■

The intuition is simple. Suppose the government could make type contingent offers conditional on new investments. For type (p, v) , the net value of new investment is $L^o(p, v)$ which is negative outside the I^o region. So the minimum the government would have to pay is $-L^o(p, v)$.

Proposition 9 Consider the program $\Gamma = \{m, h, \varepsilon\}$ where the government offers a junior loan m at time 1 at the rate h in exchange for $(1 - \varepsilon)/\varepsilon$ call options at the strike price $N + c_0$. This implements the investment set

$$I(\Gamma) = I_1^g(S, \phi)$$

if we identify the cash injection $m = (1 - \phi)S$ and the haircut $h = \phi/(1 - \phi)$. In the limit $\varepsilon \rightarrow 0$, opportunistic participation disappears:

$$\lim_{\varepsilon \rightarrow 0} U(\Gamma) = L^o$$

Finally the program achieves the minimum cost in the limit:

$$\lim_{\varepsilon \rightarrow 0} \Psi(\Gamma) = \Psi^{\min}(I(\Gamma) \setminus I^o)$$

Proof. See Appendix. ■

Figure 8 depicts the equilibrium under the efficient mechanism. The intuition is that the payoff structure to old shareholders is now:

$$f(y^e) = \min(y^e, N + c_0) + \varepsilon \max(y^e - N - c_0, 0)$$

Old shareholders are full residual claimants up to the face value of old assets $N + c_0$ and ε residual claimants beyond. A few properties are worth mentioning. First, the loan must be junior to all creditors but senior to common stock holders. Hence it could also be implemented with preferred stock. It is crucial, however, that the government also takes a position that is junior to shareholders. Dilution should happen on the upside to induce participation of firms who need it, and to limit opportunistic participation.

The call option mechanism also has some advantages that are likely to be important for reasons outside the model. The first advantage is that it limits risk shifting incentives since the government owns the upside, not the old shareholders. Second, the government can credibly commit to protecting the shareholders since it owns call options. This is important because, conditional on not failing a bank, it makes no sense to try and punish the shareholders. This can only hurt the government, but political pressures to do so appear to be large nonetheless.

In practice, there might be lower bound on ε . It might be necessary to limit dilution to avoid fears of nationalization. An approximate optimal program would then be to determine first the minimum value of ε , and then to construct the program accordingly. Also the haircut h is chosen to rule out inefficient participation (the NIP constraint). In theory, any $h > 0$ would work, but in practice, parameter uncertainty would prevent h from being too close to zero.

7 Conclusion

In this paper we study the efficiency and welfare implications of different government interventions in a standard model with debt overhang. We consider asset buy backs, cash against equity injections, and debt guarantees. We find that under compulsory participation, all interventions are equivalent. Under voluntary participation, equity injections dominate both asset buy backs and debt guarantees, and buyback programs are strictly worse when there is adverse selection across asset classes, in addition to asymmetric information at the bank level.

Comparing voluntary and compulsory programs, we find that compulsory programs are more likely to be efficient if the intervention is large. We also show that deposit insurance

reduces the expected cost of all government interventions. In the limit case in which deposits are always risky, the benefit of a bailout accrues to the government itself and the optimal solution is therefore to implement the first best at negative expected cost. Finally, we solve for the constrained optimum intervention. We find that the government should provide subsidized loans or debt guarantees in exchange for call options on equity.

A Proof of Theorem 1

A.1 Cash against equity at time 0

Suppose the government dilutes existing equity holders. The government offers m in cash against a fraction α of the equity returns. The investment domain $I(m)$ is the same as in the case of pure cash injections. At time 0, we must impose the condition that shareholders are willing to sign in

$$(1 - \alpha) E_0 [y^e(m)] \geq E_0 [y^e(0)] \quad (18)$$

The cost of the program is

$$\Psi_0^e(m, \alpha) = m - \alpha E_0 [y^e(m)]$$

Because the domain does not depend on α , it is clear that the government wants to satisfy the participation constraint (18) with equality.

$$E_0 [y^e] = \bar{p}(N + c_0) + \iint_{I^o} L^o(p, v) dF(p, v)$$

$$E_0 [y^e(m)] = \bar{p}(N + c_0 + m) + \iint_{I(m)} (L^o(p, v) + (1 - p)m) dF(p, v)$$

Eliminating α from the cost function yields $\Psi_0^e(m, \alpha) = m - (E_0 [y^e|m] - E_0 [y^e])$ and

$$E_0 [y^e(m)] - E_0 [y^e] = \bar{p}m + m \iint_{I(m)} (1 - p) dF(p, v) + \iint_{I(m) \setminus I^o} L^o(p, v) dF(p, v)$$

The expected cost of the optimally designed program is

$$\Lambda_0(m) \equiv (1 - \bar{p})m - m \iint_{I(m)} (1 - p) dF(p, v) - \iint_{I(m) \setminus I^o} L^o(p, v) dF(p, v)$$

The first term is the expected loss in bad state, the second term is the gain in borrowing costs, the third is the subsidy to new investments. It contributes positively to the cost since $L^o(p, v) < 0$ for all $(p, v) \in I(m) \setminus I^o$.

A.2 Asset buy back at date 0

Under the buy back program $c_1 = c_0 + qZ$. Hence the investment domain becomes $I(qZ)$. The expected shareholder value at date 0 is

$$E_0 [y^e(z, q)] = \bar{p}(N + c_0 - (1 - q)Z) + \iint_{I(qZ)} (L^o(p, v) + (1 - p)qZ) dF(p, v)$$

The bank's participation constraint is

$$E_0 [y^e(Z, q)] \geq E_0 [y^e(0, 0)]. \quad (19)$$

The government wants to satisfy participation constraint (19) with equality. We get

$$\bar{p}(1-q)Z = Zq \int \int_{I(qZ)} (1-p) dF(p,v) + \int \int_{I(qZ) \setminus I^o} L^o(p,v) dF(p,v)$$

Therefore the cost is

$$\begin{aligned} \Psi_0^a(Z,q) &= Zq - Z\bar{p} \\ &= (1-\bar{p})Zq - qZ \int \int_{I(qZ)} (1-p) dF(p,v) - \int \int_{I(qZ) \setminus I^o} L^o(p,v) dF(p,v) \\ &= \Lambda_0(Zq) \end{aligned}$$

This program is equivalent to the cash against equity program at date 0 when $m = Zq$. QED.

A.3 Debt guarantee at date 0

Under the program $c_1 = c_0 + (1-\phi)S$. Hence the investment domain becomes $I((1-\phi)S)$. The expected shareholder value at date 0 is

$$E_0[y^e(z,q)] = \bar{p}(N + c_0 - \phi S) + \int \int_{I((1-\phi)S)} (L^o(p,v) + (1-p)(1-\phi)S) dF(p,v)$$

This is equivalent to the asset buy-back program if we set $S = Z$ and $q = 1 - \phi$.

B Proof of Theorem 2

Let us analyze the asset buy-back program at date 1. To prove the theorem, we must show equivalent along 4 dimensions: (i) the NIP constraint, (ii) the upper schedule, (iii) the lower schedule, and (iv) the cost function.

