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Paulson's gift ☆

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ABSTRACT

We calculate the costs and benefits of the largest ever US government intervention in the financial sector announced during the 2008 Columbus-day weekend. We estimate that this intervention increased the value of banks' financial claims by $130 billion (bn) at a taxpayers' cost of $21–$44 billion with a net benefit between $86 and $109 bn. By looking at the limited cross section, we infer that this net benefit arises from a reduction in the probability of bankruptcy, which we estimate would destroy 22% of the enterprise value. The big winners of the plan were the bondholders of the three former investment banks and Citigroup, while the losers were JP Morgan shareholders and the US taxpayers.

1. Introduction

The 2008 financial crisis witnessed the largest intervention of the US government in the financial sector. The stated goal of this intervention was to "restore confidence to our financial system,"[1] through a massive transfer of resources from the taxpayers to the banking sector. From an economic point of view, such an intervention is justified only in the presence of a market failure that the government could help alleviate. If this market failure is present, then the government intervention should create, not just redistribute, value. Did this intervention create value or was it simply a massive transfer of resources from taxpayers to financial institutions? If it did create value, why? What can we learn about the possible cost of financial distress in financial institutions?

To answer these questions, we estimate the costs and benefits of the US government plan announced on Monday, October 13, 2008. The plan included a $125 bn preferred equity infusion in the nine (ten if we consider Wachovia still independent) largest US commercial banks joined by a three-year government guarantee on new unsecured bank debt issues. For brevity, throughout the paper we refer to the US Treasury-Federal Deposit Insurance Corporation (FDIC) joint plan as "Paulson's Plan," after the name of the then US Treasury Secretary, Hank Paulson.

Given the worldwide changes in financial markets occurring between Friday, October 10, and Tuesday, October 14, it is impossible to estimate the systemic

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[1] Statement by US Treasury Secretary Henry M. Paulson, Jr. on Actions to Protect the US Economy, October 14, 2008. http://www.financialstability.gov/latest/hp1205.html.

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effects of the intervention. However, it is possible to estimate its effects on the banks involved. If the intervention stopped a bank run, for instance, it should have created some value in the banking sector. To compute the intervention's effect on the value of banks, we do not limit ourselves to the changes in the value of common and preferred equity, but we look at the changes in the entire enterprise value by looking also at changes in the value of existing debt. In fact, by using liquid credit default swap (CDS) rates, we introduce a new way to perform event studies on debt.

To separate the effect of the Paulson Plan from that of other events occurring at the same time, we control for the change in the CDS rates of GE Capital, the largest non-bank financial company. This difference-in-difference approach estimates the total increase in debt value due to the plan at \$119 bn. If we add to these changes the abnormal variation in the market value of common equity (−\$2.8 bn) and of preferred equity (+\$6.7 bn), we obtain that the enterprise value of the ten banks involved in the first phase of the plan increased by \$128 bn. If we add the value increase in the derivative liabilities, we come to a total increase of \$130 bn.

This increase, however, came at a cost to the taxpayers. By computing the value of the preferred equity and the warrants the government will receive in exchange for the \$125 bn investment, we obtain an estimate between \$89 and \$112 bn. Hence, the preferred equity infusion costs taxpayers between \$13 and \$36 bn. We also estimate the cost of the debt guarantee extended by the FDIC on all the new bank debt to be worth \$11 bn. Adding of the extended guarantee on non-interest-bearing deposits and subtracting the reduction in the value of the FDIC deposit guarantee brings the total taxpayers' cost at between \$21 and \$44 bn.

Therefore, the plan had two effects: it transferred between \$21 and \$44 bn from taxpayers to the nine largest banks, but in so doing it created between \$86 and \$109 billion in value. Even if we account for a 30% deadweight cost of taxation (see Ballard, Shoven, and Whalley, 1985; Feldstein, 1999), the plan created between \$73 and \$91 bn in value. Where does this added value come from? What frictions did the plan help to resolve? Who are the main beneficiaries of the plan?

To address these questions we exploit the (very small) cross section of results at our disposition. We find that the bulk of the value added stems from the banks that were more at risk of a run. For each bank, we compute a "bank run" index, which measures the difference between the (risk-neutral) probability of default in the year immediately following and the (risk-neutral) probability of default between year one and year two, conditional on surviving at the end of year one. This index is higher when a bank is subject to a run.

We find a very high correlation (96%) between the ex ante value of the bank run index and the percentage increase in a bank enterprise value at the announcement of the plan. The big beneficiaries of the intervention were the three former investment banks and Citigroup, while the loser was JP Morgan whose total asset value decreased even before factoring in the cost of the Paulson Plan. This result is not so paradoxical. In spite of the benefits of the Paulson Plan, banks might lose value because their participation provides a negative signal to the market about the true value of the assets in place, because the future government interference in banks' affairs reduces value, or because intervention has redistributive effects across banks.

Since all the major banks were "forced" to participate by a very strong arm-twisting exercised by Treasury Secretary Paulson, it is unlikely that participation might signal any inside information about the value of the assets in place. A more realistic interpretation is that the government intervention has two conflicting effects: a negative one linked to the government's future interference in banks' affairs, and a positive one, associated with the reduction in the probability of bankruptcy and hence, the expected cost of bankruptcy. Exploiting the firm variation in this latter probability, we estimate that the expected cost of government interference is about 2.5% of enterprise value, while the cost of bankruptcy is about 22% of enterprise value.

Given the extreme volatility of markets during this period, one may wonder whether the observed outcome represents a fair assessment of the intervention's effects. For this reason, we evaluate the plan on an ex ante basis by using the standard Black and Scholes (1973) and Merton (1974) models of equity as an option on the value of the underlying assets. When we keep the assets' value constant (i.e., the intervention neither creates nor destroys any value), the model grossly underestimates the market response. According to the model, the shareholders should have lost \$25 bn and instead lost only \$3 bn. The debt holders should have gained \$49 bn and instead gain \$119 bn. To bridge this difference we need to hypothesize an increase in the value of the underlying assets. It is only if we assume an increase in the value of assets of \$113 bn that the model can approximate well the actual changes in the value of debt and equity. This alternative method confirms the magnitude of the asset increase.

Finally, we try to evaluate whether the same objective achieved by the plan could have been obtained at a lower cost to taxpayers. If the main goal was to make banks solvent, we assume that the objective is to achieve a reduction in the CDS rates equivalent to the one observed in the data after the plan. We analyze four alternative plans: the original Paulson Plan where banks' assets were purchased at market value, the original Paulson Plan with banks' assets purchased above market (we assume 20% above), a British-style equity infusion without any debt guarantee, and a debt-for-equity swap. We rate these alternatives on the basis of up-front investment required by the government, taxpayers' expected cost, taxpayers' value at risk, and government ownership of banks. While inferior to a debt-for-equity swap, the Revised Paulson Plan appears superior to the other strategies. The approach followed by the Paulson Plan, however, did not require a redistribution of between \$21 and \$44 bn from taxpayers to banks: the government could have charged more for both the equity infusion and the debt guarantee as Warren Buffett did when he invested in Goldman Sachs three weeks before the Paulson Plan.

The rest of the paper proceeds as follows. Section 2 describes the 2008 financial crisis and discusses the potential reasons for a government intervention. It also describes the details of the plan announced by the US Treasury and FDIC on October 13, 2008. Section 3 analyzes the effect of the plan on the prices of the bonds, the common equity, and the preferred equity. Section 4 computes the net cost of the preferred equity infusion and the debt guarantee. Section 5 analyzes the plan from an ex ante point of view. Section 6 studies the cost of alternative plans that would have achieved the same objective. Conclusions follow.

2. The 2008 financial crisis and rationale of government intervention

2.1. Government response to the crisis and the Revised Paulson Plan

On Friday, October 3, 2008 the US Treasury Secretary Hank Paulson obtained Congressional approval to buy distressed assets for a total of US$ 700 bn, but this plan failed to reassure investors about the solvability of the banking sector. The following week the US stock market had its worst week ever with a negative return of 18%. All the world exchanges followed suit.

During the weekend of October 11–12, British Prime Minister Gordon Brown announced his own stabilization plan, which included an injection of government money in the capital of troubled banks and a guarantee on the new debt issued by banks. On Monday, October 13, 2008, the US Treasury, the Federal Reserve, and the FDIC jointly announced the government decision to follow the British Prime Minister's footsteps. That day, the chief executive officers (CEOs) of the main nine banks were called for a meeting in Washington and briefed on the government plan. According to a *New York Times* article, the CEOs were taken by complete surprise and were coaxed into accepting the deal (Landler and Dash, 2008). Since this is the only component of the plan that arrived to the market as a surprise, we limit our analysis to the effect of this Revised Paulson Plan.[2]

Paulson's revised plan, summarized in Table 1, has three parts. First, the government injects $125 billion preferred equity investment in the nine largest US commercial banks (ten including Wachovia which has accepted an offer to be purchased by Wells Fargo). In this broad category, we also include the three surviving investment banks that either filed to become commercial banks (Goldman Sachs and Morgan Stanley) or are merging with a commercial bank (Merrill Lynch). In exchange for this preferred equity infusion, the government receives an amount of preferred equity with a nominal value equal to the amount invested. This preferred equity pays a dividend of 5% for the first five years and 9% after that. In addition, the government receives a warrant for an amount equal to 15% of the value of the preferred equity infusion with a strike price equal to the average price of the stock in the 20 working days before the money is actually invested.

The second part of the plan, contextually announced by the Federal Deposit Insurance Corporation, includes a three-year government guarantee for all new issues of unsecured bank debt until June 30, 2009.[3] The FDIC guarantee is for a maximum of 125% of the sum of the unsecured short-term debt and long-term debt maturing between then and June 2009. To provide this guarantee, the FDIC will charge a fee. When the program was first announced (on October 14, 2008) this fee was set at 75 basis points (bps). On November 12, it was changed and differentiated according to the maturity of the debt. Since we want to calculate the value at the announcement, we will use the 75 bps for all the maturities in our calculations. The last column of Table 1 approximates the maximum amount of guaranteed debt that could be issued by summing all the unsecured short-term debt plus half of the long-term debt maturing in 2009.

