Financ Mark Portf Manag (2010) 24: 3–29
DOI 10.1007/s11408-009-0125-y

Common (stock) sense about risk-shifting and bank bailouts

Linus Wilson · Yan Wendy Wu

Published online: 16 January 2010

Abstract If a bank is facing insolvency, it will be tempted to reject good loans and accept bad loans so as to shift risk onto its creditors. We analyze the effectiveness of buying up toxic mortgages in troubled banks, buying preferred stock, and buying common stock. If bailing out banks deemed "too big to fail" involves buying assets at above fair market values, then these banks are encouraged ex ante to gamble on bad assets. Buying up common (preferred) stock is always the most (least) ex ante- and ex post-efficient type of capital infusion, regardless of whether the bank volunteers for the recapitalization.

Keywords Asset substitution · Banks · Bailout · Capital Assistance Program (CAP) · Capital Purchase Program (CPP) · Capital structure · Emergency Economic Stabilization Act (EESA) · Lehman Brothers · Public-Private Investment Program (P-PIP) · Lending · Risk-shifting · Too big to fail · Troubled Asset Relief Program (TARP)

JEL Classification G21 · G28 · G38

1 Introduction

On September 15, 2008, the negotiations to sell Lehman Brothers to the British bank Barclays Plc. broke down. At the time of its US Chap. 11 bankruptcy protection fil-

L. Wilson (✉)
B.I. Moody III College of Business, Department of Economics & Finance, University of Louisiana at Lafayette, 214 Hebrard Boulevard, Moody Hall 253, P.O. Box 44570, Lafayette, LA 70504-4570, USA
e-mail: linuswilson@louisiana.edu

Y.W. Wu
Department of Economics, School of Business and Economics, Wilfrid Laurier University, 75 University Avenue West, Waterloo, ON, Canada, N2L 3C5

ing, Lehman Brothers had assets worth over 6 times that of WorldCom, the previous record holder for the largest bankruptcy in US history.[1] The prospect of the disorderly bankruptcy of a former investment bank led to considerable market turmoil.[2] On October 3, 2008, President George W. Bush signed the Emergency Economic Stabilization Act (EESA), which authorized the US Treasury to buy up to $700 billion dollars of troubled assets to stabilize the financial sector. A few weeks later the largest remaining commercial and investment banks received $125 billion from the US Treasury primarily in exchange for preferred stock, which paid dividends far less than the preferred stock that had been sold days or weeks before.[3] Press reports said that Treasury Secretary Henry M. Paulson Jr. told the CEOs of nine of the largest US banks that these stakes were bought to restore confidence to the markets and to encourage the banks to lend.[4]

This paper considers how various types of capital infusions affect banks' incentives to lend efficiently. It rigorously addresses the question of which securities should be used to recapitalize troubled banks. We consider the government's decision to recapitalize a bank that is deemed "too big to fail" by regulators. Sorting out the millions of lending and derivatives transactions associated with a top investment bank or huge commercial bank with investment banking activities may test the limits of the bankruptcy courts and create great uncertainty about the credit quality of the failed bank's counterparties.

We assume that the government cannot contract over the firm's lending policy. Instead, the government's primary mechanism for improving the troubled bank's lending decisions is recapitalizing the bank. In this paper, we assume that the troubled bank has a sufficient amount of liquid assets to make new loans. Nevertheless, since the bank is not solvent in all states of the world, it is tempted to shift risk onto its creditors. This paper finds that, in terms of inducing efficient lending, the government's purchases of new common stock is always at least or more effective than buying toxic mortgage securities or buying preferred stock. We find that the subsidies (overpayment for assets) are always necessary to induce the bank to agree to the recapitalization voluntarily.

Further, we find that preferred stock is the least effective form of recapitalization. All the gains from a preferred stock recapitalization come from the implicit government subsidy from purchasing that security. That is, it is only the regulator's overpayment for preferred stock that improves lending incentives. Because both Goldman Sachs and Morgan Stanley issued preferred stock days before and days after for yields higher than the preferred stock sold by the Treasury on October 13, there is strong

[1] Christopher Tkaczyk, November 1, 2009, "The 10 Largest US Bankruptcies," *Fortune*.

[2] David Teather, Andrew Clark, and Jill Treanor, September 17, 2008, "Barclays Agrees $1.75bn Deal for Core Lehman Brothers Business" *The Guardian*.

[3] A summary of the major Federal Reserve policy response between August 2007 and December 2008 is provided in Sarkar (2009).

[4] See Mark Landler and Eric Dash, October 15, 2008, "Drama Behind a $250 Billion Banking Deal," *New York Times*, A1. The move to buy preferred stock was a quick about face for a Treasury secretary who originally argued that the funds from the EESA would be used to buy troubled mortgage securities.

evidence that the government did overpay for those preferred shares.[5] Yet, they may not have overpaid enough to improve the lending behavior of the banks in question. Moreover, this paper proves that just because a bank agrees to a preferred stock recapitalization does not imply that the bank's lending behavior will improve. Indeed, as long as the government buys enough common stock or toxic assets, lending incentives improve without a subsidy for potentially, but not yet insolvent banks. We analyze how recapitalizations involving these three different types of asset purchases affect lending incentives.

It is well known that excessive leverage can lead to risk-shifting. Common stockholders with limited liability have incentives to shift much of the risks of speculative projects (here, loans) onto their creditors. This problem was laid out in Jensen and Meckling (1976). In this case, some of the returns from safer investments accrue to that company's more senior creditors—preferred stock holders, unsecured bondholders, and secured bond holders—when a company is nearly or actually insolvent. The common stockholders in a company that has excessive leverage are tempted to gamble for resurrection by undertaking speculative projects that are positively correlated with the firm's existing cash flows. Merton (1974) recast the value of a firm's equity as a call option on the firm's assets. In this framework, as the variance of the firm's assets is increased (as the bank takes on speculative loans), its equity is increased. Variance becomes an increasingly important component of the call option's value as the call is at or well out of the money. That is, when the bank is nearly or actually insolvent, its incentives to gamble for resurrection increase.

There is some evidence that the risk-shifting incentives of insolvent banks can significantly deplete assets. For example, Barrow and Horvitz (1993) studied insolvent savings and loans operated by the now defunct Federal Savings and Loan Insurance Corporation from 1985 to 1988. The firms operated under government conservatorship adopted much less risky strategies and on average depleted the deposit insurance

[5] Randall W. Forsyth, October 14, 2008, "Buffett Drives a Harder Bargain than Paulson: Banks get cheaper financing from Treasury than from Berkshire Hathaway," *Barron's.* The first participants in the Troubled Assets Relief Program (TARP)'s Capital Purchase Program (CPP) were Goldman Sachs, Morgan Stanley, Merrill Lynch, JPMorgan Chase, Bank of America (which agreed to acquire Merrill Lynch), Citigroup, Wells Fargo, Bank of New York Mellon, and State Street. These banks received the first $125 billion dollars of preferred stock purchased with the funds of the Emergency Economic Stabilization Act. Most of these banks repurchased the US Treasury's preferred stock on June 17, 2009. In December 2009, all nine except Citigroup announced agreements to repay the Capital Purchase Program injections before the end of 2009. Those repayments, all of which occurred after the first circulation of this paper, almost always coincided with agreements with regulators to raise common stock prior to redeeming the preferred stock. On October 13, 2008, the Treasury agreed to purchase preferred stock that paid a dividend of 5% for the first 5 years and 9% thereafter. Treasury's purchase had warrants attached worth 15% of the preferred stock's par value. Warren Buffet bought preferred stock with 10% dividends and warrants on 100% of the purchase weeks prior to the Treasury deal. Just prior to the Treasury's capital infusion, the publicly traded preferred shares of many of the banks receiving funds traded with yields between 9.62% and 11.7%. Veronesi and Zingales (2008), Congressional Budget Office (2009), and the Congressional Oversight Panel (2009) also estimate that the Treasury overpaid for its preferred stock in those banks. The corresponding author estimated in Zachary Kouwe, August 31, 2009, "As Banks Repay Bailout Money, US Sees Profit," *New York Times*, A1 that private investors did much better than taxpayers on a risk-adjusted basis. Investors buying publicly traded preferred stock, or subordinated debt if the company had no publicly traded preferred stock, in the eight large banks which had repurchased both preferred stock and warrants by the end of August 2009, enjoyed annualized returns of 44% over the taxpayers' holding period. This is nearly three times taxpayers' average annual returns of 15% in those banks.

fund less than did insolvent savings and loans that were allowed to continue operating under their existing management.

Several papers have argued that a regulator will not or should not merely close down insolvent or nearly insolvent banks and then take a *laissez-faire* policy. Malaith and Mester (1994) investigate how regulators' policy on bank closure influences a bank's portfolio choices and its levels of risk. They find that as the bank's size increases, the regulators' closure policy becomes less credible, whereas forbearance becomes more credible. Acharya and Yorulmazer (2007, 2008) argue that the necessities of bailout policy depend on the relative number of failed banks versus surviving banks. When a sufficiently large number of banks fail, granting liquidity to surviving banks so that they can purchase failed banks, dominates over a bailout policy that directly assists failed banks. Gorton and Huang (2004) also argue that it is costly for private agents to be prepared to purchase substantial amounts of assets on short notice. In this context, the government can create liquidity and improve welfare. Therefore, they argue that forbearance and bank bailouts are sometimes optimal. Acharya (1996), in arguing that not all insolvent banks should be closed, states that it is optimal to leave those insolvent banks with sufficiently large charter (going-concern) values open. Cordella and Yeyati (2003) also argue that regulatory forbearance may be optimal if the insolvent banks' charter values are large. They argue that the optimal bailout policy should be announcing and committing ex-ante to bail out insolvent institutions only in times of adverse macroeconomic conditions but not otherwise. Rochet and Tirole (1996) analyze how interbank lending can transmit one bank's problem to others and lead to systemic banking failure. They argue that banks become "too big to fail" when the failure of a single bank can propagate a crisis in the entire banking system.