Upon participation and investment, total equity value becomes

$$E_1[y^e(z,q) | p, v, i = 1] = p(N + c_0 - z) + L^o(p,v) + qz$$

Participation without investment yields

$$E_1[y^e(z,q) | p, v, i = 0] = p(N + c_0 - z + qz)$$

Now consider the three critical constraints:

- NIP: $E_1[y^e(z,q) | p, v, i = 0] < E_1[y^e(0,0) | p, v, i = 0]$ or:

$$q < 1$$

- Upper schedule: $E_1[y^e(0,0) | p, v, i = 1] > E_1[y^e(z,q) | p, v, i = 1]$ or:

$$p > q.$$

- Lower schedule: $E_1[y^e(z, q) | p, v, i = 1] > E_1[y^e(0, 0) | p, v, i = 0]$

$$L_1^a(p, v; z, q) = L^o(p, v) + (q - p)z.$$

It is therefore clear that z is either 0 or Z . It is also clear that, using the notations of the debt guarantee section, the participation set is simply

$$\Omega_1^g(Z, 1 - q)$$

where Ω_1^g was defined above in equation (15). The expected cost of the program is therefore

$$\Psi_1^a(Z, q) = Z \int \int_{\Omega^g(Z, 1 - q)} (q - p) dF(p, v) = \Lambda_1^g(Z, 1 - q)$$

and the investment domain is

$$I^o \cup \Omega_1^g(Z, 1 - q)$$

Now if we set $S = Z$ and $q = 1 - \phi$, we see that the NIP constraint, the upper and lower schedules, and the cost function are the same for the asset buy back program as for the debt guarantee program. They are therefore equivalent.

C Proof of Theorem 3

Let us analyze equity injections at date 1. Upon participation and investment, total equity value (including the share going to the government) becomes

$$E_1[y^e(m) | p, v, i = 1] = p(N + c_0) + L^o(p, v) + m$$

Participation without investment yields

$$E_1[y^e(m) | p, v, i = 0] = p(N + c_0 + m)$$

Now consider the three critical constraints

- NIP: $(1 - \alpha) E_1[y^e(m) | p, v, i = 0] < E_1[y^e(0) | p, v, i = 0]$ or:

$$(1 - \alpha)m < \alpha(N + c_0)$$

- Upper schedule: $E_1[y^e(0) | p, v, i = 1] > (1 - \alpha) E_1[y^e(m) | p, v, i = 1]$ or:

$$\alpha(p(N + c_0) + L^o(p, v)) > (1 - \alpha)m$$

- Lower schedule: $(1 - \alpha) E_1[y^e(m) | p, v, i = 1] > E_1[y^e(0) | p, v, i = 0]$ or:

$$(1 - \alpha)(L^o(p, v) + m) > \alpha p(N + c_0)$$

Now define the function

$$X(p; m, \alpha) \equiv (1 - \alpha)m - \alpha p(N + c_0)$$

We can summarize the equity program by:

$$\begin{aligned} L_1^e(p, v; m, \alpha) &\equiv (1 - \alpha)L^o(p, v) + X(p; m, \alpha) \\ U_1^e(p, v; m, \alpha) &\equiv \alpha L^o(p, v) - X(p; m, \alpha) \\ NIP &: X(1; m, \alpha) < 0 \end{aligned}$$

The participation becomes

$$\Omega_1^e(m, \alpha) = \{(p, v) \mid L_1^e(p, v; m, \alpha) > 0 \wedge U_1^e(p, v; m, \alpha) < 0\}$$

The cost function is therefore

$$\Psi_1^e(m, \alpha) = \int \int_{\Omega_1^e(m, \alpha)} (m - \alpha E_1[y^e(m, \alpha) \mid p, v, i = 1]) dF(p, v)$$

We can rewrite this in the convenient and intuitive form

$$\Psi_1^e(m, \alpha) = \int \int_{\Omega_1^e(m, \alpha)} X(p; m, \alpha) dF(p, v) - \alpha \int \int_{\Omega_1^e(m, \alpha)} L^o(p, v) dF(p, v)$$

The following table provides a comparison of the three programs:

	Debt guarantee	Asset buy back	Equity injection
Participation	$\Omega_1^g(S, \phi)$	$\Omega_1^g(Z, 1 - q)$	$\Omega_1^e(m, \alpha)$
Investment I_1	$I^o \cup \Omega_1^g(S, \phi)$	$I^o \cup \Omega_1^g(Z, 1 - q)$	$I^o \cup \Omega_1^e(m, \alpha)$
NIP constraint	$\phi > 0$	$q < 1$	$X(1, m, \alpha) < 0$
Cost function	$\Lambda_1^g(S, \phi)$	$\Lambda_1^g(Z, 1 - q)$	$\Psi_1^e(m, \alpha)$

Now let us prove that equity injections dominate the other two programs. Take a program S, ϕ . We are going to construct an equity program that has same welfare gains, and costs less. To get equity with same lower bound graph we need to ensure that:

$$L_1^e(p, v; m, \alpha) = L_1^g(p, v; S, \phi) \text{ for all } p, v$$

So we must have

$$X(p; m, \alpha) = (1 - \alpha)(1 - \phi - p)S \text{ for all } p \tag{20}$$

It is easy to see that this is indeed possible if we identify term by term: $\frac{\alpha}{1-\alpha} = \frac{S}{A+c_0-D}$ and $m = (1-\phi)S$. Therefore it is possible to implement exactly the same lower schedules. Formally, we have just shown that:

$$I_1^g(S, \phi) = I_1^e(m, \alpha).$$

Next notice that the NIP constraints are equivalent since:

$$X(1, m, \alpha) < 0 \iff \phi > 0.$$

Now consider the upper bound. Consider the lowest point on the upper schedule of the guarantee program, i.e., the intersection of $U_1^g(p, v; S, \phi) = 0$ with $L^o(p, v) = 0$. At that point, we have $\tilde{p} = 1 - \phi$ and $\tilde{v} = (x - \phi c_0) / (1 - \phi)$. But from (20), it is clear that $X(\tilde{p}; m, \alpha) = 0$, and therefore $U_1^e(\tilde{p}, \tilde{v}; m, \alpha) = \alpha L^o(\tilde{p}, \tilde{v}) - X(\tilde{p}; m, \alpha) = 0$. Therefore the upper schedule $U_1^e(p, v; m, \alpha) = 0$ also passes by this point. But the schedule $U_1^e(p, v; m, \alpha) = 0$ is downward slopping in (p, v) , so the domain of inefficient participation is smaller (see Figure 7) than in the debt guarantee case. Formally, we have just shown that:

$$\Omega_1^e(m, \alpha) \subset \Omega_1^g(S, \phi).$$

As an aside, it is also easy to see that the schedule $U_1^e(p, v; m, \alpha) = 0$ is above the schedule $L^o(p, v) = 0$ so it does not get rid completely of opportunistic participation, but it helps.

The final step is to compare the cost functions.

$$\Lambda_1^g(S, \phi) \equiv S \int \int_{\Omega_1^g(S, \phi)} (1 - p - \phi) dF(p, v)$$

$$\Psi_1^e(m, \alpha) = \int \int_{\Omega_1^e(m, \alpha)} X(p; m, \alpha) dF(p, v) - \alpha \int \int_{\Omega_1^e(m, \alpha)} L^o(p, v) dF(p, v)$$

By definition of the participation domain, we know that $L_1^e(p, v; m, \alpha) > 0$. Therefore:

$$-\int \int_{\Omega_1^e(m, \alpha)} L^o(p, v) dF(p, v) < \frac{X(p; m, \alpha)}{1 - \alpha} \text{ for all } (p, v) \in \Omega_1^e(m, \alpha)$$

Therefore

$$\Psi_1^e(m, \alpha) < \frac{1}{1 - \alpha} \int \int_{\Omega_1^e(m, \alpha)} X(p; m, \alpha) dF(p, v) = S \int \int_{\Omega_1^e(m, \alpha)} (1 - \phi - p) dF(p, v)$$

Finally, since $1 - \phi - p > 0$ for all $(p, v) \in \Omega_1^e(m, \alpha)$, and since $\Omega_1^e(m, \alpha) \subset \Omega_1^g(S, \phi)$, we have

$$\Psi_1^e(m, \alpha) < \Lambda_1^g(S, \phi).$$

QED.