The third part is an extension of the FDIC deposit insurance to all the non-interest-bearing deposits. While on October 3, 2008, the FDIC had increased deposit insurance from $100,000 to $250,000 per depositor, as part of the Temporary Liquidity Guarantee Program announced October 14, the FDIC provided for a temporary full guarantee for funds held at FDIC-insured depository institutions in non-interest-bearing transaction accounts above the existing deposit insurance limit. While we do not have the exact amount of these accounts, we can approximate it by looking at the amount of non-interest-bearing accounts (column 2 of Table 2) and the percentage of insured deposits (column 3 of Table 2), as reported in the bank call reports for September 2008.[4]

Table 2, Panel A reports other relevant information about the capital structure of these banks before the announced deal, and Table 2, Panel B provides some key market value information about these banks.

2.2. Rationale for government intervention

From an economic point of view, there are two reasons why the government intervention could create value. The first one is that the banking system was subjected to a run. To run were not the depositors, as in traditional bank runs, but short-term creditors, who refused to roll-over their short-term lending (Gorton and Metrick, 2009). Since bank runs can be inefficient (Diamond and Dybvig, 1983), stopping a bank run can create value.

Was there a bank run in early October 2008? We can partly answer this question by looking at the behavior of credit default swap rates. The credit default swap (CDS) is a contract that in case of default by the referenced entity, provides the buyer with the opportunity to exchange the defaulted debt with an amount of cash equal to the face value of that debt minus any amount recovered from the defaulted security. In other words, a credit default swap is

[2] In particular, our analysis cannot capture the effects of the other interventions under the Trouble Asset Relief Program (TARP), such as the AIG bailout, the investments in the automotive companies, etc.

[3] For more information, see http://www.fdic.gov/news/news/press/2008/pr08100b.html.

[4] These reports are available online at http://www2.fdic.gov/idasp/main.asp.

Table 1
The Revised Paulson Plan.
Equity infusion is the amount of money (in billions of US$) the government will invest in each of these banks according to the Revised Paulson Plan. The price is the market value of common equity stock at closing on 10/14/2008. The number of shares (in billions) are as of 9/30/2008 as from the latest company filings. The number of warrants is 15% of the equity infusion divided by the price of common stock on 10/14/2008. The dilution factor, which is used to price the warrants, equal $1/(1+m/n)$, where m is the number of warrants and n the number of shares. The amount of guaranteed debt is 125% of the sum of the short-term debt plus the long-term debt maturing before 6/30/2009.

	Equity infusion	Price 10/14/2008	No. of outstanding shares	No. of warrants	Dilution factor	Guaranteed debt
Citigroup	25	18.62	5.45	0.20	0.96	127.3
Bank of America	15	26.53	5.02	0.08	0.98	182.3
JP Morgan Chase	25	40.71	3.73	0.09	0.98	277.9
Wachovia	5	6.31	2.15	0.12	0.95	15.9
Wells Fargo	20	33.52	3.32	0.09	0.97	76.0
Bank of NY Mellon	3	34.76	1.15	0.01	0.99	3.6
State Street Corp	2	56.69	0.44	0.01	0.99	5.4
Goldman Sachs	10	122.9	0.43	0.01	0.97	80.9
Morgan Stanley	10	21.94	1.11	0.07	0.94	17.8
Merrill Lynch	10	18.24	1.60	0.08	0.95	32.1
Total	125.0					819.1

(a) Mkt price of the participating institution's common stock at the time of issuance, calculated on a 20-trading day trailing average (http://www.treas.gov/press/releases/hp1207.htm).
(b) Aggregate market price=15% equity infusion (http://www.treas.gov/press/releases/hp1207.htm).

an insurance against the risk of default. The party obtaining insurance pays a quarterly premium, called the CDS rate, which is quoted as basis points of premium per year per notional amount of $100. CDS rates are generally available for all the maturities between one and five years.

Since the one-year CDS reflects the probability of default this year, while the two-year CDS reflects the average probability of default over the next two years etc., the term structure of CDS rates can be used to obtain the conditional probability of default in any given year.

We obtain CDS rates data from Datastream (see Fig. 1). Appendix A contains the details of the bootstrap procedure used to obtain the probabilities of default. In particular, we compute the following conditional (risk-neutral) probability:

$$P(n) = Prob(Default\ in\ year\ n|No\ Default\ before\ year\ n). \qquad (1)$$

In a normal environment the conditional probability of bankruptcy in any given year is increasing over time, since the variance in assets' value is increasing over time. An exception is when a bank is facing the risk of a run. If today an otherwise solvent bank faces the risk of a run, its probability of bankruptcy in the near term would be much higher than the probability of bankruptcy in the future, conditional on surviving this year. If a bank run is likely, then we should find $P(1)>P(2)$, as it is more likely that default occurs in the short-term than in the longer-term, conditional on surviving. Conversely, if $P(1)<P(2)$, then it is unlikely that a bank is subject to a bank run. We therefore compute the bank run index as

$$R = P(1) - P(2) \qquad (3)$$

to gauge whether a bank is at risk of a run.[5] We compute the bank run index for the banks that are the first recipients of government funding, namely, the nine largest commercial banks (ten with Wachovia), including in this category also the three investment banks that either filed to become commercial banks or were going to merge with one. Unfortunately, CDS data on State Street and Bank of NY Mellon are not available.

Fig. 2 shows the time series of these indices for the eight banks. The vertical dotted line corresponds to October 10, 2008, the Friday before the government announcement of the Revised Paulson Plan. As can be seen, on October 10, 2008, Citigroup, Wachovia, and the three investment banks had a positive bank run index R, an indication that potentially a bank run was indeed taking place on them. It is interesting to note that before Lehman's bankruptcy on September 15, 2008, only two banks, Morgan Stanley and Merrill Lynch, displayed a positive index R. At the time of Lehman Brothers Bankruptcy, Goldman Sachs bank run index R also turned positive, and a few weeks later Citigroup's did, while the other commercial banks' indices remained unchanged.

If the main source of inefficiency is the risk of a bank run, then a government intervention that reduces the risk of a run should mainly benefit the banks at risk of a run. In other words, at the announcement of the government intervention, banks with a positive bank run index should experience an increase in the value of their assets that far exceeds the subsidy, while banks with a negative index should not.

Alternatively, the inefficiency could arise from banks being excessively levered and thus, unable to exploit future investment opportunities.[6] If this is the case, a

[5] While a bank run is a sufficient condition to have $P(1)>P(2)$, it is not a necessary one. Other reasons could make the bank more risky in the short- than in the long-term. Hence, the bank run index should be interpreted only as a proxy of the probability of a run and not as an exact measure.

[6] As it is known since Myers (1977), if a firm is burdened by a large (risky) debt, then an equity infusion provides a safety cushion to debt in those states of the world in which it would not have been paid in full. As a result, the value of risky debt goes up when new equity is raised. This transfer of value, which is also known in the literature as debt overhang or co-insurance effect, is what makes it so unattractive for equity holders to raise new equity. If banks need to raise private capital to extend new loans, they may be prevented because private equity holders refuse to provide the capital. Thus, banks may pass up on positive Net Present Value (NPV) projects, losing value.

Table 2
Main data on banks targeted by the Revised Paulson Plan.

Panel A reports balance sheet information for the banks targeted by the first phase of the plan. The information comes from the banks' 10Q filing as of 09/30/2008 (except Goldman Sachs and Morgan Stanley, whose data are as of 08/31/2008), which were the latest available on 10/10/2008. The data for the end of the third quarter are very similar. All figures in billions of US$. Panel B report some additional market information used in the analysis. Market capitalization is in billions of US$. The implied volatility is extracted from at-the-money call options on 10/10/2008 with the longest maturity available. Actual volatility is the annualized daily standard deviation of daily returns estimated during the period July–September 2008. The preferred yield is computed using the most recent preferred issue by each company that is trading. Dividend per share is obtained multiplying the last quarterly dividend times four. Maturity is the average maturity (in years) of the long-term debt outstanding. Coupon is the average coupon (in % terms) of the long-term debt outstanding.

Panel A: Balance sheet data

	Deposits			Short-term debt		Long-term debt	Other liabilities	Total liabilities	Equity	Total assets
	Total	Non-interest bearing	Percent insured	Total	Unsecured					
Citigroup	780.3	108.0	47.4	352.3	101.9	396.1	395.7	1,924.4	126.1	2,050.5
Bank of America	874.1	204.5	62.9	371.5	145.8	257.7	166.8	1,670.1	161.0	1,831.2
JP Morgan Chase	969.8	203.0	37.4	446.4	222.3	255.4	434.0	2,105.6	145.8	2,251.0
Wachovia	389.5	57.5	66.9	58.2	12.7	183.8	90.2	721.7	70.2	791.9
Wells Fargo	339.1	89.4	64.2	86.1	60.8	103.9	31.9	561.1	48.0	609.1
Bank of NY Mellon	174.2	81.7	3.1	20.3	2.9	15.5	30.0	240.0	27.5	267.5
State Street Corp	150.9	70.0	0.6	100.2	4.3	4.1	17.3	272.5	13.1	285.6
Goldman Sachs	29.1	0.0	14.3	443.5	64.7	176.4	387.2	1,036.2	45.6	1,081.8
Morgan Stanley	36.8	0.0	81.6	193.7	14.2	202.3	518.8	951.6	34.5	986.1
Merrill Lynch	90.0	0.0	85.3	242.9	25.7	232.5	272.0	837.4	38.4	875.8
Total	3,834			2,315		1,828	2,344	10,321	710	11,030