Several empirical studies document that regulators are reluctant to close down banks and will often provide some sort of government assistance during banking crises. Hoggarth et al. (2004) discuss resolutions adopted in 33 banking crises worldwide between 1977 and 2002. They find that during systemic crises, liquidity support from central banks and blanket government guarantees have been granted. Kasa and Spiegel (2008) analyze US bank closures during 1992–1997 and find that only banks performing significantly worse than the industry are closed. Brown and Dinc (2010) analyze failures among large banks in 21 major emerging markets in the 1990s and show that the government decision to close or take over a failing bank depends on the financial health of other banks in that country. Caballero et al. (2008) find that regulatory forbearance was the norm in Japan after the crash of its stock market and property price bubble in the 1990s. Over-levered banks were allowed to use questionable account adjustments to overstate their health. This in part led these banks to make poor, speculative lending decisions. Bernhardsen et al. (2009) documents that, as a measure to strengthen the troubled banking sector, the Norwegian Ministry of Finance offer to exchange up to 350 billion Norwegian Kroner of government bonds with eligible troubled banks instead of closing many of them down.

Our study provides a theoretical model that analyzes the relative merit of purchasing toxic mortgages, purchasing preferred shares, and common stock recapitalizations when banks have enough liquid assets to participate in risk-shifting. Wilson (2009), in contrast, is concerned with the effectiveness of buying toxic assets, pre-

ferred, or common stock when banks suffer from debt overhang incentives that prevent them from raising equity to make new profitable loans. Another study that does discuss a particular type of recapitalization is Chaney and Thakor (1985). That study argues that bailing out companies (not just banks) with loan guarantees induces those firms to take on speculative undertakings ex ante and does not discuss any other types of government capital injections.

Usually studies of banking bailouts involve capital injections that are pure subsidies to the recipient banks. Examples include Diamond and Rajan (2002) and Aghion et al. (1999). This focus on pure subsidies as opposed to security purchases is probably in part due to the fact that many of the recipient banks are assumed to be insolvent. In that case, the only way to put cash into a failing bank without violating the bank's creditors' claims is through a direct subsidy. In contrast, this study assumes that banks are potentially but not yet insolvent. Further, this paper assumes that recipient banks do not suffer from liquidity problems. Thus, they could sell securities of value to the government, and they have sufficient funds to make new loans.[6]

To our knowledge, the only papers that specifically mention the securities that should be used in bank bailouts do not rigorously model the regulator's optimal security choice. For example, Bebchuk (2008) and Zingales (2008) do not prove their assertions that common stock is the best way to recapitalize banks. The former paper advocates mandatory rights offerings to force banks to increase the common stock component of their capital structure. The latter advocates a mandatory debt-for-equity swap in the financial sector to achieve a higher equity-to-assets ratio for banks. Bebchuk (2008) argues that the Treasury should not overpay for troubled assets and should not mix the buying of distressed assets with direct bank capital injections. In this paper, the government buys distressed assets in the troubled bank only. We find that common equity recapitalizations always weakly dominate purchases of troubled assets (toxic mortgages). Harvey (2008) suggests that direct capital injections through equity investment are more effective than purchasing troubled assets. Proposition 6 of this paper supports these other scholars' intuition that forced common equity recapitalizations with capital coming from either private investors or the government are first-best efficient. We consider the case where the regulator lacks the credibility or the political will to force recapitalizations and still finds that common stock cash infusions are equally as effective as toxic asset purchases.

The paper proceeds as follows. The model is introduced in Sect. 2. In Sect. 3, we proceed backward though the game outlined in Fig. 1. The subgame perfect Nash equilibrium (SPE) for all the possible parameter values is outlined at the end of Sect. 3. In Sect. 4, we apply the model to two numerical examples. In Sect. 5, we

[6]The US Treasury's, Capital Purchase Program (CPP) was meant for healthy, solvent banks as determined by their regulators. See Brookings Institution, January 8, 2009, Transcript of "The Man in The Middle of the TARP: A Discussion with Treasury's Neel Kashkari," p. 6. There have been aggressive efforts by the Federal Reserve the Federal Deposit Insurance Corporation (FDIC) to guarantee that banks are liquid. The FDIC's Temporary Liquidity Guarantee Program, for example, guarantees member banks' short-term debt was initiated on October 14, 2009, and continues today. FDIC Press Release, October 14, 2008, "Temporary Liquidity Guarantee Program: FDIC Announces Temporary Program to Encourage Liquidity and Confidence in the Banking System." This program was extended until October 31, 2009. See FDIC Press Release, March 18, 2009, "Extension of Temporary Liquidity Guarantee Program Interim Rule."

Bank B decides whether or not to buy speculative mortgage securities, and Bank C decides whether to extend credit to Bank B to buy those mortgage securities.

a. The government decides whether or not to bail out Bank B.
b. Bank B chooses between a good loan and a bad loan.

a. Mortgage returns and returns from the bad loan are realized as high or low.
b. Bank C is paid back from Bank B.

Fig. 1 The sequence of events

discuss the results in light of the asset purchases by the Troubled Asset Relief Program (TARP) to date and then conclude.

2 Model

Suppose there are two banks, Bank B and Bank C. The first is the "bad" bank because it is tempted to make a bad investment in period zero. Bank B also has deposits worth D. Bank B has two choices: it can invest its deposits in period 0 and earn a safe return of zero in period 2, or it can underwrite risky mortgages with a present value $M = 2D$. The price of this illiquid mortgage investment is $M + \beta > M$ in risky mortgages. β can represent the transaction costs of this purchase or the fact that this is a bad investment ex ante.

There is some evidence that many of the mortgage or real estate based loans or securities made in the mid-2000s were negative net present value investments when they were made. Certainly the underwriting standards for a large proportion of the US home mortgages originated in 2005 and 2006 would give most people pause. The no down payment, no documents, and no stated income or assets loans were unprecedented in the history or mortgage finance and clearly ripe for abuse. These underwriting practices were not a secret from the general public or from the banks taking long positions in these assets. Improper incentive structures gave many mortgage lenders and many investment bankers securitizing the loans a vested interest in ignoring the credit quality of loans that they created.

This mortgage investment has an expected net present value of $-\beta$, where $0 < \beta$. β is a deadweight loss to society. For example, a vacant home may have little social value but takes valuable resources to build and maintain. The present value of these mortgages is a function of a Bernoulli random variable that has a probability of high returns of p and a probability of low returns of $(1 - p)$ in period 2a. The subscripts denote whether the value moved to high or low. H means the value of the mortgage portfolio increased in value in period 2a. L denotes that the mortgages declined in

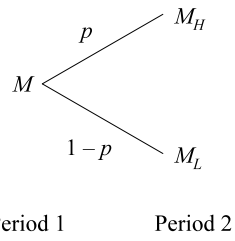


Fig. 2 Evolution of the value of the mortgage portfolio

value in periods 2a. The expected value of these mortgages is the following:

$$M = pM_H + (1-p)M_L,$$
$$\text{where } M_H > M > M_L. \tag{1}$$

The value evolution of this mortgage portfolio is illustrated in Fig. 2.

We assume that Bank B will undertake the risky mortgage investment only if its expected returns *strictly* exceed the returns in the safe asset. In period 0, Bank B and Bank C make their investments. All players are risk-neutral. The risk-free discount rate between periods is normalized to zero. To capture the impact of counterparty risk which is important to derivatives as well as to lending agreements, we will present a stylized story of lending between banks.

Bank C is potentially the "counterparty" to Bank B. If Bank B decides against investing in the risky mortgages, then Bank C can invest only in safe assets that generate a net return of zero.[7] However, we assume that there are two options for Bank C in period 0 if Bank B does invest in the risky mortgages. Bank C has deposits of magnitude $D = F$, that it can invest in safe assets that earn a return of zero, or it can lend them to Bank B. Bank B promises to pay $F + \gamma > F$ for these borrowings in period 2. If Bank C lends to Bank B, Bank C is a junior creditor to Bank B's depositors but a senior creditor to Bank B's shareholders.

If Bank B invests only in the safe assets that have expected net present value of zero when they mature in period 2, Bank B has equity capital in the form of cash of $N + \beta + \gamma$, where N, β, and γ are strictly positive. (The assumption that the firm has equity capital of N is not necessary to obtain the risk shifting result; all that is necessary is that Bank B has available liquid assets to make its investment in the bad loan because it will be unable to profitably convince new investors to fund it.) Further, let us assume that equity capital is less than total deposits

$$N + \beta + \gamma < D. \tag{2}$$

[7] This is stylized as a lending arrangement between a borrower, Bank B, and a lender, Bank C. Nevertheless, the relationship could be as counterparties in a derivative transaction. The key element is the failure of Bank B exposes other banks, Bank C, to insolvency. Brommundt et al. (2006) detail how rising credit spreads associated with the Delphi's, the auto parts supplier's, bankruptcy led to the demise of many hedge funds writing those contracts when collateral demands became too great. In the crisis of 2008, the huge insurer American International Group (AIG) was bailed out by the Federal Reserve Bank of New York to save a list of the leading global investment banks, such as Societe Generale, Goldman Sachs, and Deutsche Bank, who would have been potentially harmed if AIG defaulted on its credit default swap (CDS) obligations according to SIGTARP (2009). Thus, systemic risk could be spread by derivative as well as lending counterparties.