D Proof of proposition 3

Date 0 Cost Function

Define $v_0^m(p)$ by

$$L^m(p, v_0^m(p)) = 0$$

Then define the ex-post cost function:

$$\zeta(v, p) \equiv pm_{[0, v_0^m(p)]} + (L^o(p, v) + (1-p)m) 1_{[v_0^m(p), v_0(p)]} + m 1_{[v_0(p), 1]}$$

Note that we can rewrite the cash-against-equity cost function as

$$\begin{aligned} \Lambda_0(m; F) &= m - \int \int_{p, v} \zeta(v, p) dF(p, v) \\ &= m - E[\zeta(v, p) | F] \end{aligned}$$

The function ζ is increasing in v and in p , therefore FOSD of \tilde{F} on F , implies that $E[\zeta(v, p) | \tilde{F}] > E[\zeta(v, p) | F]$. Hence, $\Lambda_0(m; \tilde{F}) < \Lambda_0(m; F)$.

Date 1 can dominate

Choose any date 0 program, with cash m and optimal cost $\Lambda_0(m)$. Choose $\phi = 0$ and $S = m$ to get same investment set. Then,

$$\begin{aligned} \Lambda_1^g(m, 0) &= m \int \int_{I(m)} (1-p) dF(p, v) \\ \Lambda_0(m) &= m \int \int_{T \setminus I(m)} (1-p) dF(p, v) - \int \int_{I(m) \setminus I^o} L^o(p, v) dF(p, v) \end{aligned}$$

Where $T = [0, V] \times [0, 1]$. Clearly, we have $\Lambda_1^g(m, 0) < \Lambda_0(m)$ when $\int \int_{I(m)} dF(p, v)$ is small enough. Just because of the fact that date 1 program do not give away money to banks that do not need it. This is *a fortiori* true for equity injection since they dominate at date 1.

Date 0 can dominate

Consider a very large government program such that all firms invest. Then it must be that $Zq = x - c_0$ and $q = 1$ (see Figure). Then choose $m = x - c_0$. Then $I(m) = I^* = \Omega(Z, q)$. Now

$$\begin{aligned} \Lambda_1^g(Z, 0) &> \Lambda_0(m) \\ &\iff \\ (x - c_0) \int \int_{I^*} (1-p) dF(p, v) &> (x - c_0) \int \int_{T \setminus I^*} (1-p) dF(p, v) - \int \int_{I^* \setminus I^o} L^o(p, v) dF(p, v) \end{aligned}$$

Now clearly when $\Pr(I^*) \rightarrow 1$, then $\Pr(T \setminus I^*) \rightarrow 0$, so $(x - c_0) \int \int_{T \setminus I^*} (1-p) dF(p, v) \rightarrow 0$.

Over I^* , we know that $v > x$, hence $-L^o(p, v) < (1 - p)(x - c_0)$, therefore

$$-\int \int_{I^* \setminus I^o} L^o(p, v) dF(p, v) < (x - c_0) \int \int_{I^* \setminus I^o} (1 - p) dF(p, v) \leq (x - c_0) \int \int_{I^*} (1 - p) dF(p, v)$$

QED.

E Proof of proposition 5

First note that the optimization problem from the equity holders perspective remains unchanged because the investment and participation decision only depend on total debt D . Now consider the expected cost of deposit insurance. Note that the date 0 expected value of deposits is Δ because $\Delta \leq \underline{A} + c_0$. Hence, the cost of government intervention is unchanged and therefore the cost and benefits of both date 0 and date 1 programs remain unchanged.

F Proof of proposition 6

Date 0 Programs

Asset Buy Back

- Full Transfer: $\underline{A} + v < \Delta$

The date 1 expected value of deposits is

$$\begin{aligned} E_1 [y^\Delta(m) | p, v] &= p\Delta + (1 - p)(\underline{A} + c_0 + m) \text{ if } (p, v) \in T \setminus I_0(m) \\ &= p\Delta + (1 - p)(\underline{A} + v) \text{ if } (p, v) \in I_0(m) \end{aligned}$$

The date 0 expected value of deposits is

$$\begin{aligned} E_0 [y^\Delta(m)] &= \bar{p}\Delta + (1 - \bar{p})\underline{A} + \int \int_{T \setminus I_0(m)} (1 - p)(c_0 + m) dF(p, v) + \int \int_{I_0(m)} (1 - p)v dF(p, v) \\ &= \bar{p}\Delta + (1 - \bar{p})(\underline{A} + c_0 + m) + \int \int_{I_0(m)} (1 - p)(v - c_0 - m) dF(p, v) \end{aligned}$$

Assume the FDIC provides deposit insurance, i.e. the FDIC covers the face value of deposits. The date 0 expected cost of deposit insurance is

$$\begin{aligned} \Psi_0^F(m) &= \Delta - E_0 [y^\Delta(m)] \\ &= (1 - \bar{p})(\Delta - \underline{A} - c_0 - m) - \int \int_{I_0(m)} (1 - p)(v - c_0 - m) dF(p, v) \end{aligned}$$

The date 0 cost of government intervention without accounting for FDIC is

$$\Lambda_0(m) = (1 - \bar{p})m - m \int \int_{I_0(m)} (1 - p) dF(p, v) + \int \int_{I_0(m) \setminus I^o} (x - pv - (1 - p)c_0) dF(p, v)$$

Now consider the change in the expected cost of deposit insurance

$$\begin{aligned}\Lambda_0^F(m) &= \Psi_0^F(m) - \Psi_0^F(0) \\ &= -(1 - \bar{p})m + m \int \int_{I_0(m)} (1 - p) dF(p, v) - \int \int_{I_0(m) \setminus I^o} (1 - p)(v - c_0) dF(p, v)\end{aligned}$$

For simplicity, assume that the FDIC and the government have the same marginal dead-weight loss of raising taxes. The net cost of government intervention is

$$\Lambda_0(m) + \Lambda_0^F(m) = - \int \int_{I_0(m) \setminus I^o} (v - c_0) dF(p, v)$$

Note that this term is the expected benefit from investments taken because of the government intervention.

- Partial Transfer: $\underline{A} + c_0 < \Delta < \underline{A} + v$

The date 1 expected value of deposits is

$$\begin{aligned}E_1[y^\Delta(m) | p, v] &= p\Delta + (1 - p) \max(\Delta, \underline{A} + c_0 + m) \text{ if } (p, v) \in T \setminus I_0(m) \\ &= \Delta \text{ if } (p, v) \in I_0(m)\end{aligned}$$

The date 0 expected value of deposits is

$$\begin{aligned}E_0[y^\Delta(m)] &= \Delta \Pr(I_0(m)) + \Pr(T \setminus I_0(m)) \bar{p}\Delta + \int \int_{T \setminus I_0(m)} (1 - p) \max(\Delta, \underline{A} + c_0 + m) dF(p, v) \\ &= \Delta - \int \int_{T \setminus I_0(m)} (1 - p) (\Delta - \max(\Delta, \underline{A} + c_0 + m)) dF(p, v)\end{aligned}$$

The expected cost of deposit insurance is

$$\Psi_0^F(m) = \int \int_{T \setminus I_0(m)} (1 - p) (\Delta - \max(\Delta, \underline{A} + c_0 + m)) dF(p, v)$$

Now consider the change in the expected cost of deposit insurance

$$\Lambda_0^F(m) = \int \int_{T \setminus I_0(m)} (1 - p) (\Delta - \max(\Delta, \underline{A} + c_0 + m)) dF(p, v) - \int \int_{T \setminus I^o} (1 - p) (\Delta - \underline{A} - c_0) dF(p, v)$$

Note that when $\Delta \rightarrow (\underline{A} + c_0)$, then $\Lambda_0^F(m) \rightarrow 0$. This means the expected change in the cost of deposit insurance goes to zero as deposits become safe. Also note that when $\Delta \rightarrow (\underline{A} + v)$, then

$$\Lambda_0^F(m) \rightarrow -(1 - \bar{p})m + m \int \int_{I_0(m)} (1 - p) dF(p, v) - \int \int_{I_0(m) \setminus I^o} (1 - p)(v - c_0) dF(p, v)$$

which is the change in expected cost of deposit insurance in the full transfer case. The government cost is $\Lambda_0^F(m) + \Lambda_0(m)$.