Panel B: Other market information

	Mkt. cap 10/14/08	Implied volatility	Actual volatility	Preferred yields	Dividends per share	Average maturity	Average coupon
Citigroup	101.5	77.59%	170.76%	12.46%	1.28	8.0	4.17
Bank of America	133.1	77.75%	193.52%	8.83%	2.56	8.6	3.66
JP Morgan Chase	151.7	57.37%	152.34%	8.84%	1.52	6.8	3.69
Wachovia	13.6	79.08%	696.48%	11.33%	0.20	7.1	3.57
Wells Fargo	111.3	56.48%	125.54%	8.73%	1.36	6.3	4.47
Bank of NY Mellon	40.0	85.79%	177.78%	8.16%	0.96	7.6	5.41
State Street Corp	24.7	67.00%	166.84%	7.25%	0.96	7.2	2.65
Goldman Sachs (a)	52.6	67.73%	90.50%	7.79%	1.40	7.2	4.93
Morgan Stanley (a)	24.3	88.57%	151.25%	11.16%	1.08	5.4	4.71
Merrill Lynch	29.2	82.23%	177.94%	11.55%	1.40	4.9	3.26
Average	68.2	73.96%	210.29%	9.61%	1.27	6.9	4.05
Total	681.9						

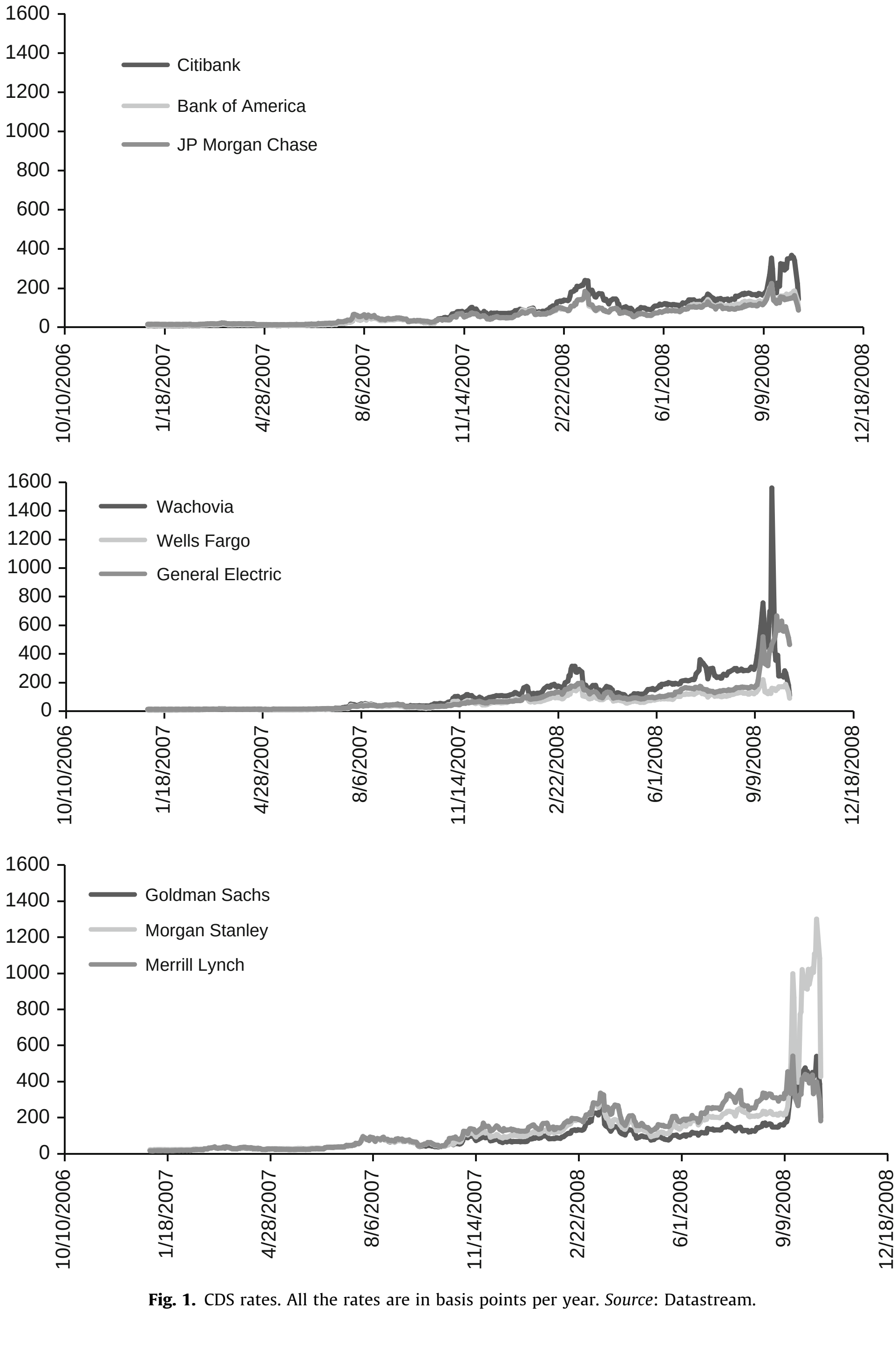

Fig. 1. CDS rates. All the rates are in basis points per year. *Source*: Datastream.

government intervention that injects new capital in banks would prevent this loss in valuable investment opportunities. If the banking sector were perfectly competitive, the entire value saved would accrue to the companies receiving the financing. But if the banking sector were perfectly competitive, then the loss of a few banks would have no negative consequences in the economy, because the others would step in to provide the financing with no friction. Hence, if debt overhang is the main inefficiency that the government intervention is meant to solve, then we should find that the change in the enterprise value of the bank exceeds the taxpayers' cost of the rescue.

A government intervention can have negative effects too. First, the government can impose restrictions on banks' decisions (for example, executive compensation or

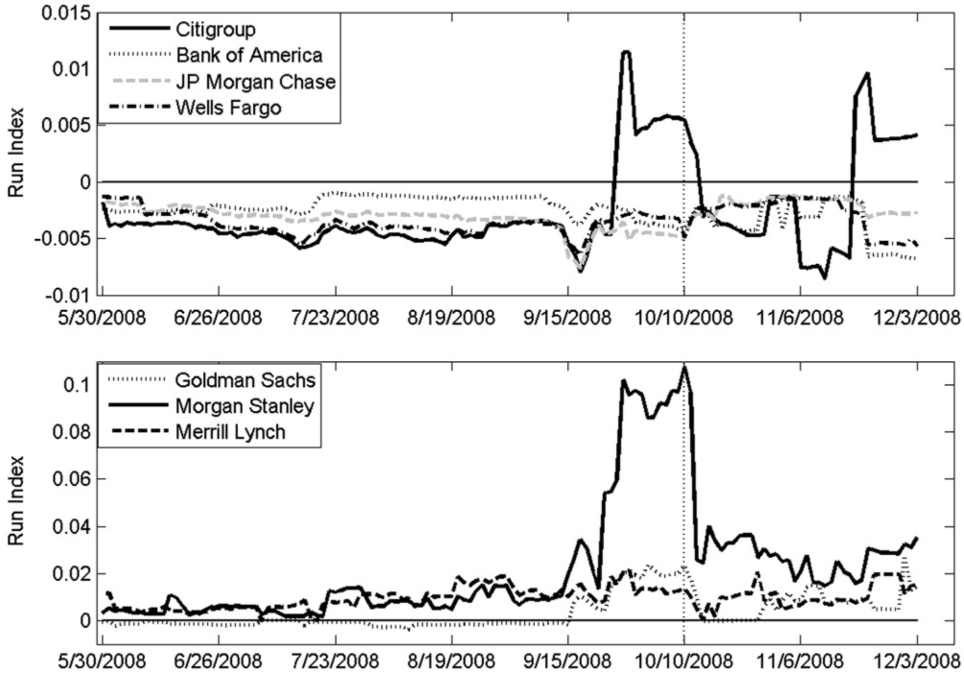

Fig. 2. The Bank Run Index. The figure plots the difference $R_t = P_t(1) - P_t(2)$, where $P_t(n)$ is the conditional probability of default in year n after t, conditional on not defaulting before n. These conditional probabilities are inferred from the term structure of CDS rates.

lending requirements) that reduce a bank's profit. Second, the government can introduce political criteria into the lending decisions, reducing a bank's profitability (Sapienza, 2004). Finally, the government intervention can delay or block the natural transfers of assets to the more efficient managers, reducing the overall profitability of the banking industry. The first and second effects are more likely to be present in banks where government ownership becomes larger, while the third one is likely to manifest itself in the price of the better-run banks, which will be prevented from taking advantage of the acquisition opportunities.

3. Effect of the plan announcement on the value of the banks' financial claims

In this section, we test the effectiveness of the government intervention through an event study analysis. An event study is unable to measure the systemic effect of the government intervention, as such an effect is commingled with many other events taking place at the same time. Therefore, we will be able to estimate only the differential impact of the government intervention on the banking sector compared to the rest of the economy. If the source of the inefficiency is debt overhang or a bank run, we should find evidence that the banking sector is, in fact, the main beneficiary of the government help. If we do not find such a differential effect, however, then we should conclude that the main effect has been to stave off a panic or a systemic event unrelated to the banking sector.

Event studies have generally focused on the changes in the market value of equity since the value of equity, which is a residual claim, is most sensitive to information and/or decisions. However, when a company is highly levered (as banks are), bond prices are also very sensitive to the value of the underlying assets. Unfortunately, bond prices are generally not very liquid and, generally, it is very difficult to undertake a proper event study on the value of debt. However, the development of the credit default swap market has made such a study possible.

3.1. *An event study on bonds*

The market for CDSs, barely existing in 1999, reached more than \$57 trillion of notional amount by June 2008. Given the high volume, this market provides a reliable measure of the changes in the value of debt, much more reliable than the sparse quote on bonds. In fact, the availability of daily CDS rates opens the possibilities of systematic event studies on bonds and so on the entire value of the enterprise. In what follows we outline how.

3.1.1. *Methodology*

If a debt becomes less risky, it appreciates in value. When we cannot observe this appreciation directly, we can measure it by looking at the reduced cost of insuring this debt with a CDS. This cost will go down since a reduction in the risk of default translates into a reduction in the CDS rates. If we ignore the counterparty risk, the market value of a bond (B) plus the present value of the cost of insuring it with the CDSs equals the value of a government bond (*GB*) with similar rate and maturity, or[7]

$$B+PV(Insurance\ Cost)=GB. \quad (4)$$

The present value of the insurance cost can be obtained as the discounted value of the cost of insuring the existing debt (as measured by the CDS rate) in each year t (from today to the maturity of the longest maturity bond) multiplied by the probability the company did not default up to year t times the amount of existing debt $D(t)$ that will not have matured by year t:

$$PV(Insurance\ Cost)=\sum_{t=0}^{T}\frac{CDS(t)}{10000}D(t)Q(t)Z(t), \quad (5)$$

where $Z(t)$ is the risk-free discount factor, and $Q(t)$ is the risk-neutral probability of not defaulting up to time t, obtained in Eq. (A.2) in Appendix A.