Bank C has equity normalized to be worth 0 at the beginning of period 0 in the base case where it does not grant credit to Bank B. Banks B has access to a risk-free, positive net present value loan in period 1, which we will call the "good loan." This loan has a present value of π. This loan is extended by Bank B in period 1b, and it will receive the proceeds in period 2a. The net present value of the social benefits from extending the good loan, which do not accrue to the lender, are $\Pi > 0$. The magnitude of the good loan is the size of the cash reserve, N.

Bank B does not have to make the good loan; instead, it can take on a speculative, bad loan. The timing of this second lending opportunity is the same as the first. It is assumed that these are mutually exclusive investment opportunities. Bank B can only make the good loan or the bad loan. This second type of loan, the bad loan, has a negative net present value of a magnitude of $-\lambda < 0$. λ represents the expected loss to investing in the bad loan. Thus, total investor wealth, which includes shareholder plus creditor wealth, is destroyed by investing in the bad loan. Suppose the bad loan costs N and has expected value of $N - \lambda > 0$ where $\lambda > 0$. This loan is perfectly positively correlated with the mortgages securities' returns. Let us assume that $\sigma - \lambda > 0$. $\sigma - \lambda$ is the return in excess of the amount invested in the bad loan in the high state. Further, let us assume that $-\sigma[(1-p)/p]$ is the net loss from the loan in the low demand state. Let us define the ratio of the low state probability over the high state probability as the following:

$$\phi \equiv \frac{1-p}{p} > 0. \tag{3}$$

ϕ is merely a notational convenience. In the high demand state, the project returns $N + \sigma - \lambda > N$. In the low demand state, the bad loan returns a positive amount, which is less than the principal, $N - \sigma/\phi - \lambda$, where, by assumption, $N > N - \sigma/\phi - \lambda > 0$. The present value of these returns is

$$p(N + \sigma - \lambda) + (1-p)(N - \sigma/\phi - \lambda) = N - \lambda < N. \tag{4}$$

This loan's net present value is $-\lambda < 0$, and the net present value of social benefits from the bad loan that do not accrue to the lender are normalized to zero. Therefore, the difference in aggregate social benefits from the bad loan and the good loan is $\pi + \Pi + \lambda > 0$. That is, if the good loan is made and the bad loan avoided, society gains the net present value of the good loan to investors, π, and the additional social benefits of the good loan, Π. Further, when Bank B forgoes the bad loan, it does not destroy wealth of magnitude λ.

If Bank B fails to pay back Bank C, it is assumed that there is an exogenous social cost of $K > 0$. Further, let us assume that the high state net returns for the negative NPV loan exceed the net returns for the positive net present value loan. That is,

$$\sigma - \lambda > \pi. \tag{5}$$

Both Bank B and Bank C maximize expected returns to shareholders. If either bank defaults on a loan commitment or fails to pay back depositors, their shareholders will be wiped out. Both banks' shareholders have limited liability.

The government is assumed to maximize ex post social returns in period 1a. We assume that the government will provide capital to Bank B in period 1a if this strictly

increases ex post social surplus. The government is assumed to have the power to regulate the payment of dividends, share buybacks, or cash acquisitions for any bank accepting government funds. Thus, we will assume that any leverage decreasing capital infusion cannot be undone by capital structure adjustments made by the recipient bank. Any expected losses to the government from the capital infusion, which may take the form of a direct or indirect subsidy, leads to deadweight losses from taxation. These losses are proportional to the size of any subsidy. That is, the losses from a subsidy are $\tau|S|$, S, where $S \in (-\infty, \infty)$ and $1 > \tau > 0$. Therefore, all else equal, the regulator strictly prefers to offer a subsidy of zero. It seems reasonable that the deadweight losses of any subsidy are substantial, but far less than unity. Ballard et al. (1985) estimates that the deadweight losses from taxation are between 13 and 24% of every dollar of government revenue. In contrast, Goolsbee (1998) estimates that the deadweight cost of the corporate income tax are between 5 to 10% of every dollar raised.

3 Analysis

We solve this model by backward induction. Bank B is the last player to move in this game in period 1b. Therefore, we solve Bank B's problem in period 1b. Next, we solve the government's problem in period 1a. After that, we solve Bank C's decision in period 0 to act as a counterparty to Bank B, and Bank B's decision to buy speculative mortgage securities.

3.1 Bank B's problem in period 1b, given there is no government intervention

In this subsection, we explore Bank B's decision to underwrite the good loan, the bad loan, or make no loan at all if there is no government intervention under various potential scenarios. If Bank B makes no loan or the bad loan instead of the good loan, this will serve as a rationale for the government to intervene in period 1a to prevent this inefficient lending.

Because $M = 2D = F + D$, and $N > \lambda + \sigma/\phi$ it must be the case that

$$M + N - D - F - \lambda - \sigma/\phi > 0. \tag{6}$$

Let us make the following assumption:

$$M_L + N - D - F + \pi < 0. \tag{7}$$

That is, the bank is insolvent with a low demand realization even with the increase in the net present value, π, which comes from making the good loan.

3.1.1 Bank B's problem when it did not buy mortgage securities in period 0

If Bank B invests only in safe securities in period 0, it will be solvent in both states of the world if it makes the safe loan in period 1. Let us denote the aggregate value of equity after the good loan is made by E_F^+, where the superscript "+" denotes that

the good loan has been made and the subscript "F" denotes that Bank B has chosen risk-free investment for its deposits in period 0.

$$\begin{aligned} E_F^+ &= p\max(N+\beta+\gamma+\pi,0)+(1-p)\max(N+\beta+\gamma+\pi,0),\\ E_F^+ &= N+\beta+\gamma+\pi. \end{aligned} \tag{8}$$

It is clear that the value of the current shareholders' claims have risen from $N+\beta+\gamma$ to $N+\beta+\gamma+\pi$.

Alternatively, the value of the troubled bank given that it makes the bad loan under these circumstances is the following, where the superscript "$-$" denotes that the bad loan has been chosen:

$$E_F^- = p\max(N+\beta+\gamma+\sigma-\lambda,0)+(1-p)\max(N+\beta+\gamma-\sigma/\phi-\lambda,0). \tag{9}$$

Since $N-\sigma/\phi-\lambda>0$, the firm is solvent, regardless of the bad loan's returns.

$$E_F^- = N+\beta+\gamma-\lambda. \tag{10}$$

The value of Bank B's equity with the good loan in (8) exceeds its equity value with the bad loan in (10) by $\pi+\lambda>0$. Therefore, we can conclude that the best response of Bank B in period 1b is to make the good loan and avoid the bad loan in this case.

3.1.2 Bank B's problem in period 1b when it bought toxic mortgages in period 0

Here, we look at the bank's lending decision in period 1b, given that it buys toxic mortgages in period 0.

$$E^+ = p\max(M_H+N-F-D+\pi,0)+(1-p)\max(M_L+N-F-D+\pi,0).$$

We know that $E^+ = p(M_H+N-F-D+\pi)$ because $M_H+N-F-D+\pi > M_H+N-F-D-\lambda-\sigma/\phi>0$, but $M_L+N-F-D+\pi<0$. Therefore, the value of the bank is raised by the good loan, but the debts of Bank B are still risky.

The value of the new and old equity with the negative net present loan is denoted by the superscript "$-$."

$$\begin{aligned} E^- = {} & p\max(M_H+N+\sigma-F-D-\lambda,0)\\ & +(1-p)\max(M_L+N-\sigma/\phi-F-D-\lambda,0). \end{aligned} \tag{11}$$

Since $\sigma-\lambda>\pi$ and $M_H+N-F-D+\pi>0$, but $M_L+N-F-D+\pi<0$. This implies that the bank's equity is higher from making the speculative loan than from making the positive NPV loan. That is,

$$E^- = p(M_H+N+\sigma-F-D-\lambda) > E^+ = p(M_H+N-F-D+\pi). \tag{12}$$

Since only one loan can be made and $\sigma-\lambda>\pi$, the bad loan will be Bank B's choice.

Proposition 1 *Bank B will make the bad loan and avoid the good loan if it buys toxic mortgages in period* 0.

Proof This follows from $E^- - E^+ = p(\sigma - \lambda - \pi) > 0$. □

3.2 Regulatory remedies

3.2.1 Government's problem in period 1a

We now consider a variety of remedies that a regulator can implement in period 1 that can improve the ex post lending of the troubled bank. These remedies also potentially decrease deposit insurance liability and reduce the counterparty risk that could hurt the healthy bank.

In the absence of government intervention, the bank will make the bad loan and avoid the good one. In this case, the benefits to the government in period 1 are the social gains from the good loan being made, $\pi + \Pi$, minus the NPV of the bad loan, λ, minus the expected social costs of Bank C's becoming insolvent, $K(1 - p)$. These benefits, $\pi + \Pi + \lambda + K(1 - p)$, must be weighed against the costs of the deadweight losses from taxation by the subsidy τS. As long as $(\pi + \Pi + \lambda) + K(1 - p) > \tau S$, the government's ex post best response will be to bail out Bank B directly, thus indirectly bailing out creditor Bank C. This is similar to the regulator's problem in Frexias (1999). In that model, the regulator supports bailout when the social cost of the bank's insolvency is too high. Unlike that paper and other literature on bank bailouts, this paper specifically analyzes the effectiveness of the types of capital infusions used to bail out the problem bank.