The net cost of date 0 debt guarantees and date 0 equity injections is equivalent because all date 0 programs have the same cost function.

Date 1 Programs

Asset Buy Back Program

- Full Transfer: $\underline{A} + v < \Delta$

Date 1 expected value of deposits is

$$\begin{aligned} E_1 [y^\Delta(Z, q) | p, v] &= p\Delta + (1-p)(\underline{A} + c_0) \text{ if } (p, v) \in T \setminus (I^\circ \cup \Omega_1^g(Z, 1-q)) \\ &= p\Delta + (1-p)(\underline{A} + v) \text{ if } (p, v) \in I^\circ \cup \Omega_1^g(Z, 1-q) \end{aligned}$$

Date 0 expected value of deposits is

$$E_0 [y^\Delta(Z, q)] = \bar{p}\Delta + (1-\bar{p})(\underline{A} + c_0) + \int_{I^\circ \cup \Omega_1^g(Z, 1-q)} \int (1-p)(v - c_0) dF(p, v)$$

The expected cost of deposit insurance is

$$\Psi_0^F(Z, q) = (1-\bar{p})(\Delta - \underline{A} - c_0) - \int_{I^\circ \cup \Omega_1^g(Z, 1-q)} \int (1-p)(v - c_0) dF(p, v)$$

The change in the cost of deposit insurance is

$$\Lambda_0^F(Z, q) = - \int_{\Omega_1^g(Z, 1-q)/I^\circ} \int (1-p)(v - c_0) dF(p, v)$$

Expected government cost is

$$\Psi_1^g(Z, q) = Z \int_{\Omega_1^g(Z, 1-q)} \int (q-p) dF(p, v) = \Lambda(Z, 1-q) - \int_{\Omega_1^g(Z, 1-q)/I^\circ} \int (1-p)(v - c_0) dF(p, v)$$

- Partial Transfer: $\underline{A} + c_0 < \Delta < \underline{A} + v$:

The date 1 expected value of deposits is

$$\begin{aligned} E_1 [y^\Delta(Z, q) | p, v] &= p\Delta + (1-p)(\underline{A} + c_0) \text{ if } (p, v) \in T \setminus (I^\circ \cup \Omega_1^g(Z, 1-q)) \\ &= \Delta \text{ if } (p, v) \in I^\circ \cup \Omega_1^g(Z, 1-q) \end{aligned}$$

The date 0 expected value of deposits is

$$E_0 [y^\Delta(Z, q)] = \Delta - \int_{T \setminus (I^\circ \cup \Omega_1^g(Z, 1-q))} \int (1-p)(\Delta - \underline{A} - c_0) dF(p, v)$$

The expected cost of government insurance is

$$\Psi_0^F(Z, q) = \int_{T \setminus (I^o \cup \Omega_1^g(Z, 1-q))} \int (1-p)(\Delta - \underline{A} - c_0) dF(p, v)$$

The change in expected cost of deposit insurance is

$$\Lambda_0^F(Z, q) = - \int_{\Omega_1^g(Z, 1-q)/I^o} \int (1-p)(\Delta - \underline{A} - c_0) dF(p, v)$$

Note that when $\Delta \rightarrow (\underline{A} + c_0)$, then $\Lambda_0^F(Z, q) \rightarrow 0$. Also note that when $\Delta \rightarrow (\underline{A} + v)$, then

$$\Lambda_0^F(Z, q) \rightarrow - \int_{\Omega_1^g(Z, 1-q)/I^o} \int (1-p)(v - c_0) dF(p, v)$$

Total government cost is

$$\Psi_1^a(Z, q) = Z \int_{\Omega_1^g(Z, 1-q)} \int (q-p) dF(p, v) = \Lambda(Z, 1-q) - \int_{\Omega_1^g(Z, 1-q)/I^o} \int (1-p)(\Delta - \underline{A} - c_0) dF(p, v)$$

The results also apply to date 1 debt guarantees because date 1 asset buy backs and date 1 debt guarantees have the same cost function.

Date 1 Equity Injection

Note that we can compute the expected cost of date 1 equity injections similarly to the date 1 asset buy back program. The only difference is the participation region is capital 1 cash injection $\Omega^e(m, \alpha)$ and the participation region in date 1 asset buy back $\Omega_1^g(Z, 1-q)$. It turns out that the change in the expected cost of deposit insurance $\Lambda_0^F(m)$ is equivalent under both programs because both in the full and partial transfer case the difference in the participation region cancels out when computing the difference in expected cost of deposit insurance. It follows that the relative ranking of programs is unchanged because all programs have the same reduction in costs due to deposit insurance.

G Optimal programs

G.1 Proof of proposition 7

Just to illustrate the logic, let us compare the date 0 debt guarantee with the optional date 0 debt guarantee. Participation is decided at date 0. Banks give an equity share α in exchange for the right (not the obligation) to use the debt guarantee program (S, ϕ) at

date 1. The increase in shareholder value is

$$\begin{aligned}
E_0 [y^e (\Gamma)] - E_0 [y^e] &= \int \int_{I_1^g(S, \phi)} L_1^g(p, v; S, \phi) dF(p, v) - \iint_{I^o} L^o(p, v) dF(p, v) \\
&= S \int \int_{I_1^g(S, \phi)} (1 - \phi - p) dF(p, v) + \int \int_{I_1^g(S, \phi) \setminus I^o} L^o(p, v) dF(p, v) \\
&= \Lambda_1^g(S, \phi) + \int \int_{I_1^g(S, \phi) \setminus I^o} L^o(p, v) dF(p, v)
\end{aligned}$$

If the government asks for equity ex-ante, then the net cost to the government is

$$\tilde{\Lambda}_0(S, \phi) = - \int \int_{I_1^g(S, \phi) \setminus I^o} L^o(p, v) dF(p, v)$$

To compare with:

$$\Lambda_0(m) = m \int \int_{T \setminus I(m)} (1 - p) dF(p, v) - \int \int_{I(m) \setminus I^o} L^o(p, v) dF(p, v)$$

Where $T = [0, V] \times [0, 1]$. So it is clear that with $s = m$, the investment domains are the same, and the cost saving is

$$\Lambda_0(s) - \tilde{\Lambda}_0(S, \phi) = m \int \int_{T \setminus I(m)} (1 - p) dF(p, v) - \int \int_{I(m) \setminus I^o} L^o(p, v) dF(p, v) + \int \int_{I_1^g(S, \phi) \setminus I^o} L^o(p, v) dF(p, v)$$

So it is clear that the ex-ante optional program strictly dominates in all cases. First, one can always set $\phi = 0^+$ and $S = m$ in which case $I_1^g(S, \phi) = I(m)$ and the cost reduction is

$$m \int \int_{T \setminus I(m)} (1 - p) dF(p, v)$$

which corresponds to idle cash wasted on banks that do not make new investment. In addition, the optional program allows for greater flexibility in the design on the investment set. In particular, Figure 6 shows that the optional program is better at getting the high v in the low p region without admitting a lot of low v in the high p region.