A decline in the risk of a bond not triggered by a change in the bond's rate and/or maturity should not affect the value of its corresponding government bond.[8] Since the right-hand side of (4) remains constant, an increase in the value of B due to a reduction in risk translates into an equivalent reduction in the present value of the insurance cost

$$\Delta B=-\Delta PV(CDS)$$

with

$$\Delta PV(CDS)=\sum_{t=0}^{T}\frac{CDS_1(t)}{10000}D(t)Q_1(t)Z(t)-\sum_{t=0}^{T}\frac{CDS_0(t)}{10000}D(t)Q_0(t)Z(t), \quad (6)$$

where the index 1 indicates after the fact and the index 0 before the fact.

3.1.2. Application

We obtain from Datastream CDS rates for contracts up to five years for all banks, except for the two smallest banks, Bank of New York and State Street, for which CDS contracts are unavailable. Given the small amount of outstanding debt these two banks have, we can ignore them without much of an effect on the results. Fig. 1 plots the five-year CDS rates for the eight banks for which they are available from January 1, 2007 to October 14, 2008.

To gauge the magnitudes of the change, we report the five-year CDS rates for the relevant dates in Table 3. The risk-neutral probabilities of no default $Q(t)$, computed in Appendix A, depend on an assumption about recovery rate. We report our results for an intermediate value, 20%.[9] Since this choice is somewhat arbitrary, Section 4.6 discusses the robustness of our conclusion to various assumptions, including larger or smaller recovery rates.

To measure the changes in the value of the debt surrounding the announcement of the new Paulson Plan, we look at the changes in CDS rates between Friday, October 10 and Tuesday, October 14 (see Table 3). We then apply formula (6) to estimate the change in value of debt.

There are, however, two problems in using the raw variation in CDS rates to measure the effect of the plan. First, this variation reflects only the additional value of the revised plan vis-à-vis the old one. Given the vague description of the original troubled asset purchase plan, the poor market response (the week of October 3 through October 10 had the worst performance on record), we are not too worried about this problem. Nevertheless, we should interpret all the results as differential impacts.

The second problem is that a lot of things changed during the weekend October 11–12, including the rescue organized by the Europeans. At the same time, several bad events did not happen. For example, a feared international ban on short-sales that was rumored to be introduced at the G-8 meeting during the weekend did not occur. Since CDSs are an alternative to short-sales to bet on the value of a company falling, the fear of a ban on short-sales could have artificially pushed up CDS rates before the weekend.

To identify the impact that other factors could have had on the CDS rates of financial firms we look at the CDS rates of the largest financial firm not involved in the intervention: GE Capital. Interestingly, the five-year CDS rate of GE Capital dropped from 590 to 466 basis points over those two trading days. Since at the announcement of the plan, the government did not intervene on GE Capital, we can use this change as a control for all the other events that occurred during the weekend including possible systemic effects of the plan. Eventually, however, the same conditions offered to banks were extended to GE too. If the market anticipated (at least with positive probability) this possibility, then GE would not be a good control. For this reason, in Section 4.6 we test the robustness of our results to using a CDX index.[10]

To isolate the effect of the Paulson strategy itself, we apply the same methodology widely used to correct for market movements in event studies on stocks. In particular, for each bank we subtract from the raw change in insurance cost given in expression (6) the percentage change in insurance costs of GE Capital (our control) multiplied by the ex ante cost of insurance of the bank:

$$Adjusted\ \Delta PV(CDS)=\Delta PV(CDS)-PV_0(CDS)\times\frac{\Delta PV^{GE}(CDS)}{PV_0^{GE}(CDS)}. \quad (7)$$

The results are in column 6 of Table 3. Overall, the bonds gained \$124 bn in value. The bonds of the three old investments banks gained the most from the plan. The adjusted

[7] Eq. (4) represents an arbitrage-free condition that holds in general, but during the fall of 2008 many basic arbitrage conditions were violated and this was no exception. It is our understanding that the violations were due to the illiquidity of the corporate bond market and not of the CDS market. Nevertheless, for our exercise to hold, we do not need this condition to hold precisely, but only that the magnitude of the deviation did not change (or did not change much) over the two days we consider.

[8] Our calculations are predicated upon the fact that the price of government bonds did not change during the event windows. In fact, the one-year CDS rate on US government bonds dropped from 21.3 to 18.5 bps, while the five-year CDS rated dropped from 33 to 28.7 bps. Since this corresponds to a (slight) increase in the government bonds, ignoring it has the effect of underestimating the increase in market value produced by the Paulson Plan.

[9] The historical average recovery rate of bonds is about 40%, but it declines to about 20% during recessions (see, e.g., Chen, to appear).

[10] Ignoring the possible effect of the plan on GE will underestimate the effects of the plan. Given the strong positive effect, our main results would be unchanged.

Table 3
Change in the value of long-term debt around the announcement of the Revised Paulson Plan.

CDS rates refer to a five-year debt instrument and are expressed in basis points per year. The source is Bloomberg. The adjusted gain is the present value of the reduction in insurance costs paid on all the debt outstanding, with the actual structure of maturity, as a result of a drop in the CDS rates, adjusted for the percentage reduction in GE cost. As a discount rate we use 3.5%. The debt and the adjusted gain data are in billions of US$.

	Five-year CDS spread 10/10/08	Five-year CDS spread 10/14/08	Raw decline	Long-term debt			Net derivative payables		
				LT debt	GE adj. gain	CDX adj. gain	Amount net deriv.	GE adj. gain	CDX adj. gain
Citigroup	341.7	144.6	197.1	396.1	21.4	23.9	103.4	3.6	3.9
Bank of America	186.2	99.2	87.0	257.7	4.2	5.1	26.5	0.3	0.3
JP Morgan Chase	162.5	88.0	74.5	255.4	3.6	4.2	85.8	0.8	0.9
Wachovia	267.5	109.2	158.3	183.8	7.5	8.4	13.4	0.4	0.4
Wells Fargo	186.7	89.8	96.9	103.9	1.6	1.8	10.8	0.1	0.1
Bank of NY Mellon				15.5					
State Street Corp				4.1					
Goldman Sachs	540.0	201.7	338.3	176.4	17.6	19.0	103.9	6.7	7.1
Morgan Stanley	1300.9	427.1	873.8	202.3	51.6	54.4	68.4	11.8	12.5
Merrill Lynch	398.3	182.5	215.8	232.5	13.0	14.3	55.6	2.6	2.8
General Electric Capital	590.0	465.8	124.2						
CDX Index	213.0	176.8	36.2						
Total				1,828	120.5	131.3	467.8	26.3	28.0

gains of the three were \$87 bn. Among the old commercial banks, Citigroup stood to gain the most, both in level, \$21 bn, and in percentage of outstanding debt, 5.3%.

3.2. An event study on common stock

Table 4, Panel A reports the results of a standard event study on the value of common stock around the announcement of the Revised Paulson Plan. Like the bond prices, we use the period from Friday, October 10 to Tuesday, October 14 as the event window. During that period the market rose by 11%, while the stock of the companies involved in the plan rose by 34%. This might seem a huge difference, but we need to compute the beta of each of these securities since the equity betas of firms close to default can be very high. In fact, when we estimate the beta of the common stock of these banks by using the daily return from January 1, 2007 to October 9, 2008, we obtain on average a beta of 2.2. Our estimates are reported in the second column of Table 4.

When we market-adjust these changes, the average return over the event period drops to 10%, with huge variation: from −24% of Wachovia to a +103% return of Morgan Stanley. Once again, the return on Morgan Stanley could be the effect of the announcement of the finalization of the Mitsubishi investment. It is important to keep in mind, though, that ignoring the impact of this news has the effect of overestimating the benefits of the Paulson Plan.

We obtain the value added to common equity by the plan when we multiply the abnormal return and the market capitalization as of Friday, October 10th. If we adjust the individual stock movement for the market movement by using the actual beta, we learn that overall, banks' shareholders do not benefit from the plan (−\$2.8 bn). There is, however, a wide variation. While JP Morgan shareholders lose \$34 bn, Morgan Stanley's gain \$11 bn, while Citigroup and Goldman shareholders gained roughly \$8 bn each.

3.3. An event study on preferred equity

We perform a similar analysis for the preferred equity. Given the amount of preferred outstanding, these numbers will not change the overall results. Nevertheless, it is useful to add this piece of information.

The biggest problem in performing this event study is the definition of the preferred. Several of these firms have different classes of preferred and not all these classes are traded. Hence, as a reference price for all the preferred shares outstanding we choose the most recently issued preferred that is actively traded. The numbers and the results are presented in Table 4, Panel B.

All the preferred increased in price by +36%, well above the market return of +11%. To compute excess returns, we estimate the beta of each preferred stock using the daily returns from January 1, 2007 to October 9, 2008.[11] The results are reported in Table 4, Panel B. Once these differences are accounted for, the preferred increased in value at the announcement of the plan by \$6.7 bn.

3.4. Other claims

We have only computed the change in value of debt and equity claims, but we have not computed the changes in the value of the other liabilities. In particular, we know that there is a dense network of positions in derivative contracts and credit default swaps, whose value depends

[11] In a few cases, the span is shorter because we could not find any preferred traded on Bloomberg.

Table 4
Change in the value of equity around the announcement of the Revised Paulson Plan.

Panel A refers to common equity, while Panel B to preferred equity. The market capitalization is price per share on 10/10/2008 times the number of shares outstanding. The betas are estimated from daily stock prices during the period 1/1/07–10/9/08. The daily prices are from Bloomberg. As a price for the preferred equity we use the most recently issued preferred of each company, assuming that all preferred of each bank have the same characteristics. The abnormal return equals raw return—beta∗market return, where the market return (measures as S&P 500) increased by 11% over those two trading days. Value increase is the product of the initial market capitalization time the abnormal return. Market capitalizations and value increases are in billions of US$.