Buying toxic mortgages The regulator can buy the troubled mortgages at a price $M + S_M \equiv \overline{M}$. $S_M \geq 0$ represents the amount above the fair market value that the regulator pays for the mortgage securities. In this paper, we distinguish between market value and fair market value. Fair market value is defined as the market price of the asset when there is zero probability of a government subsidy. (While this would be difficult to disentangle in practice, it seems reasonable that the fair market value would be less than current market price, which often takes into consideration the possibility of a government bailout.) We will see that some such subsidy is often necessary to either induce the bank to lend efficiently or voluntarily participate in the recapitalization or both.

When the regulator buys the risky mortgages, the troubled bank goes from having a risky asset to having a safe asset worth $\overline{M}$ in both the high asset value state and the low asset value state. The bad bank will make the good loan and forgo the risk shifting loan if the expected equity value after the bailout is higher with the good loan than with the bad loan. The value of the bad bank's equity with the good loan and the mortgage bailout is $E_M^+ \equiv \overline{M} + N - F - D + \pi$. The bank will consider taking on the negative net present value loan only if its equity is wiped out in the low demand state, which is the case when $M + S_M + N - F - D - \sigma/\phi - \lambda < 0$. Given that the bad loan is profitable to the bank's shareholders, the value of equity with the bad loan is $E_M^- \equiv p(\overline{M} + N - F - D + \sigma - \lambda)$. The good loan will be made when $E_M^+ \geq E_M^-$.

Lending will be efficient with the mortgage recapitalization if and only if the efficient lending constraint (EL_M) in (13) is satisfied.

$$(EL_M) \quad S_M \geq \frac{1}{\phi}(\sigma - \lambda - \pi) - (M + N - F - D + \pi) \equiv \tilde{S}_M \gtreqless 0. \tag{13}$$

The first term in parenthesis on the right-hand side (RHS) of (13) is positive because $\sigma - \lambda - \pi > 0$. Yet, the sign of $-(M + N - F - D + \pi)$ is negative. Thus, the overall sign is ambiguous. Therefore, it is conceivable, for some parameter values, that the inequality in (13) is satisfied if the subsidy, S_M, was zero. Therefore, an ex post subsidy to troubled banks is not always necessarily to induce efficient lending. If the bank swaps the risky mortgages for a safe asset, some of the gains from the swap will be realized by the bank's creditors. If Bank B's creditors' gains are not too large, no subsidy will be needed.

The bank will sell the toxic mortgages only if the value of its shareholders' claims is higher from selling the toxic mortgages and making the good loan than keeping the toxic mortgages and making the bad loan. That is, the bad bank voluntarily sells its toxic mortgages and reduces its risk if $E_M^+ - E^- \geq 0$. Yet, this is not possible unless the subsidy (overpayment) for the mortgages is sufficiently large. Given that the bank makes the safe loan,

$$E_M^+ - E^- = (M + S_M + N - D - F + \pi) - p(M_H + N - D - F + \sigma - \lambda) \geq 0. \tag{14}$$

This can be the case only if the subsidy is positive. If we rearrange (14) and use the inequalities in (5) and (7) to sign the RHS of the inequality below, we can conclude that the subsidy must be strictly positive for the bad bank to volunteer to sell the toxic mortgages. We denote this as the voluntary participation constraint for the mortgage swap program (VP_M). This constraint says that $S_M \geq \hat{S}_M$, the latter of which is defined below:

$$(VP_M) \quad S_M \geq -(1-p)(M_L + N - D - F + \pi) + p(\sigma - \lambda - \pi) \equiv \hat{S}_M > 0. \tag{15}$$

It is useful to consider whether it is the EL_M or the VP_M constraint that binds. The binding constraint determines the minimum subsidy necessary to achieve both efficient lending and voluntary participation. It may not always be the case that the troubled bank's shareholders must participate voluntarily. Regulators can threaten banks with rescinded charters, less access to the Fed's lending facilities, and other sanctions if they refuse to participate in the recapitalization program. However, regulators do not always take such a tough stance. Malaith and Mester (1994) argue that regulators' discretion in rescinding bank charters leads to suboptimal lending decisions by banks. It seems reasonable that the threat to rescind the charter or limit access to lending facilities may not be credible, especially for banks deemed "too big to fail." Alternatively, Armstrong et al. (1994, p. 92) argues that regulators may be more interested in currying favor with the regulated executives if the regulators envision entering or reentering the banking sector. If voluntary participation is necessary, then both the EL_M and VP_M constraints must be satisfied. In particular, $\max\{\tilde{S}_M, \hat{S}_M\}$ will

give us the minimum subsidy such that both constraints are satisfied. The difference between $\hat{S}_M - \tilde{S}_M$ is the following sum:

$$\hat{S}_M - \tilde{S}_M = p\left\{[M_H + N - F - D + \pi - \sigma/\phi] + \frac{1}{\phi}(\lambda + \pi)\right\} > 0. \quad (16)$$

We know from (6) that sign of the term on the RHS in square brackets is positive. The remaining terms are also clearly positive. Therefore, we know that satisfaction of the voluntary participation constraint means that the efficient lending constraint is slack.

Preferred stock infusion Suppose that the government decides to buy preferred stock in the troubled bank, but that it weakly overpays for the stock in the sense that the preferred dividends promised to the government are less than or equal to the present value of what the government paid for the shares. Let us denote the amount paid for the preferred dividends as $\overline{R} \equiv R + S_R > 0$. Further, the present value of the preferred dividends is R, where $R \in [0, \overline{R}]$. $S_R \in [0, \overline{R} - R]$ represents the subsidy the government is giving the troubled bank by accepting as future dividends weakly less than the full present value of what it paid for the preferred stock.

With the preferred stock infusion, the present value of the bad bank, given that it makes the good loan, is the following:

$$\begin{aligned} E_R^+ = {} & p(M_H + S_R + N - D - F + \pi) \\ & + (1 - p)\max\{(M_L + S_R + N - D - F + \pi), 0\}. \end{aligned} \quad (17)$$

The value of the equity, given that the bank takes on the bad loan, is the following:

$$\begin{aligned} E_R^- = {} & p(M_H + S_R + N - D - F + \sigma - \lambda) \\ & + (1 - p)\max\{(M_L + S_R + N - D - F - \sigma/\phi - \lambda), 0\}. \end{aligned} \quad (18)$$

If the bank's equity is wiped out in the low demand state with the good loan, then the bank's shareholders prefer the risk shifting loan because $\sigma - \lambda > \pi$. Further, if the bank's shareholders are not wiped out in the low demand state with the bad loan, they will definitely prefer the positive net present value loan. This is the case when $M_L + S_M + N - D - F - \sigma/\phi - \lambda > 0$. The troubled bank's shareholders will be indifferent to the two loans only when their shares have a positive value in both states of the world with the good loan, or when shares are wiped out in the bad state of the world with the bad loan.

Lending is efficient with preferred stock infusions if and only if the subsidy is sufficiently large and the efficient lending constraint (EL_R) below is satisfied:

$$(EL_R) \quad S_R \geq \frac{1}{\phi}(\sigma - \lambda - \pi) - (M_L + N - F - D + \pi) \equiv \tilde{S}_R > 0. \quad (19)$$

The first term in parentheses on the right hand side (RHS) is positive because $\sigma - \lambda - \pi > 0$. The second term in parenthesis on the RHS is negative because $M_L +$

$N - F - D + N + \pi < 0$. This implies that the subsidy must be strictly positive to be effective in inducing efficient lending.

The troubled bank will voluntarily accept a preferred stock infusion that leads to efficient lending only if $E_R^+ - E_L^- \geq 0$.

$$E_R^+ - E^- = (M + S_R + N - D - F + \pi) - p(M_H + N + \sigma - F - D - \lambda) \geq 0. \tag{20}$$

This relationship can be rearranged to show that the subsidy for preferred stock is strictly positive.

$$(VP_R) \quad S_R \geq -(1-p)(M_L + N - F - D + \pi) + p(\sigma - \lambda - \pi) \equiv \hat{S}_R > 0. \tag{21}$$

To discover which constraint must bind for both constraints to be satisfied, we subtract $\hat{S}_R - \tilde{S}_R$ from (21) and (19):

$$\hat{S}_R - \tilde{S}_R = -p\left[\frac{1}{\phi}(\sigma - \lambda - \pi) - (M_L + N - F - D + \pi)\right] < 0. \tag{22}$$

This implies that $\tilde{S}_R > \hat{S}_R$; thus, the binding constraint is the efficient lending constraint (EL_R), and the slack and satisfied constraint is the voluntary participation constraint (VP_R). Therefore, as long as the subsidy is large enough to make lending efficient, the troubled bank's shareholders will want to participate in the program.

Common stock infusion Suppose the regulator buys a common equity stake in the troubled bank equal to $\bar{E} \equiv E + S_E$, where E is the fair market value of the equity stake and $S_E \geq 0$ is the subsidy that taxpayers are giving to the troubled bank's shareholders. The value of the equity in the troubled bank if it makes the good loan is:

$$E_E^+ = p(M_H + N + E + S_E - D - F + \pi) + (1-p)\max\{(M_L + N + E + S_E - D - F + \pi), 0\}. \tag{23}$$

If, however, the bank makes the bad loan after the equity infusion, the value of its equity is

$$E_E^- = p(M_H + N + E + S_E - D - F + \sigma - \lambda) + (1-p)\max\{(M_L + N + E + S_E - D - F - \sigma/\phi - \lambda), 0\}. \tag{24}$$

Shareholders will only be indifferent between the two investment policies after the equity infusion if $E_E^+ = E_E^-$. Indifference between the good and bad loans occurs only if the bank both defaults with the bad loan and is also always solvent with the good loan. Equation (25) rewrites the inequality $E_E^+ - E_E^- \geq 0$, where both $M_L + N + E + S_E - D - F + \pi > 0$, and $M_L + N + E + S_E - D - F - \sigma/\phi - \lambda \leq 0$.