G.2 Proof of proposition 8

Let us show that pure equity dominates. Let m be total money injection, sum of m' from equity and qZ from asset buy-back. Now define the function

$$X(p) \equiv (1 - \alpha)(m - pZ) - \alpha p(N + c_0)$$

The usual calculations lead to

$$\begin{aligned} L &\equiv (1 - \alpha) L^o(p, v) + X(p) \\ U &\equiv \alpha L^o(p, v) - X(p) \\ NIP &: X(1) < 0 \end{aligned}$$

The participation becomes

$$\Omega = \{(p, v) \mid L > 0 \wedge U < 0\}$$

The cost function is therefore

$$\Psi = \iint_{\Omega} X(p) dF(p, v) - \alpha \iint_{\Omega} L^o(p, v) dF(p, v) \quad (21)$$

Now take any program. To get the same investment curve, we need the same lower bound, and therefore the same function $X(p)$. But then we now from (21) that the cost function is the same. Also we know that the NIP constraint is $X(1) < 0$, so it is also the same. Thus, all that matters is the participation domain Ω . So we need only to look at the upper bound U . We want to exclude as many banks as possible, so we want U to be as high as possible. The way to do so is obviously to have α as high as possible. But of course we must keep the function $X/(1 - \alpha)$ constant. Therefore we must keep $Z + \frac{\alpha}{1 - \alpha}(N + c_0)$ constant. As α goes up, Z must go down. Therefore we want to set $Z = 0$. Therefore asset buy back cannot improve the equity program.

The same exact proof works for debt guarantees. QED.

G.3 Proof of Proposition 9

In the good state, the residual payoffs conditional on investment are

$$N + c_0 + m + \frac{L^o(p, v) + (1 - p)m}{p}$$

The loan gets repaid first, then shareholders get

$$\begin{aligned} y^e &= \max\left(N + c_0 + \frac{L^o(p, v) + (1 - p)m}{p} - hm, 0\right) \text{ if } i = 1 \text{ and } a = A \\ y^e &= \max(N + c_0 - hm, 0) \text{ if } i = 0 \text{ and } a = A \end{aligned}$$

As soon as $y^e > N + c_0$, the options are in the money and the number of shares jumps to $1 + \frac{1 - \varepsilon}{\varepsilon} = \frac{1}{\varepsilon}$. So the old shareholders get only a fraction ε of the value beyond $N + c_0$. Their payoff function is therefore:

$$f(y^e) = \min(y^e, N + c_0) + \varepsilon \max(y^e - N - c_0, 0)$$

So old shareholders are full residual claimants up to the face value of old assets $N + c_0$ and ε residual claimants beyond. Now let us think about their decisions at time 1. As usual only the payoffs in the non default state matter. If they do not invest they get $N + c_0$. If they do investment, they can get more if and only if $L^o(p, v) + (1 - p)m > phm$. The lower participation constraint is therefore

$$L^o(p, v) + (1 - (1 + h)p)m > 0$$

It converges to L^m if $h \rightarrow 0$. We can compare this to the equity injection schedule $L_1^e(p, v; m, \alpha)$, we can identify the same cash injection m , and the dilution factor

$$\alpha = \frac{m(1+h)}{N+c_0+m(1+h)}$$

If we compare to debt guarantee $L_1^g(p, v; S, \phi) = L^o(p, v) + (1-\phi-p)S$. Then

$$m = (1-\phi)S \text{ and } h = \frac{\phi}{1-\phi}$$

Next consider the upper schedule. Investing alone gets $N+c_0+L^o(p, v)/p$ so they opt in if and only if $L^o(p, v) > \varepsilon(L^o(p, v) + (1-(1+h)p)m)$

$$U = L^o(p, v) - m\varepsilon \frac{1-(1+h)p}{1-\varepsilon}$$

It converges to $L^o(p, v)$ when $\varepsilon \rightarrow 0$. The NIP constraint is simply

$$h > 0.$$

Finally, the cost of the program is small because the government gets all the upside value of the new projects. The expected payments to the old shareholders converge to $p(N+c_0)$. So the government gets expected value $L^o(p, v) + m$ by paying m at time 1. The total cost is therefore:

$$-\int \int_{I(\Gamma) \setminus I^o} L^o(p, v) dF(p, v)$$

It is positive since $L^o(p, v) < 0$ for all $(p, v) \in I(m) \setminus I^o$.

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Fig 1: Information & Technology