	Market cap 10/10/2008	Estimated beta	Raw return	Abnormal return		**Value increase**	
				Beta = 1	Est. beta	Beta = 1	Est. beta
Panel A: Common equity							
Citigroup	76.89	1.97	0.32	0.21	0.10	16.1	7.9
Bank of America	104.71	2.08	0.27	0.16	0.04	16.9	4.4
JP Morgan Chase	155.19	1.77	−0.02	−0.13	−0.22	−20.5	−33.6
Wachovia	11.07	4.28	0.23	0.12	−0.24	1.3	−2.7
Wells Fargo	93.99	1.73	0.18	0.07	−0.01	7.0	−0.5
Bank of NY Mellon	30.48	1.85	0.31	0.20	0.11	6.2	3.3
State Street Corp	18.79	1.70	0.31	0.20	0.13	3.8	2.4
Goldman Sachs	38.01	1.60	0.38	0.27	0.21	10.4	7.9
Morgan Stanley	10.74	2.19	1.27	1.16	1.03	12.4	11.0
Merrill Lynch	25.20	2.47	0.16	0.05	−0.11	1.2	−2.8
Total	565.1					54.8	−2.8
Average		2.16	0.34	0.23	0.10		
Panel B: Preferred equity							
	Market cap 10/10/2008	Estimated beta	Raw return	Abnormal return		Value increase	
				Beta = 1	Est. beta	Beta = 1	Est. beta
Citigroup	9.48	1.35	0.37	0.26	0.22	2.4	2.1
Bank of America	11.28	0.19	0.22	0.11	0.20	1.2	2.2
JP Morgan Chase	5.32	0.45	0.12	0.01	0.07	0.0	0.4
Wachovia	5.90	1.27	0.20	0.09	0.06	0.5	0.3
Wells Fargo	0.34	0.36	0.22	0.11	0.18	0.0	0.1
Bank of NY Mellon							
State Street Corp							
Goldman Sachs	0.74	0.50	0.21	0.10	0.15	0.1	0.1
Morgan Stanley	0.30	1.14	1.13	1.02	1.01	0.3	0.3
Merrill Lynch	4.50	1.03	0.39	0.28	0.28	1.3	1.2
Total	37.9					5.9	6.7
Average		0.79	0.36	0.25	0.27		

upon the counterparty value and hence, it is affected by the Paulson Plan. While this is certainly true, it might only impact our conclusions as far as we look at individual companies, but it can hardly impact our overall conclusions. The reason is that the vast majority of these contracts are within the group of these ten banks. Indeed, recently released Depository Trust and Clearing Corporation (DTCC) data show that about 90% of the transactions on credit derivatives are between security dealers. Since we focus on the ten largest banks, they must account for most of the transactions.[12] In addition, a 2007 International Swaps and Derivatives (ISDA) survey on Counterparty Risk Concentration – carried out before the current crisis – found that inter-dealer exposures are modest, as among the top ten dealers, almost 100% of derivatives are covered by Credit Support Annexes, which establish guidelines for credit risk mitigation. The same survey also shows that among the top ten dealers, collateralization in derivative transactions reduces the risk exposure of about 80% from their five largest counterparties. Although we do not have aggregate numbers and self-reported survey results should be taken with a degree of suspicion, these findings do suggest that derivative transactions are highly collateralized, and mainly taking place among the largest security dealers.

While the results above suggest that the impact on the aggregate results from including other liabilities should be modest, we nonetheless quantify the gain from counterparty exposure as follows: first, from the balance sheet we obtain the net liability position from derivative securities. Second, we impute the maturity of these derivative positions from the Bank for International Settlement tables, which report the average maturity of various over-the-counter (OTC) derivatives. Finally, we treat these liabilities as "debt" and use the same methodology illustrated in Section 3.1 to compute the increase in value of these liabilities. The raw value of this computation is reported in the last column of Table 3.

When we follow this procedure, the total value of derivative liabilities increases by $26 billion at the announcement of the Paulson Plan. This amount grossly overestimates the impact of the plan on the net derivative liabilities, since collateralization reduces by 80% the actual exposure to counterparty risk. When we adjust for this the next value increase is only $5.2 billion. Section 4.6 discusses the robustness of our conclusions to variations in this assumption.

3.5. Overall increase in value

In Table 5, we compute the overall value increase due to the plan as the sum of the three most variable components on the right-hand side of the balance sheet. The market value of debt increased by $119 bn, the aggregate derivative liabilities by $5.5 bn, the market value of preferred by $6.7 bn, while the market value of equity dropped by $2.8 bn. Overall, the total value of financial claims in the top ten banks increased by $128 bn as a result of the plan.

This increase cannot be considered as the value added of the plan, since the government is deploying considerable resources to implement this plan. To assess the net aggregate effect of the revised plan, we need first to compute the cost taxpayers paid for it.

4. Taxpayer's cost and aggregate effects

4.1. Cost of the preferred equity infusion

On October 13, the government announced that it will invest $125 bn in the top ten banks. The $125 bn represents the size of the investment, not its costs, since the government receives in exchange some claims on the underlying companies. Thus, the actual cost is the difference between the amount invested and the value of those claims.

In order to calculate these claims – preferred equity and warrants – we need to make some assumptions. First, we assume that the preferred equity will be redeemed after five years, i.e., right before it starts to pay a 9% dividend. This assumption over-estimates the value of preferred equity because only firms whose cost of capital will be above 9% will choose not to redeem, but that would be bad news for the government, as it would receive 9% instead of a higher market value.

The second key assumption in the valuation of the government's claim is at what rate we discount the 5% dividend paid by the preferred in the first five years. Since there is room for disagreement we adopt two different approaches. In Table 6, Panel A we compute the present value of the preferred dividend by using the yield on existing preferred shares, as reported by Bloomberg. As discussed earlier, we use the data from the most recently issued preferred shares with available data. Instead, in Panel B we use a capital asset pricing model with the beta estimated from common stock.

Third, we compute the value of warrants as ten-year American options on the stocks, adjusted for the usual dilution adjustment (see Table 2, Panel A). In this calculation, we assume that dividend disbursement remains constant at its latest level. Given that the recent banking crisis did not spur banks to decrease dividend disbursement in the past year, assuming constant dividends seems plausible.[13] Note that Paulson's Plan forbids banks from increasing dividends without authorization from the Treasury only for the first three years. Thus, there is a serious risk that the banks will increase their dividends after that, reducing the value of the government's warrants. For this reason, we use two hypotheses. In Table 6, Panel A we use the actual maturity of the warrant (ten years). In Panel B we assume the effective maturity of three years, assuming that the banks'

[12] We do not consider here the effects of the funds given to AIG, which helped many foreign counterparties.

[13] Indeed, we think this assumption is in fact conservative, as it would be in the interest of banks to increase dividends after the three-year lock out, in order to decrease the value of outstanding warrants.

Table 5
Aggregate effects of the Revised Paulson Plan.

The changes in the value of common and preferred equity come respectively from Table 4a and b. The changes in the value of the debt and in net derivative payables come from Table 3. The total of change in derivative payables is equal to the sum of the individual components times 20%, to take into account collateralization and the fact that in aggregate most derivative transactions are between the large dealers. The total benefit is the sum of the three above components. The net cost of equity infusion comes from Table 6 and the net cost of the debt insurance from Table 7. The total cost is the sum of these two above components. The net benefit is the difference between the total benefit and the total cost. All figures are in billions of US$.

	Change in the value of common equity	Change in the value of preferred equity	Change in the value of debt	Change in value of derivative liabilities	Reduction in the cost of deposit insurance	Total	Net cost of equity infusion	Net cost of unsecured debt insurance	Cost of extended deposit guarantee	Total	Net benefit	% Net benefit
Citigroup	7.9	2.1	21.4	0.7	1.1	33.3	4.8	3.0	0.4	8.2	25.1	1.2%
Bank of America	4.4	2.2	4.2	0.1	0.3	11.3	1.2	0.2	0.0	1.4	9.8	0.5%
JP Morgan Chase	−33.6	0.4	3.6	0.2	0.2	−29.4	1.8	0.6	0.3	2.7	−32.1	−1.4%
Wachovia	−2.7	0.3	7.5	0.1	0.7	5.9	0.7	0.2	0.0	0.9	5.0	0.7%
Wells Fargo	−0.5	0.1	1.6	0.0	0.2	1.3	1.5	0.0	0.0	1.5	−0.1	0.0%
Bank of NY Mellon	3.3	0.0			0.0	3.3	0.1		0.0	0.1	3.3	1.2%
State Street Corp	2.4	0.0			0.0	2.4	0.0		0.0	0.0	2.4	0.8%
Goldman Sachs	7.9	0.1	17.6	1.3	0.0	27.0	0.1	3.5	0.0	3.6	23.3	2.1%
Morgan Stanley	11.0	0.3	51.6	2.4	0.8	66.0	1.4	2.1	0.0	3.5	62.5	6.4%
Merrill Lynch	−2.8	1.2	13.0	0.5	0.4	12.3	1.7	1.3	0.0	2.9	9.4	1.1%
Total (pessimistic case)	−2.8	6.7	120.5	5.3	3.7	133.3	35.8	10.8	0.7	47.3	86.0	0.8%
Total (oversight panel)	−2.8	6.7	120.5	5.3	3.7	133.3	28.4	10.8	0.7	39.9	93.4	0.8%
Total (optimistic case)	−2.8	6.7	120.5	5.3	3.7	133.3	13.2	10.8	0.7	24.8	108.6	1.0%
Without Morgan Stanley												
Total (pessimistic case)	−13.8	6.4	68.9	2.9	2.9	67.3	32.7	8.7	0.7	42.2	25.2	0.2%
Total (oversight panel)	−13.8	6.4	68.9	2.9	2.9	67.3	24.2	8.7	0.7	33.6	33.7	0.3%
Total (optimistic case)	−13.8	6.4	68.9	2.9	2.9	67.3	11.8	8.7	0.7	21.3	46.1	0.4%

shareholders will pay dividends so as to eliminate any gain for the government.