If the government buys common equity for a price $\bar{E} \equiv S_E + E$, lending will be efficient if and only if the efficient lending constraint below (EL_E) is satisfied.

$$(EL_E) \quad S_E \geq \frac{1}{\phi}(\sigma - \lambda - \pi) - (M_L + N - D - F + \pi) - E \equiv \tilde{S}_E. \tag{25}$$

Unlike the case with preferred stock, there is no need for the government to subsidize the common equity infusion to make lending efficient. The efficient lending subsidy is positive for some parameter values when the government buys the speculative mortgages. In contrast, the efficient lending subsidy for buying common equity can be zero for *all* parameter values.

The subsidy required for efficient lending is zero when the equity stake bought by the government must meet or exceed, $\tilde{E}$, which is defined below:

$$E \geq \tilde{E} \equiv \frac{1}{\phi}(\sigma - \lambda - \pi) - (M_L - D - F + \pi) > 0. \tag{26}$$

Let us define $\tilde{S}_E^*$ to be the government's strictly preferred subsidy if the EL_E is the only constraint the government must satisfy. The government strictly prefers to minimize the absolute value of the subsidy because of the deadweight loss of taxation. (A negative subsidy on Bank B is a tax that is also associated with deadweight losses.) Therefore, $\tilde{S}_E(\tilde{E}) \equiv \tilde{S}_E^* = 0$ is the strictly preferred subsidy and the government will want to buy an equity stake worth at least $\tilde{E}$.

What subsidy is needed for Bank B to volunteer for the government's funds? The bank's current shareholders will voluntarily take on the new equity only if it raises the value of their stake. Without the equity infusion, the value of their stake is $E^- = p(M_H + N - F - D + \sigma - \lambda)$. With the equity infusion that leads to efficient lending, the value of their current shareholders' stake is $E_E^+ - E = p(M_H + S_E + N - D - F + \pi) + (1-p)(M_L + S_E + N - D - F + \pi)$. The bank's shareholders will volunteer for the equity infusion if $(E_E^+ - E) - E^- \geq 0$. This relationship can be rearranged to be the following voluntary participation constraint (VP_E):

$$(VP_E) \quad S_E \geq p(\sigma - \lambda - \pi) - (1-p)(M_L + N - D - F + \pi) \equiv \hat{S}_E > 0. \tag{27}$$

Thus, the bank's current shareholders will agree to the equity infusion only if they are given a positive subsidy. If regulators could force banks to recapitalize, no subsidy would be needed to induce efficient lending. Yet, if they want banks to volunteer for the equity recapitalizations, the subsidy must meet or exceed the right-hand-side (RHS) of (27).

To discover which constraint, the efficient lending constraint or voluntary participation constraint, is sufficient to ensure the bank both lends efficiently and voluntarily participates in the equity recapitalization, let us compare $\hat{S}_E - \tilde{S}_E$:

$$\hat{S}_E - \tilde{S}_E = E - p\left[\frac{1}{\phi}(\sigma - \lambda - \pi) - (M_L - F - D + \pi)\right] \gtreqless 0. \tag{28}$$

The sign of (28) is ambiguous. Without knowing the relative magnitudes of E and the quantity in square brackets (which has only positive terms inside those brackets), we cannot determine which constraint produces the bigger subsidy. Nevertheless, E is a choice variable of the regulator. If the regulator is acting in the public interest, he or she will want to minimize the subsidy because it creates ex ante incentive problems for the bank in period 0. In addition, the regulator will want to minimize the subsidy because it leads to deadweight losses from taxation of magnitude τS_E. Therefore, if

(28) has a negative sign, the regulator will want to increase the equity stake that it buys until $\hat{S}_E - \tilde{S}_E \geq 0$, because increasing E reduces the efficient lending (EL_E) subsidy $\tilde{S}_E$, but it does not affect the voluntary participation constraint.

Let us define a minimum best response level of common equity, $\hat{E}$, bought by the regulator such that the voluntary participation constraint binds and the subsidy is minimized. From (28), this minimum common equity purchase is

$$E \geq \hat{E} \equiv p\left[\frac{1}{\phi}(\sigma - \lambda - \pi) - (M_L - F - D + \pi)\right] > 0. \tag{29}$$

If Bank B can be forced to participate, then $\tilde{S}_E(\tilde{E}) \equiv \tilde{S}_E^* = 0$ when an equity stake at least as large as $\tilde{E}$ in (26) is taken in Bank B.

Comparing the costs The voluntary participation constraint is identical across all the different securities used to recapitalize the troubled bank. If we compare (15), (21), and (27) to each other, the following relationships emerge in (30) and Proposition 2.

Proposition 2 *The minimum subsidies for which the troubled bank's participation constraints are satisfied are identical regardless of whether the government buys toxic mortgages, preferred stock, or common stock in that bank.*

$$\hat{S}_M = \hat{S}_R = \hat{S}_E. \tag{30}$$

The other major relationship that emerges is that the minimum efficient lending subsidy is different for each of the different securities used to recapitalize Bank B. The minimum efficient lending subsidy is given by (13), (19), and (25). We know $\tilde{S}_R > \tilde{S}_M$ because when we compare (19) to (13), the following inequality is obtained:

$$\tilde{S}_R - \tilde{S}_M = p(M_H - M_L) > 0. \tag{31}$$

Further from (13) we know that $\tilde{S}_R > 0$, which is clearly higher than the government's efficient lending subsidy with common stock, $\tilde{S}_E^* = 0$.

$$\begin{aligned} &\tilde{S}_R > \tilde{S}_M, \\ &\tilde{S}_R > \tilde{S}_E^* = 0. \end{aligned} \tag{32}$$

Proposition 3 *Regardless of whether voluntary participation is necessary or not, preferred stock recapitalizations are strictly dominated by both common stock recapitalizations and the regulator's purchase of toxic mortgages.*

Proof This follows from (32) and (30). The participation subsidies for all types of recapitalizations are identical according to (30). Yet, the efficient lending subsidy for preferred stock is greater than both the efficient lending subsidy for common equity and the purchases of toxic mortgages. □

Proposition 4 *If banks must voluntarily participate in the program, then a regulator, acting in the public interest, will be indifferent between a strategy of buying a common equity or buying toxic mortgages. If the regulator buys common equity, the common equity stake will be* $E \in [\hat{E}, +\infty)$, *and the regulator will pay as subsidy* $\hat{S}_E = \hat{S}_M$.

Proof Proposition 4 follows from (30) and (32). The minimum equilibrium stakes of common equity are found by (29), if the bank must volunteer for the recapitalization. First, there is no difference between the three types of recapitalizations (buying mortgages, buying preferred stock, or buying common stock) in terms of the voluntary participation constraint, according to (30). Yet, there is a big difference between the three alternatives in terms of the efficient lending constraint, according to (32). The efficient lending constraint is always slack for toxic mortgage purchases and common stock recapitalizations. Yet, it is always the binding constraint for preferred stock recapitalizations. Thus, the subsidy is minimized given that voluntary participation is required for common stock or toxic mortgage purchases. □

In practice, a benevolent government probably will not be indifferent between common stock and toxic mortgage purchases even if both lead to the same minimum subsidy for some parameter values. It is much harder to arrive at a fair market value for toxic mortgages, relative to the banks publicly traded common equity. Therefore, it seems that, in fact, not only is the subsidy weakly lower with common equity versus buying toxic mortgages, but common equity is much easier for the regulators to value.

The purchase of toxic assets will always be less efficient than common stock recapitalizations if the regulator has to pay an asset manager to price the toxic assets. The structure of subsidized, nonrecourse debt in the Public-Private Investment Program (P-PIP) appears to be a subsidy to both the asset manager and the recipient bank. Further, the put option implicit in nonrecourse debt means that the "Private Investor," the asset manager, who has sole control of the bidding process, has a strong incentive to overbid for the toxic asset. This overbidding incentive arises due to the Private Investor's ability to pass most of the losses to taxpayers. Thus, as currently formulated, there is most likely a double subsidy in the toxic asset purchase plan formally announced on March 23, 2009, by the US Treasury.[8] The P-PIP subsidizes the asset manager and the banks. See the Appendix for an illustrative example.

This paper only considers the subsidy made to the troubled banks by government purchases of toxic assets. Thus, the case is probably even stronger for common stock recapitalizations than the results in Proposition 4 suggest. Wilson (2010) uses the Merton (1974) framework to describe why distressed or insolvent banks might not part with their assets outside some form of bankruptcy regime, even if the government does offer to overpay for assets. In the Appendix, we demonstrate, using the parameters in the numerical example introduced in the next section, that the Public-Private Investment Program would be ineffective in convincing troubled banks to sell toxic assets.

[8] See Edmund L. Andrews, Eric Dash and Graham Bowley, March 21, 2009, "Toxic Asset Plan Foresees Big Subsidies for Investors," *New York Times*, A1.