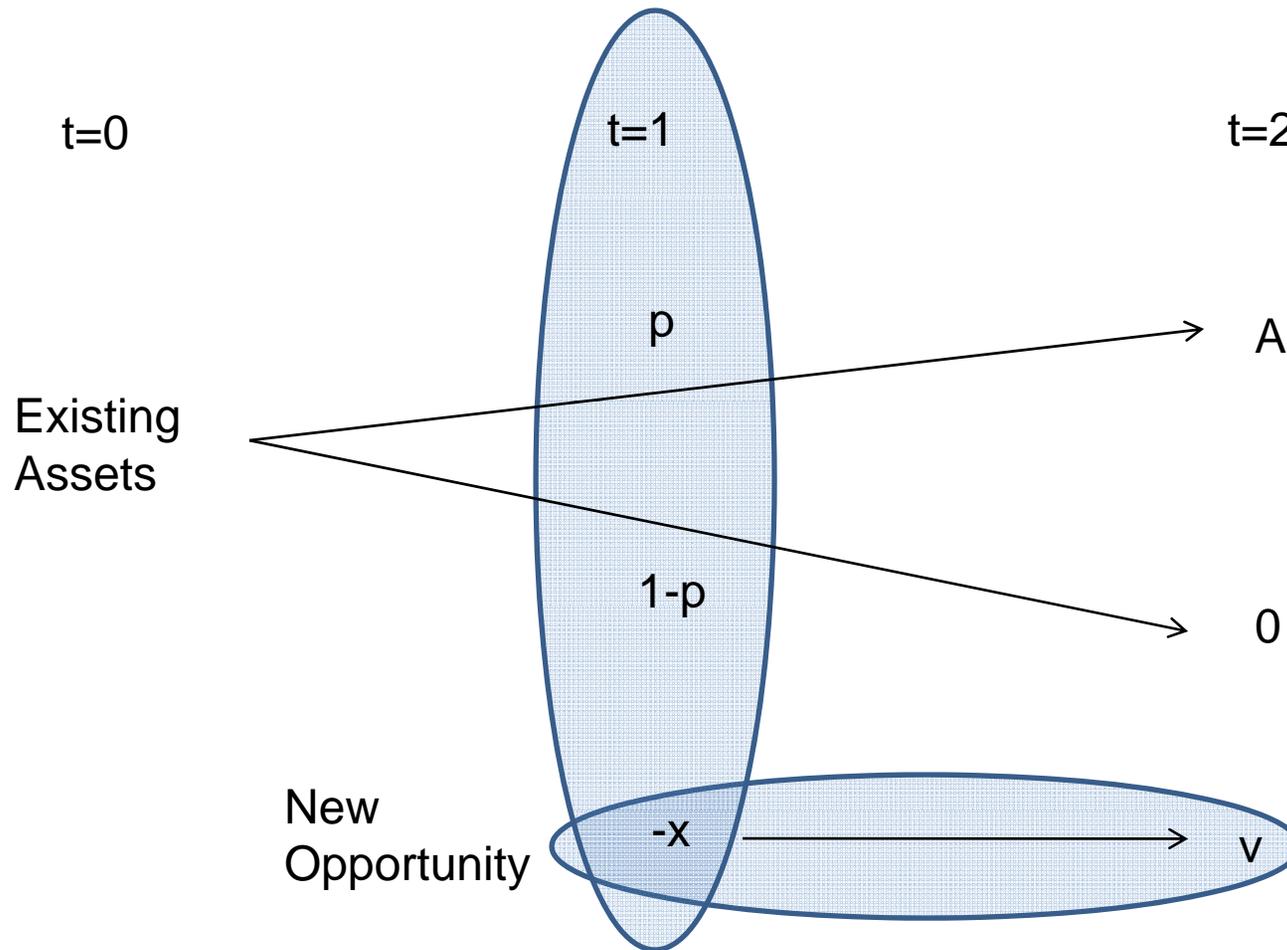


Fig 2: Equity Payoffs

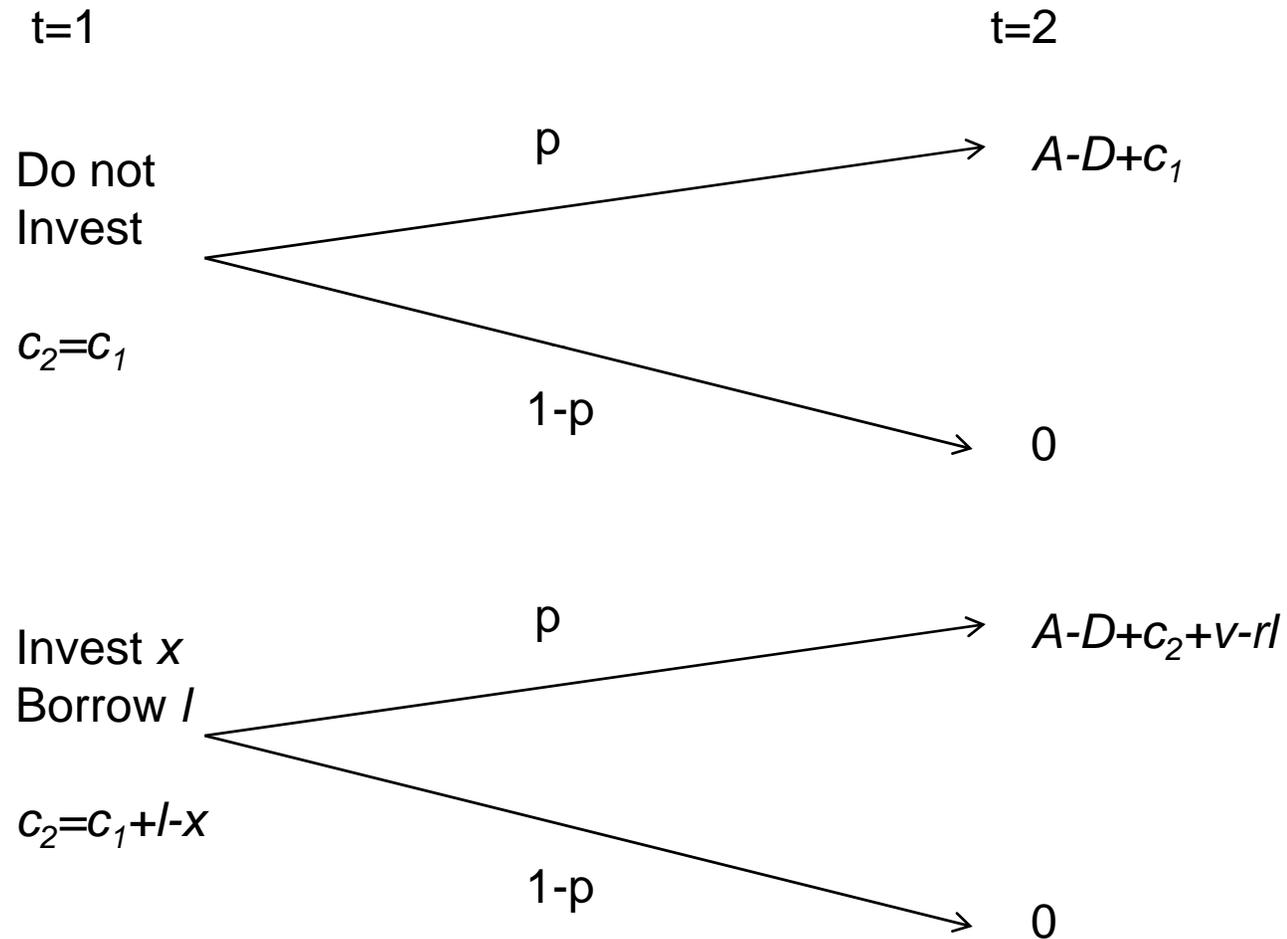


Fig 3: First Best

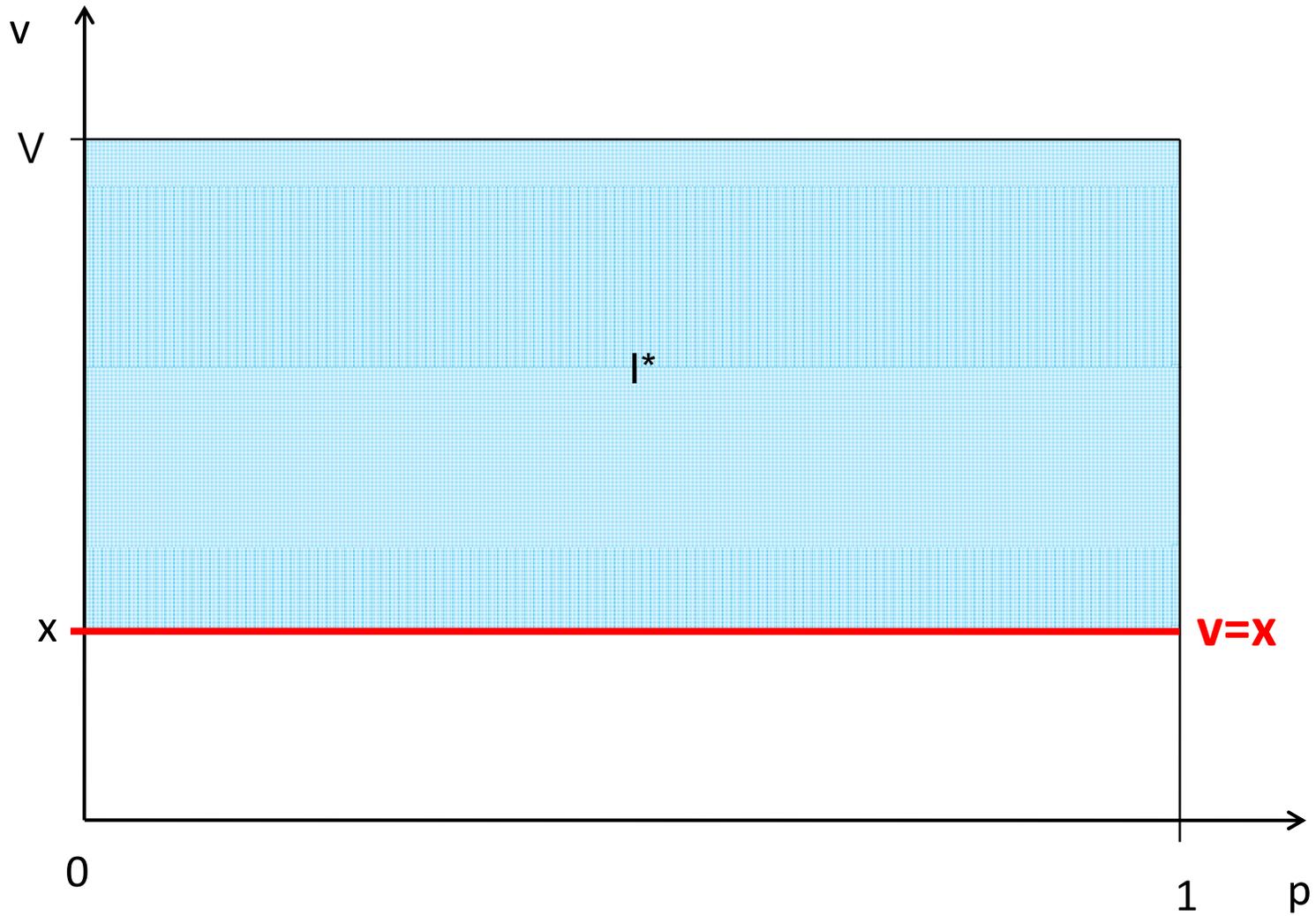