In both cases we value the warrants by using the implied volatility from at-the-money call options with the longest maturity available. The implied volatility is also reported in Table 2, Panel B.[14] In neither case do we price in the option banks have to buy back the warrant at an agreed "fair market" price. In so doing we are overestimating the value of the warrant received by the government, since we are not pricing in the likely discount the government will grant when the banks want to buy the warrants back.[15]

Table 6, Panel A, which contains the most optimistic estimates of the value of the government's claim, estimates the value of the preferred at $101 bn and the value of the 15% of warrants at $10.5 bn, for a total value of $112 bn. By contrast, Panel B, which contains the most conservative estimates of the value of the government's claim, values the preferred at $82 bn and the value of the 15% of warrants at $7 bn, for a total value of $89 bn. Hence, depending on the estimates, the preferred equity infusion cost taxpayers between $13 and $36 bn.

Finally, we price these warrants assuming a constant volatility. With jumps and stochastic volatility, these long-maturity warrants could be substantially more valuable. Since this will only reduce the cost of the government intervention, it would only increase the size of the value created by the plan.[16]

The total values of the securities in Table 6 can be compared with the results of the February Oversight Report from the Congressional Oversight Panel, released on February 6, 2009. The international valuation firm Duff & Phelps was retained by the US government to assess the fair valuation of the securities obtained in exchange for the capital infusion. Although not all banks we analyze were included in the report, we can assess the difference in valuation on the common set of firms. Citigroup: $15.5 bn; Bank of America: $12.5 bn; JP Morgan Chase $20.6 bn; Wells Fargo plus Wachovia: $23.2 bn; Goldman Sachs: $7.5 bn; Morgan Stanley: $5.8 bn. These values

[14] The value of American options, both for exchange-traded and the warrants, is computed through a standard finite difference method.

[15] According to several reports (e.g. Beals, 2009), in several instances the government has been too accommodating. For example, Old National, the first one to repurchase the warrants, bought back warrants over $15 m-worth of shares for $1.2 m (Beals, 2009).

[16] On December 10, 2009, the warrants of JP Morgan were auctioned off. This provides us with a market test of our model. For this reason, we recomputed the model used in Table 6, Panel A with the data as of December 10, obtaining a value of the warrant equal to $944 million, which is higher than (but very close to) the valued fetched in the marketplace ($936 million).

Table 6
Shareholders' net gain from the government's equity infusion.

This table provides two estimates of the present value of the claims the government is receiving in exchange for the equity infusion. In Panel A the present value of the preferred is computed using the yield to maturity of the bonds and the warrant is assumed to have a maturity of ten years. In Panel B the present value of the preferred is computed using the CAPM beta, while the warrant is assumed to have an effective maturity of three years since it is not protected against the payment of dividend after that date. Finally, the Congressional Oversight Report provided valuation of the same claims for all of our banks, except Merrill Lynch, Bank of NY Mellon and State Street. We impute their values using the average difference between our valuation the Report valuation for the common set of banks. In addition, Wachovia and Wells Fargo are reported jointly in the Report, and we split their values according to the equity infusion percentage in the second column.

Panel A: Optimistic

	Our calculations					Congr. oversight report	
	Equity infusion	Theoretical value of preferred	Theoretical value of warrant	Total theoretical value claim	Difference	Total theoretical value claim	Difference
Citigroup	25	18.1	2.0	20.2	4.8	15.5	9.5
Bank of America	15	12.7	1.1	13.8	1.2	12.5	2.5
JP Morgan Chase	25	21.2	2.0	23.2	1.8	20.6	4.4
Wachovia	5	3.8	0.5	4.3	0.7	4.6	0.4
Wells Fargo	20	17.0	1.5	18.5	1.5	18.6	1.4
Bank of NY Mellon	3	2.6	0.3	2.9	0.1	2.6	0.4
State Street Corp	2	1.8	0.2	2.0	0.0	1.8	0.2
Goldman Sachs	10	8.9	1.0	9.9	0.1	7.5	2.5
Morgan Stanley	10	7.7	1.0	8.6	1.4	5.8	4.2
Merrill Lynch	10	7.5	0.8	8.3	1.7	7.2	2.8
Total	125.0	101.3	10.5	111.8	13.2	96.6	28.4

Panel B: Pessimistic

	Our calculations					Minimum between pessimistic and congr. oversight report	
	Equity infusion	Theoretical value of preferred	Theoretical value of warrant	Total theoretical value claim	Difference	Value claim	Difference
Citigroup	25	16.5	1.5	18.0	7.0	15.5	9.5
Bank of America	15	9.6	0.9	10.5	4.5	10.5	4.5
JP Morgan Chase	25	17.3	1.3	18.6	6.4	18.6	6.4
Wachovia	5	1.9	0.3	2.2	2.8	2.2	2.8
Wells Fargo	20	14.0	1.0	15.0	5.0	15.0	5.0
Bank of NY Mellon	3	2.0	0.2	2.3	0.7	2.3	0.7
State Street Corp	2	1.4	0.1	1.5	0.5	1.5	0.5
Goldman Sachs	10	7.2	0.6	7.9	2.1	7.5	2.5
Morgan Stanley	10	6.2	0.7	6.9	3.1	5.8	4.2
Merrill Lynch	10	5.8	0.6	6.4	3.6	6.4	3.6
Total	125.0	81.9	7.3	89.2	35.8	85.3	39.7

Table 7
Cost of the bank debt guarantee provided by the FDIC.

The CDS rates, in basis points, are for a three-year contract and are obtained from Datastream. All the balance sheet information is as of 09/30/08, apart from Goldman Sachs and Merrill Lynch whose values are as of 08/31/08. The total debt guaranteed is 125% of the short-term unsecured debt. The total cost of the Government guarantee is discounted value of the difference between the value of this guarantee (CDS rate times the value of the debt guaranteed) minus the cost to the banks (75 basis points times the value of the debt guarantee) over the period of the guarantee (the next three years). All values in billions of US$, exception made for the CDS rates.

	Debt insurance				Deposit insurance		
	Unsecured short-term debt	Three-year CDS spread 10/14/2008	Total guaranteed debt	Total cost of insurance	Uninsured non-int. bearing deposits	Total cost of insurance	Savings from deposit guarantee
Citigroup	101.9	155.9	127.3	3.0	56.8	0.39	1.1
Bank of America	145.8	79.1	182.3	0.2	75.9	0.03	0.3
JP Morgan Chase	222.3	82.3	277.9	0.6	127.1	0.28	0.2
Wachovia	12.7	117.3	15.9	0.2	19.1	0.00	0.7
Wells Fargo	60.8	74.1	76.0	0.0	32.1	0.00	0.2
Bank of NY Mellon	2.9		3.6				
State Street Corp	4.3		5.4				
Goldman Sachs	64.7	227.7	80.9	3.5	0.0	0.00	0.0
Morgan Stanley	14.2	490.3	17.8	2.1	0.0	0.00	0.8
Merrill Lynch	25.7	213.5	32.1	1.3	0.0	0.00	0.4
Total	655.3		819.1	10.8	310.8	0.7	3.7

mostly fit between our optimistic and pessimistic case, except for Citigroup and the two investment banks, whose values are even below our pessimistic estimates. Substituting these values into our optimistic case leads to a total cost of $28.4 bn, while substituting them into our pessimistic case leads to a total cost of $39.7 bn. These findings lend support to our pricing methodology.

4.2. Cost of the debt guarantee

The FDIC offered a government guarantee to all new issues of unsecured bank debt until June 2009 for three years.[17] To measure the ex ante cost of this guarantee, we will make use once again of the CDS rates, albeit this time the three-year maturity CDS since the guarantee is a three-year one.

Thanks to this FDIC guarantee, the nine (plus one) banks can issue unsecured debt guaranteed by the government. Thus, it is as if they save the cost of insuring their own new debt issues for three years. The rate the FDIC charges for this is 75 basis points. Since this guarantee is limited to 125% of the existing unsecured short-term debt plus the long-term debt maturing up to June 2009, in Table 7, we compute the maximum amount of guaranteed debt that can be issued and multiply it by CDS rates minus the 75 basis points. This is the annual cost, which discounted over the three years using the Treasury discount curve leads to $11 bn. The biggest beneficiaries of this guarantee are Goldman Sachs, $3.5 bn; Citigroup $3 bn; and Morgan Stanley $2.1 bn.

Some might argue that this is a hypothetical cost. If none of these banks fail, the realized cost of this guarantee will be zero (in fact, negative, since the banks pay a fee to insure themselves). Yet, if an option ends up expiring out-of-the-money, it does not imply that the ex ante value of that option is zero nor that the firm underwriting it does not pay any cost. In fact, our Value-at-Risk calculation in Section 6 shows it is quite likely the government will be called to guarantee the debt of some banks.

4.3. The cost of the extended guarantee on uninsured transactional accounts

For completeness, we try to calculate the value of the extended insurance on the non-interest-bearing accounts. To estimate the amount of non-interest-bearing accounts that were uninsured as of October 12, we take the total amount of non-interest-bearing accounts as of September 30, 2008 from the call report and multiply it by the percentage of uninsured deposits (also from the call report). This amount is reported in column 5 of Table 7.

As is well-known from the work of Merton (1977), the FDIC deposit guarantee can be considered a put option on the asset of the firm, and thus, its value can be computed from the (modified) Merton model discussed in Appendix B

[17] In an earlier version of the paper, we assumed that the guarantee was for all the new issues of debt and not just the unsecured component. This makes an enormous difference, especially for the investment banks for which most of the short-term debt is secured. A careful reading of the Temporary Liquidity Guarantee Program (http://www.fdic.gov/news/board/08BODtlgp.pdf) confirmed that the guarantee was extended only to unsecured new debt issued.