The most expensive subsidy is the infusions of preferred stock. In this case, the efficient lending constraint is more important than the voluntary participation constraint. That is, $\max\{\hat{S}_R, \tilde{S}_R\} = \tilde{S}_R > \hat{S}_E$, as revealed by (22). The reasoning behind this result is that the preferred stock provides the troubled bank with an incentive similar to that arising from debt, because preferred shareholders' claims are senior to common equity. Adding more senior claims to common equity increases the incentives to engage in risk shifting. Further, preferred stock does not reduce the variability of the bank's returns, as does purchasing the troubled mortgage assets. Yet, it is easier to determine the fair market value of preferred stock than that of mortgage securities (but not that of common equity). Unfortunately, the subsidy in the preferred stock capital injection is the sole means of increasing the common equity value of the troubled bank and reducing the risk of equity returns. Therefore, a preferred stock infusion, if it is to be effective in correcting lending incentives, must be the largest subsidy of the three types of recapitalizations, and it is a clearly dominated strategy for all parameter values.

Bank B's investment decision in period 0 Suppose that the government cannot force Bank B to participate in the common equity recapitalization. Bank B will be bailed out by the government in period 1a when Bank B bought toxic mortgages and the lowest cost subsidy is less than the marginal costs of not providing the subsidy. The benefits of bailing out Bank B are π, the net present value of the good loan; Π, the social benefit of the good loan in excess of its net present value; $(1-p)K$, the expected systemic cost of Bank B's failure; and, λ, the avoided expected loss from making the bad loan. These benefits of bailing out Bank B must be weighed against the deadweight loss of the subsidy from the bailout, $\tau \hat{S}_E$.

That is, if

$$\tau \hat{S}_E < \pi + \Pi + (1-p)K + \lambda, \tag{33}$$

the government will bail out Bank B in period 1a 100% of the time. Therefore, the present value of Bank B's mortgage investment including the expected subsidy is $M + \hat{S}_E$. Given that the bank paid $M + \beta + \gamma$ to buy these assets, it only makes sense for Bank B to choose the toxic mortgages over the safe assets if the expected subsidy strictly exceeds the overpayment for these assets $\hat{S}_E > \beta + \gamma$. If this inequality is satisfied, Bank B will choose to buy the toxic mortgages, and Bank C will agree to be its counterparty. If bailouts always occur, Bank C can earn a guaranteed profit of γ by lending to Bank B.

Proposition 5 *If Bank B must voluntarily participate in any bailout, then the subgame perfect Nash equilibrium (SPE) is one of the following, depending on the magnitude of the parameter values*:

(a) *If both* $\hat{S}_E > \beta + \gamma$ *and* $\pi + \Pi + \lambda + K(1-p) > \tau \hat{S}_E$, *then Bank B will borrow from Bank C to buy toxic mortgages. The government will bail out Bank B with either subsidized purchases of common stock or buy its toxic mortgages. The subsidy will be* $\hat{S}_E = \hat{S}_M > 0$. *Regardless of the mortgage returns in period* 1, *Bank B will make the good loan in period* 1b, *and Bank C will be paid back with certainty.*

(b) *If either* $\hat{S}_E \leq \beta + \gamma$ *or* $\pi + \Pi + \lambda + K(1-p) \leq \tau \hat{S}_E$, *then Bank B will invest in safe assets, and there will be no bailout.*

Social welfare is very different under each of the scenarios in Proposition 5. Ex ante, period 0 social welfare in scenario a is $\pi + \Pi - \beta - \tau \hat{S}_E$. This is clearly less than social welfare under scenario b, $\pi + \Pi$. Clearly, social welfare would be benefit if the government could commit to not bail out Bank B when the bank must voluntarily participate.

If the government can force the bank to participate in the common stock recapitalization, there is no conflict between ex post and ex ante welfare maximization for the government. According to Proposition 6, the government (or private investors)[9] can buy an equity stake at fair market value in the troubled bank large enough so that no subsidy is necessary to induce efficient lending.

Proposition 6 *If voluntary participation in the bailout is not necessary, then the subgame perfect Nash equilibrium (SPE) is that Bank B will buy safe assets and there will be no bailout, regardless of the parameter values.*

Proof We know from (32) that the subsidy required to bail out the troubled bank is weakly the smallest when common equity is used and the troubled bank's voluntary participation constraint can be ignored.

Suppose that Bank B did buy mortgage securities in period 0. The government could push the subsidy to zero in period 1a. In this scenario, the government will weakly prefer to buy common equity $E \in [\tilde{E}, +\infty)$. Thus, the subsidy will be zero in all possible states of the world if Bank B buys toxic mortgages. Bank B's shareholders must sacrifice $\beta + \gamma > 0$ to underwrite mortgage securities. The cost $\beta + \gamma$ exceeds the benefit, which is the expected subsidy of zero. Therefore, Bank B will purchase risk-free assets, and there will be no bailout in equilibrium. □

4 Numerical examples

In this section, we explore two numerical examples. In the first example, Bank B invests in the toxic mortgages, and there is a bailout in equilibrium. The relative magnitude of the minimum subsidy necessary for voluntary participation in this first example is 5.1% of period 1a assets if the recapitalization involves common equity. In the second example, the mortgage portfolio does not fluctuate much in value, and Bank B will choose to buy safe securities instead of the mortgages because the expected subsidy is too small. Social welfare is the highest in the second example.

Suppose that the following parameter values describe the game.

$$\beta = \$46,$$
$$\gamma = \$4,$$

[9] If the common stock is sold at fair market value, then private investors can be the source of funds, but if a subsidy is required, the subsidy has to come from the government.

$$\begin{aligned} N &= \$100, \\ \tau &= 0.1, \\ K &= \$40, \\ \sigma &= \$55, \\ \lambda &= \$5, \\ \pi &= \$5, \\ \Pi &= \$20, \\ N &= \$100, \\ D &= F = \$500. \end{aligned} \tag{34}$$

Example 1 Let us specify the probability of success and the evolution of the mortgage values that satisfy (1) and (3).

$$\begin{aligned} p &= 0.4, \\ \phi &= 1.5, \\ M_L &= \$840, \\ M &= \$1{,}000, \\ M_H &= \$1{,}240. \end{aligned} \tag{35}$$

We know from (4) that, for these parameter values, the speculative loan pays $N + \sigma - \lambda = \$100 + \$55 - \$5 = \$150$ in case of success and $N - \sigma/\phi - \lambda = \$100 - \$55/1.5 - \$5 = \$58.\bar{3}$ if returns are low in period 2. Since the speculative loan costs \$100, the profits from the bad loan are \$50 in the case of success and $-\$41.\bar{6}$ when returns are low.

Suppose that voluntary participation is necessary for any government recapitalization. The cost of subsidizing the firm to participate in a common equity recapitalization or in a sale of toxic mortgages can be found by inserting the parameter values in (34) and (35) into (27) below:

$$\hat{S}_M = \hat{S}_R = \hat{S}_E = \$51. \tag{36}$$

We know by inserting the parameters in (34) and (35) into (29) that, if the government is prepared to buy common stock worth at least

$$\hat{E} = \$74, \tag{37}$$

or about 7.4% of the bank's period 1a assets ($\hat{E}/M = \$74/\$1{,}000$), then the government will be able to ensure that the voluntary participation constraint subsidy satisfies the efficient lending constraint. Yet, the government pays $\$51 + \$74 = \$125$ for this stake, and only expects to receive 59.2% of its investment back. $\$74/\$125 = 0.592$.

If we plug in the parameter values in (34) and (35) into the efficient lending constraint for buying toxic mortgages in (13), then the minimum efficient lending subsidy

is $\tilde{S}_M = -\$75$. Clearly, the efficient lending constraint is slack and the voluntary participation constraint is binding if the government buys toxic mortgages. If the regulator buys mortgages, it would pay the voluntary participation subsidy of \$51 in (36), plus their fair market value of \$1,000. Thus, the government expects to receive about 95.1% of its toxic mortgage investment back. $\$1{,}000/(\$1{,}000 + \$51) \approx 0.951$. The subsidy amount is the same for a mortgage bailout and common equity recapitalization. The common stock recapitalization requires a far smaller initial outlay of capital, but its expected percent payback is less than a purchase of toxic mortgages.

Preferred stock recapitalizations are clearly dominated by both mortgage and common equity bailouts. We can obtain the minimum efficient lending subsidy by inserting the parameter values in (34) and (35) into (19), which gives us $\tilde{S}_R = \$84$. The minimum efficient lending subsidy, $\tilde{S}_R$, for preferred stock bailouts is clearly higher in this case (and for all parameter values). That is,

$$\tilde{S}_R = \$84 > \hat{S}_M = \hat{S}_R = \hat{S}_E = \$51. \tag{38}$$

From the regulator's point of view, it makes sense to bail out the bank only if the expected gains from the subsidy exceed its cost. If Bank B held toxic mortgages in period 1a, then the benefits from bailing out the bank ex post would be $\pi + \Pi + \lambda + K(1-p) = \$54$, which is obtained by inserting the parameters in (34) and (35) into the right-hand side of (33). The cost would be $\tau \hat{S}_E = \$5.1$. The cost of the bailout is obtained from combining the percent deadweight loss of taxation parameter, $\tau = 0.1$, from (34) with the voluntary participation subsidy, $\hat{S}_E = \$51$, in (36). Together, the cost of the bailout is $\tau \hat{S}_E$, according to the left-hand side of (33). Clearly, the government finds it ex post efficient to bail out Bank B if the bank holds mortgages. That is, $\tau \tilde{S}_E = \$5.1 < \pi + \Pi + \lambda + K(1-p) = \$54$.