Fig 4: Debt Overhang

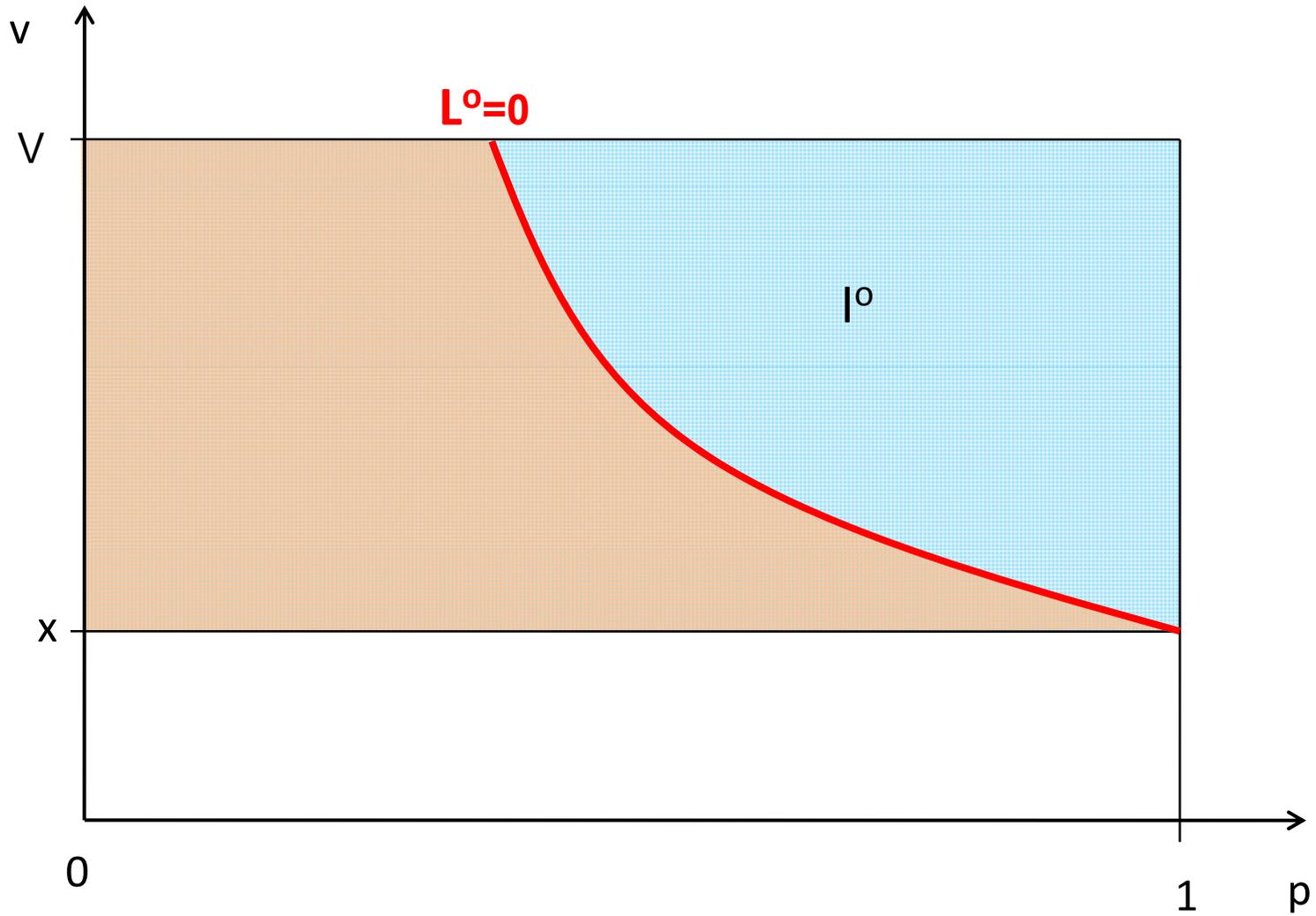


Fig 5: Cash at time 0

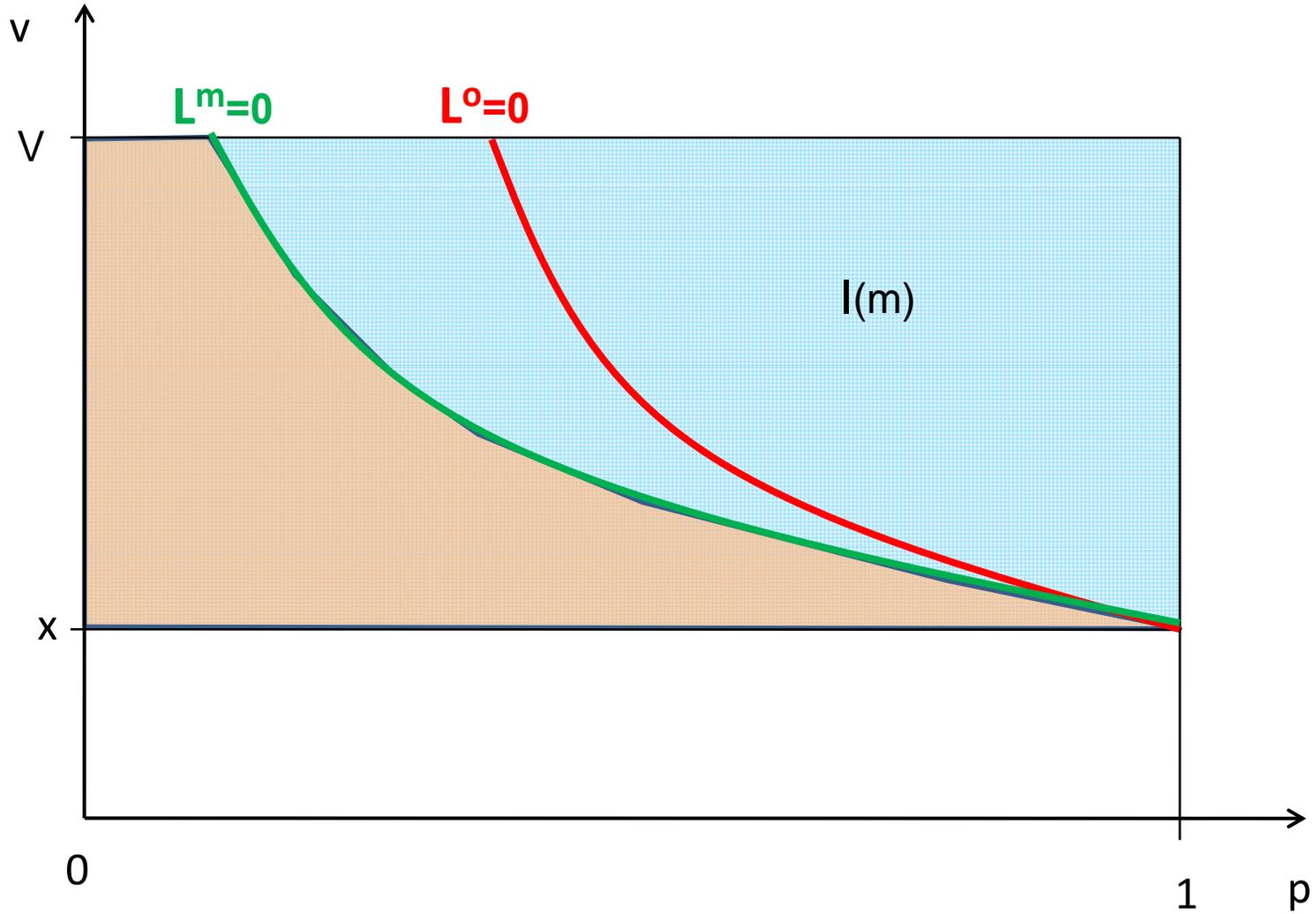


Fig 6: Debt Guarantee at time 1