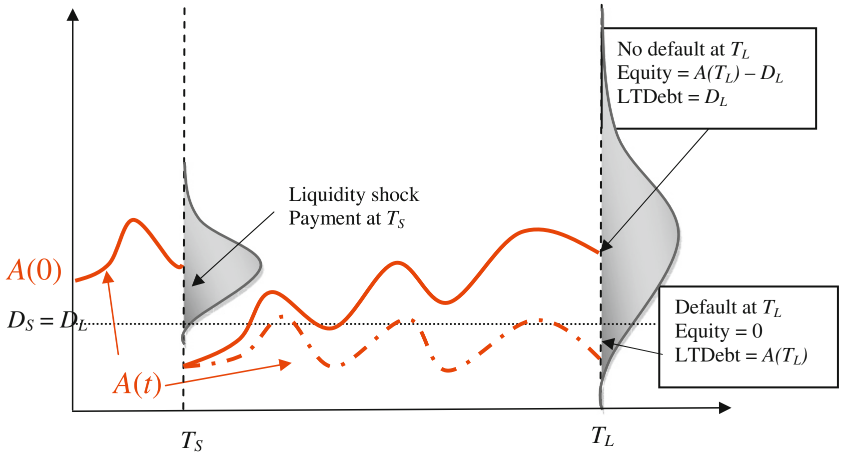

Fig. 3. An illustration of the model. Assets $A(t)$ move over time. At T_S there is the rollover of short-term debt and deposits. However, at this time, there is also a probability p of a liquidity shock, which reduces the value of assets by x, that is, if the liquidity shock hits then $A(T_S)=xA(T_S-)$. If at $T_S A(T_S) < D_S$, there is default at T_S. In this case, equity and long-term debt holders are wiped out, while short-term bond holders receive $A(T_S)$. If $A(T_S) > D_S$, assets $A(t)$ evolve according to a lognormal model until T_L. At T_L, default occurs if $A(T_L) < D_L$. In the computations we further divide the short-term debt in deposits, while long-term debt include also other liabilities.

and illustrated in Fig. 3. In this model, we assume that banks can either default in a short period, T_S=3 month, when it rolls over its short-term debt (and deposits), or much later, when long-term debt matures. At time T_S the firm may also be hit by a liquidity shock, with probability p, which makes its asset value drop to x% of its pre-shock value. This assumption allows us to obtain a calibration of the model that is able to match both the short-term and the long-term CDS rates. We calibrate the model CDS rates, equity value, and return volatility to the data on October 10, 2008, before the announcement, using the procedure described in Appendix B, which also contains more details of the model. To be conservative, however, we consider the value of the put option on October 14, 2008, after the government announcement, so that we take into account the resulting higher value of assets and lower probability of default. To control for other confounding news between October 10 and 14, 2008, we exploit the estimation results in Sections 3.1 and 3.2, and use the adjusted value of equity and debt in the calibration for the latter date. Given the calibrated values of the (modified) Merton model, we can compute the value of the FDIC deposit guarantee put option.

The estimated value of this put option for the additional debt insured is reported in column 6 of Table 7. The amounts are very small. The biggest beneficiary is Citigroup with \$390 million. Overall, the total cost of this guarantee is \$0.7 bn.

4.4. *The savings on the FDIC put option on commercial banks*

One qualification to the previous calculations is that the government intervention, both the preferred equity infusion and the FDIC guarantee on debt, will decrease the value of the FDIC guarantee on deposits. This is an implicit gain for the government. We resort to our structural model in order to compute the change in value of this put option.

We calibrate the (modified) Merton model to both equity and debt (CDS) data before and after the government announcement, i.e., October 10 and October 14, 2008, respectively, as explained above. Given the calibrated models, we compute the value of the put options on these two dates, and then calculate the difference. The result is in the last column of Table 7, which shows a small effect on the value of the put option. The reason is that in order to match short-term CDS rates, on both dates the model implies small probabilities of default, but large decreases in asset value in case of default. The increase in asset values and the decrease in the probability of default are small compared to the losses in case of a liquidity shock. Thus, the change in value of put options is small as well.

4.5. *Aggregate analysis*

Table 5 summarizes the overall effects of the Revised Paulson Plan. As stated in Section 3, the plan increased the value of banks' financial claims by \$128 bn. If we add the \$3.7 bn of reduction in the cost of the FDIC deposit insurance, the total value increase amounts to \$131.5 bn. This goal was achieved at a cost that in the more optimistic valuation is \$25 bn and in the less optimistic one \$47 bn, with a net effect between \$84 and \$107 bn.

These estimates are obtained attributing all the gains of Morgan Stanley to the Paulson Plan. If we exclude Morgan Stanley from the analysis, the value increase is only \$66 bn, with a cost between \$21–\$42, with a net benefit oscillating between \$24 and \$45 bn. Where does this value come from? We try to answer this question in Section 4.7. Before doing so, however, we check the robustness of our results to different assumptions.

One possible objection to interpreting the large gain in market value as value creation is that this might represent the market anticipation of future transfers of taxpayers' money to the banking sector. While possible, we regard this possibility as unlikely. Given the opposition that TARP

Table 8
Summary of robustness check results.

This table reports the final aggregate results from numerous robustness checks. Each column reports the final net benefit of the government intervention from Table 5. The four cases correspond to the four assumptions we made in the calculations, namely optimistic/pessimistic in terms of the valuation of the securities the US government received in exchange of the capital infusion (see Table 6) and with or without Morgan Stanley, whose price moved also because of the announcement of a capital infusion from Mitsubishi. Each row reports the parameter we changed compared to the base case, reported in the first row.

	With Morgan Stanley Oversight			W/o Morgan Stanley Oversight		
	Pessimistic	Report	Optimistic	Pessimistic	Report	Optimistic
Base case	86.0	93.4	108.6	25.2	33.7	46.1
CDS recovery 0%	93.7	101.1	116.3	28.6	37.2	49.5
CDS recovery 40%	75.0	82.5	97.6	20.1	28.7	41.0
LIBOR discount	84.2	91.6	106.8	23.8	32.4	44.7
Control by CDX	97.5	105.0	120.1	33.8	42.4	54.7
Beta-2 St. Err	96.3	103.8	118.9	35.3	43.9	56.2
Beta+2 St. Err	77.0	84.5	99.6	16.4	25.0	37.3
100% Derivative exposure	107.8	115.2	130.3	37.5	46.1	58.4
50% Derivative exposure	94.6	102.0	117.2	30.2	38.8	51.1
30% Deadweight cost of tax	72.7	82.4	91.0	13.4	35.6	40.6
54% Deadweight cost of tax	63.4	74.5	86.2	5.1	29.0	36.5
Average	86.2	94.2	108.4	24.5	35.7	46.9

encountered in Congress it is hard to imagine additional funds for banks. Furthermore, the cost of more bailouts should have been reflected in higher US government CDS rates, while these dropped during the Columbus Day-weekend.

Another objection is that the rescue represented a redistribution of value from other banks, who would have acquired the assets of distressed banks at lower prices, to the rescued banks. The negative return of JP Morgan is suggestive in this sense. To exclude this possibility we computed the excess return of an ETF (KRE), which replicates the KBW Regional Banking index, during this long weekend. That the excess return is positive (+4%) is inconsistent with this alternative interpretation.

4.6. Robustness

In this section we investigate the robustness of our conclusions to some key alternative hypotheses about the underlying quantities. More robustness is presented in Appendix C.

The summary results are contained in Table 8, which reports only the final aggregate values in the last column of Table 5, for six cases: pessimistic, oversight report, optimistic scenarios, and with and without Morgan Stanley. For instance, the first row of Table 8, the base case, shows the same results reported in the second to last column of Table 5. Each subsequent row contains the estimates of the value added in the six scenarios when one hypothesis is changed (explained in the first column) from the base case.

4.6.1. CDX as control

A reasonable concern about our control is that during the event window, General Electric Capital may have been affected by the expectation that it will eventually be included in the Plan or by its own idiosyncratic shock. Therefore, as a robustness check we use the CDX index as a control. The CDX index represents the cost of insurance against default on a diversified portfolio of 125 firms. In particular, the insurance buyer pays a quarterly premium during the life of the insurance, and in exchange it receives from the insurance seller the notional minus recovery amount anytime any of the underlying names defaults.

There are two complications on performing the adjustment in expression (4): the first is that CDX quotes are only available for five-year contracts. We therefore assume that CDX quotes are constant across maturities. The second complication is that we do not have the outstanding debt for the referenced entity (the 125 names in the index). To circumvent this problem we proceed as follows: for each bank i we first compute the present value of insurance costs (formula (5)) using the CDX index, which we denote by $PV^i(CDX)$. We then use expression (4) with $PV^{GE}(CDS)$ substituted by $PV^i(CDX)$ to compute the adjusted change in the value of the bonds. The resulting ratio $\Delta PV^i(CDX)/PV^i_0(CDX)$ provides the percentage change in the value of firm i debt were the CDX its insurance premium, instead of CDS^i. The results are again similar. In particular, the range of value created is between \$98 and \$120 bn (\$34 and \$55 bn without Morgan Stanley).

4.6.2. Full exposure derivatives net positions

As an additional check, we consider the case in which in aggregate security dealers bear the full credit risk exposure in their derivative net positions. This is clearly an overstatement, as most of these transactions are between them, and not with respect to other counterparties. Still, it is informative to see how important this exposure is in our calculations. We find that accounting for the full net derivative liabilities, the range of value created is between \$108 and \$119 bn (\$38 and \$58 bn without Morgan Stanley), while a 50% exposure leads to a range of \$95–\$106 bn (\$30–\$51 bn without Morgan Stanley). Again, our major conclusions remain.

4.7. Some evidence on the sources of the costs and benefits of the plan

Where does the value increase come from? One possibility is that the capital infusion and the renewed access to funds enables banks to take advantage of the positive net present value lending opportunities. Yet, we know from Ivashina and Scharfstein (to appear) that the discretionary lending of the major banks went down, not up during this period. Of course, one could argue that in the absence of the intervention the positive NVP lending would have dropped even further. Unfortunately, since this counterfactual is difficult to pin down, this proposition seems untestable.