The expected subsidy is $\hat{S}_E = \$51$, According to Proposition 5, this must be weighed against the loss of shareholder value for overpaying for the mortgages and the price of renting Bank C's deposits, $\beta + \gamma = \$50$. ($\beta$ and γ are given in (34).) Therefore, the subgame perfect Nash equilibrium (SPE) for the parameter values in (34) and (35) is that Bank B will buy toxic mortgages, and there will be a bailout. Bank C's profits from lending its deposits are $\gamma = \$4$. Thus Bank C will lend to Bank B in period 0. This example has the subgame perfect Nash equilibrium described in Proposition 5a. Following Proposition 5 above, we calculated social welfare for scenario 5a when there is a bailout in equilibrium as there is in this example. Social welfare will be the net present value of the good loan, π, the add-on social benefits of the good loan, Π, less the deadweight loss from underwriting the toxic mortgages, $-\beta$, and the deadweight loss from the subsidy, $-\tau \hat{S}_E$. That is, $\pi + \Pi - \beta - \tau \hat{S}_E = -\$26.1$. In the Appendix, we extend this example to demonstrate how the US Treasury's toxic asset plan would be ineffective in getting Bank B to part with its toxic mortgages.

Example 2 Suppose that the mortgage portfolio has the following parameter values:

$$p = 0.6,$$
$$\phi = 0.\bar{6},$$

$$M_L = \$850, \tag{39}$$
$$M = \$1{,}000,$$
$$M_H = \$1{,}100.$$

Inserting the parameters from (34) and (39) into (27), the minimum subsidy necessary for Bank B to voluntarily participate in the equity recapitalization is

$$\hat{S}_E = \hat{S}_M = \hat{S}_R = \$45. \tag{40}$$

The minimum equity stake that must be purchased by the government to ensure that both the voluntary participation and efficient lending constraints are satisfied is obtained by plugging in the parameters in (34) and (39) into (29). That stake is worth $\hat{E} = \$127.5$ or about 12.75% of the period 1a assets, which are worth \$1,000.

The cost of the subsidy to the regulator is the deadweight loss of taxation associated with the subsidy in (40). The deadweight loss of taxation is \$4.5, which is derived by multiplying the right-hand side of (40) by the parameter, $\tau = 0.1$ in (34). The government will weigh this against the ex post benefits of the good loan, $\pi + \Pi$, minus the social losses associated with the bad loan, $-\lambda$, plus expected costs of a default on Bank B's obligation to Bank C in period 2, $(1-p)K$. In total, the ex post social benefits of the bailout, which are obtained from the right-hand side of (33) and the parameter values in (34) and (39), are $\$46 = \pi + \Pi + \lambda + (1-p)K$. This bailout exceeds its cost $\tau \hat{S}_E = \$4.5$. Therefore, the regulator will be willing to bail out Bank B if that bank holds toxic assets in period 1a.

Yet, Bank B will not want to buy mortgages in period 0. The lost equity capital associated with buying the mortgages according to (34) is $\beta + \gamma = \$50$. Yet, from (40) the subsidy is worth $\hat{S}_E = \$45$. $\$45 < \$50$; therefore, Bank B and Bank C will buy safe debt. Thus, the SPE for these parameter values conforms to Proposition 5b. Under the parameter values in (34), social welfare in scenario 5b, according to the discussion following Proposition 5, is $\pi + \Pi = \$25$.

5 Conclusion

This paper demonstrates that the securities used to bail out banks, which are perceived as "too big to fail," affects welfare. The paper analyzes recapitalizations involving buying toxic mortgages, buying preferred stocks, and buying common stock. From both an ex post and ex ante perspective the least expensive bailout occurs when the government buys common equity. Preferred stock is the most expensive security analyzed in terms of its affects on ex ante and ex post welfare. This finding casts some doubt on the effectiveness of the Troubled Asset Relief Program, which was passed by Congress and signed by President George W. Bush on October 3, 2008, as it has been implemented up to the time of this writing because the US Treasury has primarily used preferred stock to recapitalize banks.

Let us briefly summarize of results of this paper. Since we used backward induction to solve the game in Fig. 1, we discuss the subgame perfect Nash equilibrium results in the reverse order of their appearance on the timeline in Fig. 1. In Sect. 3, we

first explore Bank *B*'s loan choice decision in period 1-b, given that it holds a risky mortgage portfolio. Given that toxic mortgages are purchased, we find that Bank *B* takes on the bad loan and rejects the good loan without government intervention in period 1-a. For some parameter values, the government bails out Bank *B* in period 1-a. Given that there will be a bailout in period 1-a, the regulator always weakly prefers to use common stock. Finally, in period 0, Bank *B* decides whether or not to invest in risky mortgages. If the expected subsidy exceeds the overpayment for the mortgage securities and the cost of borrowing its counterparty's, Bank *C*'s, deposits, Bank *B* buys speculative mortgage assets. Welfare is always the highest if Bank *B* finds it unprofitable to invest in the toxic mortgages. Therefore, the smaller subsidies will lead to the first-best social welfare for more parameter values.

Veronesi and Zingales (2008) estimate that the $125 billon in TARP monies given to the first nine institutions included a subsidy worth between $13 and $36 billion to the recipient banks. Whether this subsidy was enough to encourage efficient lending is an open question. Nevertheless, our first numerical example indicates that the size of the subsidy necessary to induce efficient lending with preferred stock may be very large relative to the bank's assets. This paper finds that if banks are tempted to engage in risk-shifting, the mere fact that banks are voluntarily participating in a preferred stock recapitalization is not sufficient to guarantee that the capital infusion and the taxpayer subsidy that accompanies it will induce banks to make good loans. (We know this because the voluntary participation subsidy for preferred stock infusions is strictly less than the efficient lending subsidy for preferred stock.) Veronesi and Zingales (2008) find little evidence that the value of these banks' equity rose with the announcement of the TARP investment. Therefore, a $13 to $36 billion subsidy may have been just barely enough to even guarantee that the voluntary participation constraint was satisfied for the first nine institutions.

There are other concerns about the TARP bailout not explicitly addressed in this paper that are very important for any intervention to be effective. Recipients of the bailout monies should be prohibited from engaging in leverage-increasing transactions, including, but not limited to cash dividends, share buybacks, and cash acquisitions.[10] Cash acquisitions increase the bank's leverage or reduce the acquirer's cash cushion, and thus increase the risk of its equity, all else equal. Banks will often be tempted to undo any leverage-decreasing transaction, which includes a taxpayer subsidy, with a leverage-increasing transaction.

It is also somewhat surprising that so many banks have received TARP funds. Certainly, many of those banks are not "too big to fail." As of September 30, 2009, 685 financial institutions had received $204.6 billion from the Capital Purchase Program (CPP), which was the largest program in the Troubled Asset Relief Program

[10]The terms of the TARP Capital Purchase Program (CPP) do specify that the government can veto common dividend increases and share repurchases for the first 3 years after the recipient bank is awarded funds. Both those actions would increase the bank's leverage and counteract the beneficial effects of the recapitalization. Source: "TARP Capital Purchase Program, Senior Preferred Stock and Warrants, Summary of Senior Preferred Terms" US Department of the Treasury. Cash acquisitions are prohibited in the terms of the Capital Assistance Program formulated under US Treasury Secretary Timothy Geithner, but this program has not issued any new securities as of the time of writing. Source: US Treasury, February 10, 2009, "Fact Sheet: Financial Stability Plan."

(TARP).[11] The Capital Purchase Program gave cash in exchange for primarily preferred stock in "healthy banks." Many of the banks that have received TARP funds probably would not pose a systematic risk if they were closed down due to insolvency.[12] It is not clear that the closure of all but the handful of giant commercial and investment banks pose any short- or long-term damage to the financial system as a whole. For this reason, the banking sector as a whole may be made healthier if the weaker regional banks are restructured in receivership and their assets sold to stronger institutions. It may be more efficient to restructure rather than recapitalize insolvent banks. Acharya and Yorulmazer (2008) and Diamond and Rajan (2002) discuss in more detail how many, and which small banks should be bailed out; this paper, instead, focused on which securities should be used to bail out banks that are deemed "too big to fail."

This paper is the first to rigorously consider the optimal securities used in bank bailouts from both an ex ante and ex post perspective when banks are tempted to engage in risk shifting. In this paper, the big bank is tempted to shift risk onto creditors when, due to its toxic mortgage portfolio, the bank is facing the prospect of insolvency. The regulator, attempting to maximize ex post welfare, chooses among buying the bank's toxic mortgages, recapitalizing the bank with preferred stock, or buying common stock. We find that common stock recapitalizations always produce the lowest subsidy to the troubled bank. Indeed, no subsidy is needed to induce efficient lending if the troubled, but not yet insolvent, bank can be forced to sell common equity (to the government or private investors) at its fair value. Higher subsidies in recapitalizations are more likely to encourage the bank to buy troubled mortgages in the first place. Therefore, common stock recapitalizations always lead to the lowest ex ante distortions. Preferred stock recapitalizations are the least efficient and lead to the largest subsidy. Indeed, the implicit subsidy in preferred stock infusions is the only thing that induces efficient lending ex post. Contrast this with toxic asset purchases and common stock injections that can encourage efficient lending without any costly subsidies. Preferred stock's seniority creates similar incentives to debt and exacerbates risk-shifting incentives. This paper casts doubt on the effectiveness and the efficiency of the US Treasury's attempts to recapitalize banks through the Troubled Assets Relief Program, because TARP primarily uses preferred stock to recapitalize over-leveraged banks, the program is unlikely to lower incentives to make speculative loans.

Acknowledgement We would like to thank an anonymous referee for several suggestions that improved the manuscript.

[11] See pp. 14 and 24 of US Treasury, Office of Financial Stability, *Agency Financial Report Fiscal Year 2009 ended September 30, 2009*.