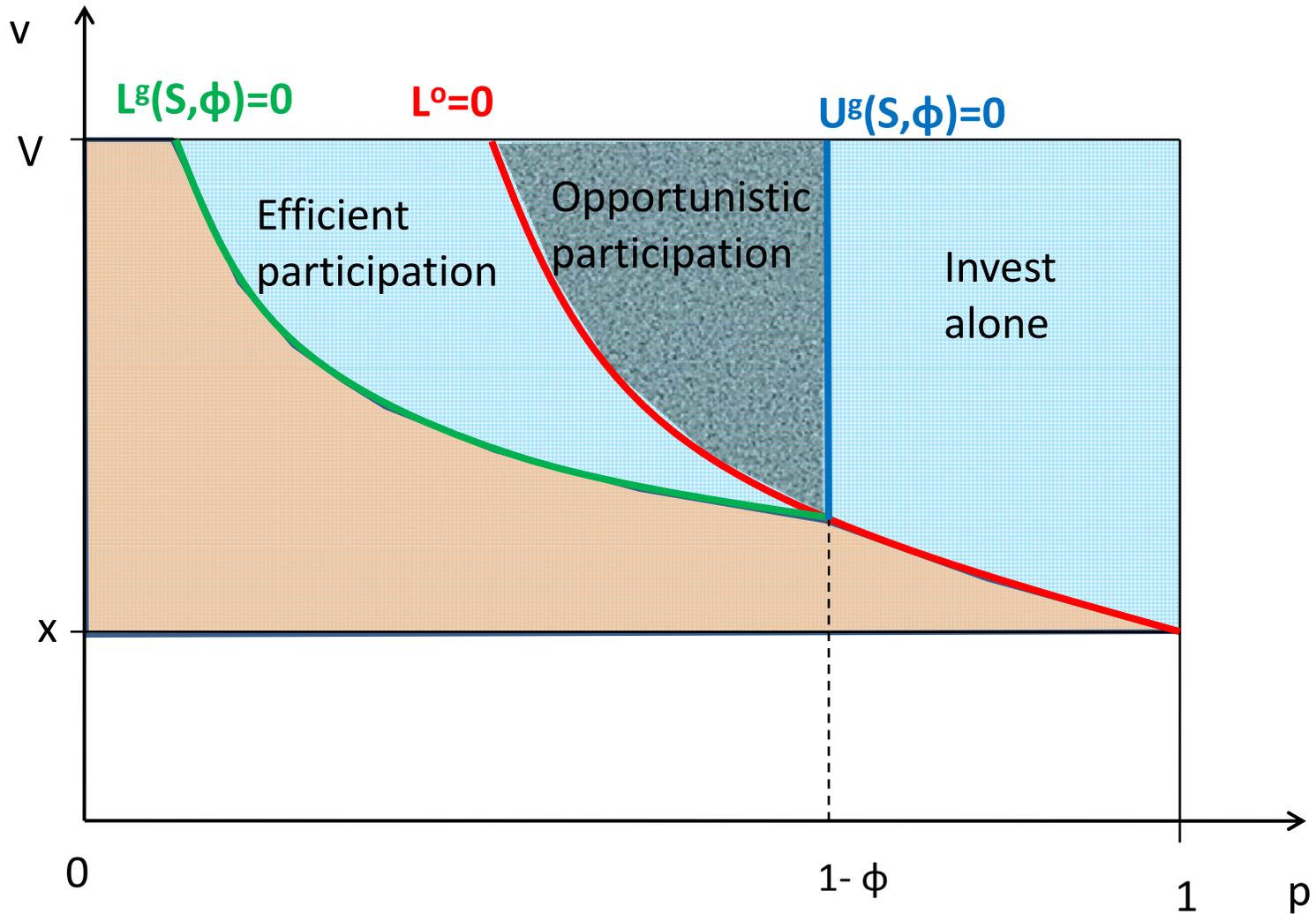


Figure 7: Equity injection at time 1

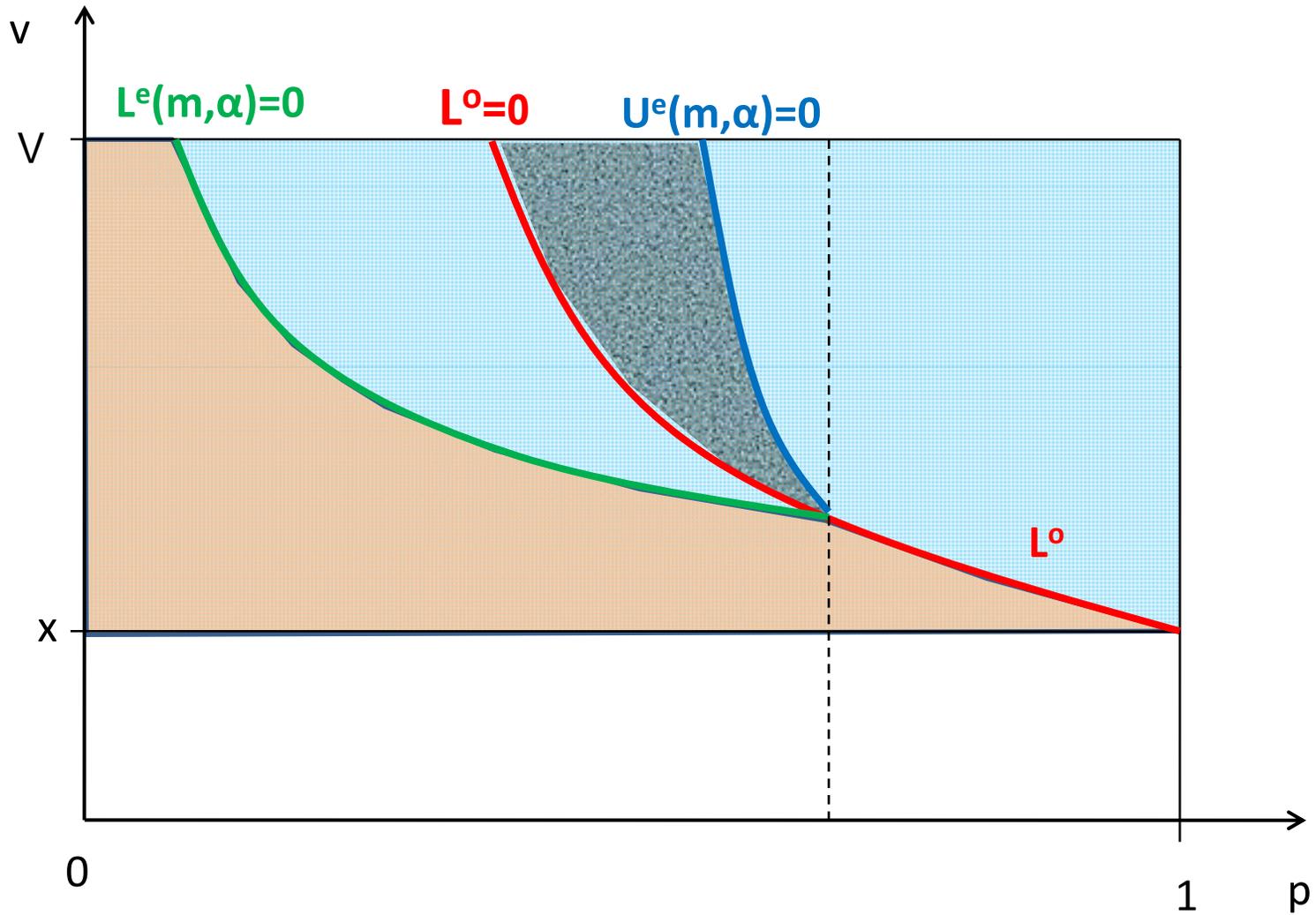


Figure 8: Efficient Mechanism