[12] Through mid-November 2009, three Capital Purchase Program (CPP) recipients have either entered FDIC receivership or Chap. 11 with little measurable effect on the financial system. See Paul Kiel, November 14, 2009, "Regulators Seize Another Recipient of TARP 'Healthy Bank' Bailout," *ProPublica*. CIT Group had over $71 billion in assets at the time of its filing,. according to Michael J. de la Merced, November 2, 2009, "Creditors Back CIT's Bankruptcy," *New York Times*, B1.

Appendix: An example of the ineffectiveness of the public-private investment program (P-PIP)

The P-PIP Legacy Loans Program announced by the US Treasury on March 23, 2009, allows "Private Investors" to purchase existing loans from recipient banks. This is an attempt by the US Treasury to remove toxic assets from banks' balance sheets. Here, we extend Example 1 in Sect. 4, where a bailout was ex post desirable. In this extension, we incorporate the terms of the Legacy Loans Program. That program gives the asset manager an incentive to overbid for troubled assets. The Legacy Loans program gives the Private Investor more subsidized leverage as compared to the Legacy Securities Program of the P-PIP. Thus, the Legacy Loans Program gives the asset manager the greatest incentives to overbid. Yet, we will demonstrate that the asset manager will not overbid enough to either get the bank to sell the assets or to encourage the troubled bank to lend efficiently in the future.

According to the program's terms, the asset manager must put up $1/14$ of the total purchase price. Up to $6/7$ of the purchase price can come from FDIC-guaranteed, nonrecourse loans. The remaining $1/14$ of the investment comes from TARP funds supplied by the US Treasury. The asset manager has control in buying the assets, but the US Treasury has an equal share in the profits if the investment pays off its nonrecourse debt.[13] With nonrecourse debt, the manager can walk away from the loan without jeopardizing any assets except for the toxic mortgages purchased. That is, she can walk away from the loan and give the less valuable asset to the FDIC (and by extension to US taxpayers) if things go badly. In Example 1, (35), we stated that there was a 40% chance that the toxic assets would be worth \$1,240, and a 60% chance that they would be worth \$840. The risk-free rate is zero and all market participants are risk neutral. Thus, the fair market value of these mortgages is \$1,000. Assuming that the manager bids over \$840 for the toxic assets, she will want to bid no more than M^* where

$$\frac{0.4}{2}\left(\$1{,}240 - \frac{6}{7}M^*\right) - \frac{1}{14}M^* \geq 0. \tag{41}$$

That is, 40% off the time she pays of the loan and shares the profits with the US Treasury. For this privilege, she must pay $1/14$ of M^*. A little algebra shows that

$$M^* \leq \$1{,}021.18. \tag{42}$$

Thus, the manager is willing to bid more than the toxic asset is worth. That is, \$1,021.18 > \$1,000. Yet, (36) shows that the bank's shareholders will not part with their toxic assets for less than \$1,000 plus a subsidy of \$51 or \$1,051. Thus, there will be no deal.[14]

[13] See US Treasury, March 23, 2009, "Fact Sheet Public-Private Investment Program," and Edmund L. Andrews, Eric Dash and Graham Bowley, March 21, 2009, "Toxic Asset Plan Foresees Big Subsidies for Investors," *New York Times*, A1.

[14] We do not discuss numerical Example 2 here because it was a subgame perfect Nash equilibrium that the bank would never buy toxic assets in the first place in Example 2.

References

Acharya, S.: Charter value, minimum bank capital requirement and deposit insurance pricing in equilibrium. J. Bank. Finance **20**, 351–375 (1996)

Acharya, V.V., Yorulmazer, T.: Too many to fail—an analysis of time-inconsistency in bank closure policies. J. Financ. Intermed. **16**, 1–31 (2007)

Acharya, V.V., Yorulmazer, T.: Cash-in-the-market pricing and optimal resolution of bank failures. Rev. Financ. Stud. **21**, 2705–2742 (2008)

Aghion, P., Bolton, P., Fries, S.: Optimal design of bank bailouts: the case of transition economies. J. Inst. Theor. Econ. **155**, 51–70 (1999)

Armstrong, M., Cowan, S., Vickers, J.: Regulatory Reform: Economic Analysis and the British Experience. MIT Press, Cambridge (1994)

Ballard, C., Shoven, J., Whalley, J.: The total welfare cost of the united states tax system: a general equilibrium approach. Nat. Tax J. **38**, 125–140 (1985)

Barrow, J.M., Horvitz, P.M.: Response of distressed firms to incentives: thrift institution performance under the fslic management consignment program. FM: J. Financ. Manag. Assoc. **22**(3), 176–184 (1993)

Bebchuk, L.A.: A better plan for addressing the financial crisis. Economists' Voice **5**(5) (2008), Article 7

Bernhardsen, T., Kloster, A., Smith, E., Syrstad, O.: The financial crisis in Norway: effects on financial markets and measures taken. Finan. Mark. Portf. Manag. **23**, 361–381 (2009)

Brommundt, B., Felsenheimer, J., Gisdakis, P., Zaiser, M.: Recent developments in credit markets. Financ. Mark. Portf. Manag. **20**, 221–234 (2006)

Brown, C., Dinc, S.: Too many to fail? Evidence of regulatory reluctance in bank failures when the banking sector is weak. Rev. Financ. Stud. (2010, forthcoming)

Caballero, R.J., Hoshi, T., Kashyap, A.: Zombie lending and depressed restructuring in Japan. Am. Econ. Rev. **98**, 1943–1977 (2008)

Chaney, P.K., Thakor, A.V.: Incentive effects of benevolent intervention, the case of government loan guarantees. J. Public Econ. **26**, 169–189 (1985)

Congressional Budget Office: The troubled asset relief program: report on transactions through December 31, 2008 (2009)

Congressional Oversight Panel: February oversight report, valuing the treasury's Assets, February 6, 2009 (2009)

Cordella, T., Yeyati, E.L.: Bank bailouts: moral hazard vs. value effect. J. Financ. Intermed. **12**, 300–330 (2003)

Diamond, D.W., Rajan, R.G.: Bank bailouts and aggregate liquidity. Am. Econ. Rev. **92**, 38–41 (2002)

Freixas, X.: Optimal bail out policy, conditionality and constructive ambiguity. Social Science Research Network (1999)

Goolsbee, A.: Taxes, organizational form and the dead weight loss of the corporate income tax. J. Public Econ. **69**, 143–152 (1998)

Gorton, G., Huang, L.: Liquidity, efficiency, and bank bailouts. Am. Econ. Rev. **94**, 455–483 (2004)

Harvey, C.R.: The financial crisis of 2008: what needs to happen after TARP. Working Paper, Duke University (2008)

Hoggarth, G., Reidhill, J., Sinclair, P.: On the resolution of banking crises: theory and evidence. Bank of England Working Paper No. 229 (2004)

Jensen, M.C., Meckling, W.H.: Theory of the firm: managerial behavior, agency costs and ownership structure. J. Financ. Econ. **3**, 305–360 (1976)

Kasa, K., Spiegel, M.M.: The role of relative performance in bank closure decisions. Federal Reserve Bank of San Francisco, Economic Review, pp. 17–29 (2008)

Malaith, G.J., Mester, L.J.: A positive analysis of bank closure. J. Financ. Intermed. **3**, 272–299 (1994)

Merton, R.C.: On the pricing of corporate debt: the risk structure of interest rates. J. Finance **29**, 449–470 (1974)

Rochet, J.C., Tirole, J.: Interbank lending and systemic risk. J. Money Credit Bank. **28**, 733–762 (1996)

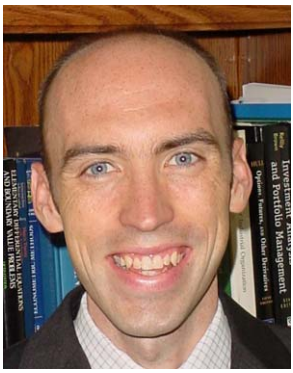
Sarkar, A.: Liquidity risk, credit risk, and the federal reserve's responses to the crisis. Financ. Mark. Portf. Manag. **23**, 335–348 (2009)

SIGTARP: Office of the Special Inspector General for the Troubled Asset Relief Program, Factors affecting efforts to limit payments to AIG counterparties, SIGTARP-10-003, November 17, 2009

Veronesi, P., Zingales, L.: Paulson's gift. Working Paper, University of Chicago (2008)

Wilson, L.: Debt overhang and bank bailouts. Social Science Research Network (2009)

Wilson, L.: The put problem with buying toxic assets. Appl. Financ. Econ. **20**(1–2), 31–35 (2010)
Zingales, L.: Why Paulson is wrong. Economists' Voice **5**(5), Article 3 (2008)



Linus Wilson is an Assistant Professor of Finance at the University of Louisiana at Lafayette. He received his D.Phil. from Oxford University in 2007. He has written over twenty academic papers on bank bailouts, warrant pricing, the Madoff Ponzi scheme, CEO pay, capital structure in professional partnerships, industrial market structure, bankruptcy, entrepreneurship, and mutual funds. His work on the US banking sector rescue, the Troubled Asset Relief Program (TARP), has been cited in numerous news articles in media outlets such as *The New York Times*, *The Wall Street Journal*, and *The Financial Times*.

Yan Wendy Wu is an Assistant Professor at the Economic Department of Wilfrid Laurier University, Waterloo, Canada. She received her Ph.D. degree from Simon Fraser University in 2003. Her current research interests are in the areas of financial crises, corporate governance, and applied option pricing. She had published in scholarly journals on corporate fraud, executive compensation, and derivative pricing. Her research received Southwester Finance Association Best Paper in Corporate Finance award in 2007.