By contrast, it is possible to test, albeit with very few observations, the proposition that the value created arises from the reduction of the risk of a bank run. As described in Section 2.2, we can construct an index of the probability of a bank run by looking at the difference between the probability of bankruptcy over the next year and over the following one, conditional on not going bankrupt this year. In Fig. 4A we plot the net percentage gain produced by the Paulson Plan on the index of the probability of a bank run. As we can see, the observations lay on almost a straight line (a linear regression has an R-squared of 92%). Note that there is nothing mechanical about this relationship. The explanatory variable is a difference between probabilities of bankruptcy embedded in CDS rates as of October 10, 2008, while the dependent variable is a relative increase in enterprise value, where the adjusted change in CDS rates from October 10 to 14, 2008 plays a role. The data seem to confirm that the banks more at risk of a run gained the most during this period.

In Fig. 4B we repeat the same exercise with the difference that the explanatory variable is a bank's past performance (measured as stock return from July 1, 2007

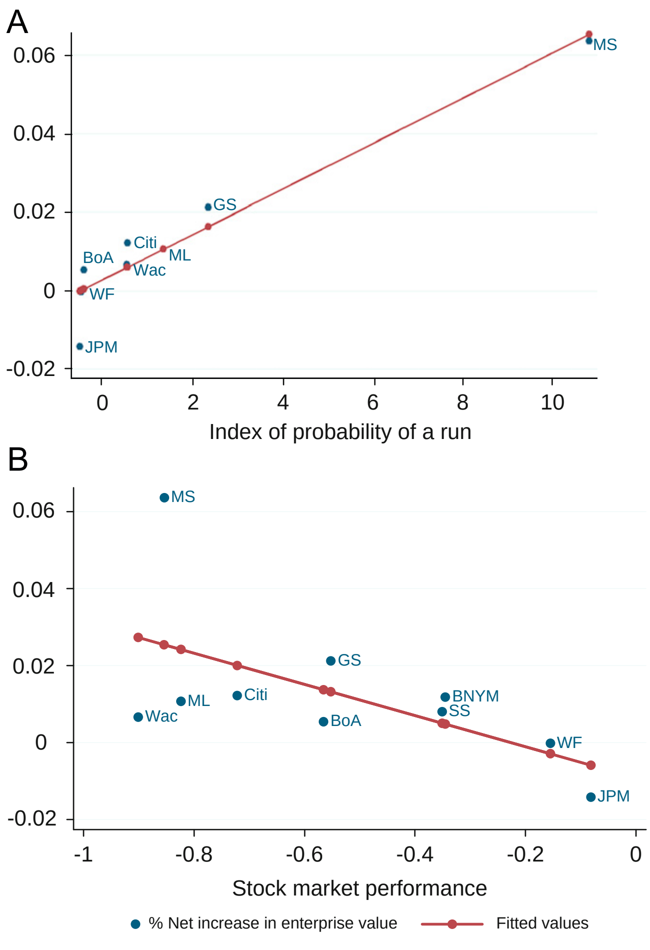

Fig. 4. Predicting the size of the net value increase. (A) plots the net percentage value increase at the announcement of the plan on the run index, i.e. the difference in the probability of default embedded in the one-year CDS rates and in the three-year CDS rates before the announcement. (B) plots the net percentage value increase at the announcement of the plan on the equity market performance of the corresponding stock during the crisis, i.e. from 7/1/07 to 10/10/08 ((A) % net increase in enterprise value on probability of run and (B) % net increase in enterprise value on previous stock market). BoA=Bank of America, Citi=Citigroup, GS=Goldman Sachs, JPM=JPMorgan, ML=Merrill Lynch, MS=Morgan Stanley, Wac=Wachovia, WF=Wells Fargo.

Table 9
Implied estimates of the cost of bankruptcy.

This table estimates the value of bankruptcy costs implicit in the market response to the Revised Paulson Plan. The first two columns report the total enterprise value (book value of debt and preferred plus market value of common equity) and the change in the market value of each of the banks involved in the Paulson Plan (all values are in billions of US$). The third and fourth columns report the risk neutral probability of bankruptcy embedded in the CDS rates before and after the announcement. Columns five and six report the implicit estimate of the bankruptcy costs calculated according to formula (8) in the text.

	Enterprise value	Change in enterprise value	Prob of default 10-October	Prob of default 14-October	Estimated bankruptcy	
					Costs bn $	Costs %
Citigroup	2,026	25	5.08	2.16	150	7.4%
Bank of America	1,803	10	1.43	0.76	101	5.6%
JP Morgan Chase	2,257	−32	1.42	0.77		
Wachovia	735	5	4.05	1.66	35	4.8%
Wells Fargo	672	0	1.45	0.69		
Bank of NY Mellon	280	3				
State Street Corp	297	2				
Goldman Sachs	1,089	23	9.74	3.72	94	8.7%
Morgan Stanley	976	62	30.33	8.26	163	16.7%
Merrill Lynch	867	9	7.69	3.26	66	7.6%
Total	11,002					
Recovery rate	0.2					
Discount rate	0.1					

to October 10, 2008. Even in this case we obtain a very high fit, where the banks that performed the worst gained the most. Performance during this period, however, is highly correlated with the probability of a bank run at the end of the period. When we run a regression with both, only the probability of a bank run remains significant.

Reducing the probability of a run implies reducing the probability that a firm will face the direct and indirect costs of bankruptcy. Given our estimates of the gain and of the changes in the probability of bankruptcy, we can verify whether the costs of bankruptcy implicit in our estimates are reasonable.

The value of any firm can be written as the discounted value of the future cash flow (CF_t) of a 100% equity-financed firm minus the expected value of the future bankruptcy costs:[18]

$$V=\frac{CF_1-p_1BC}{1+r}+\frac{CF_2-p_2(1-p_1)BC}{(1+r)^2}+\frac{CF_3-p_3(1-p_1)(1-p_2)BC}{(1+r)^3}+\cdots,$$

where we have assumed that the probability of bankruptcy p_i is independent from period to period. If, in addition, we assume that the probability of bankruptcy is constant after year five, we can rewrite this expression as

$$V=\sum_{t=0}^{\infty}\frac{CF_t}{(1+r)^t}+BC\left[\frac{p_1}{1+r}+\frac{p_2(1-p_1)}{(1+r)^2}+\frac{p_3(1-p_1)(1-p_2)}{(1+r)^3}+\frac{p_4(1-p_1)(1-p_2)(1-p_3)}{(1+r)^4}+\frac{p_5(1-p_1)(1-p_2)(1-p_3)(1-p_4)}{(1+r)^5}+\frac{\frac{p_5}{r+p_5}}{(1+r)^5}\right].$$

Under the (strong) assumptions that the announcement of the Paulson Plan does not alter the future cash-flow values and does not change the bankruptcy costs (but only the probability of bankruptcy), we can infer the cost of bankruptcy from the changes in the enterprise value before and after the announcement of the Paulson Plan as[19]

$$BC=\frac{\Delta V}{\Delta p}, \tag{8}$$

where ΔV is the change in the enterprise value at the announcement and

$$\begin{aligned}\Delta p=&\left[\frac{p_1^0}{1+r}+\frac{p_2^0(1-p_1^0)}{(1+r)^2}+\frac{p_3^0(1-p_1^0)(1-p_2^0)}{(1+r)^3}+\frac{p_4^0(1-p_1^0)(1-p_2^0)(1-p_3^0)}{(1+r)^4}+\frac{p_5^0(1-p_1^0)(1-p_2^0)(1-p_3^0)(1-p_4^0)}{(1+r)^5}+\frac{\frac{p_5^0}{r+p_5^0}}{(1+r)^5}\right]\\&-\left[\frac{p_1^1}{1+r}+\frac{p_2^1(1-p_1^1)}{(1+r)^2}+\frac{p_3^1(1-p_1^1)(1-p_2^1)}{(1+r)^3}+\frac{p_4^1(1-p_1^1)(1-p_2^1)(1-p_3^1)}{(1+r)^4}+\frac{p_5^1(1-p_1^1)(1-p_2^1)(1-p_3^1)(1-p_4^1)}{(1+r)^5}+\frac{\frac{p_5^1}{r+p_5^1}}{(1+r)^5}\right],\end{aligned}$$

where p_t^0 is the (risk-neutral) probability of bankruptcy in year t embedded in the CDS rates before the announcement of the Paulson Plan and p_t^1 is the same probability after the announcement.

[18] Nothing prevents the bankruptcy cost to be so large as to wipe out all the future cash flow. Hence, this formulation does not imply that the firm will necessarily survive after bankruptcy.

[19] In Section 5.5, we will provide some evidence that the cost of bankruptcy conditional on entering bankruptcy does not change much during the event windows.

Table 9 reports such estimates. The inferred bankruptcy costs oscillate between \$34 and \$164 bn, corresponding to between 5% and 17% of the enterprise value. These estimates seem reasonable, but decisively on the low side. Cutler and Summers (1988) estimate the cost of financial distress to be over 30% of the combined market value of Texaco and Pennzoil. Opler and Titman (1994) find that financially distressed firms lose 26% of their sales, while Andrade and Kaplan (1998), who study the cost of financial distress for firms that underwent a leveraged buyout (and so are likely not to have very high cost of financial distress), estimate it to be between 10% and 20% of firm value. Finally, Korteweg (2007) finds that the cost of financial distress in bankruptcy is, on average, 30% of firm value, albeit he finds that it is -14% in the banking industry.

One possible reason for such low estimates is that the assumption of invariance of cash flow at the announcement is false. In fact, government intervention per se (without any cost of financial distress) might be bad news for future cash flow. If we drop the invariance of cash flow, we can write the percentage change in enterprise value at the announcement of the plan as

$$\frac{V^1-V^0}{V^0} = \frac{\sum_{t=0}^{\infty}(CF_t^1/((1+r)^t)) - \sum_{t=0}^{\infty} CF_t^0/((1+r)^t)}{\sum_{t=0}^{\infty} CF_t/(1+r)^t)} + BC\Delta p.$$

Since Δp varies from company to company, if we regress the percentage change in enterprise value at the announcement on a constant and Δp, we obtain

$$\frac{V^1-V^0}{V^0}_i = -0.025^{***} + 0.22^{***}\Delta p_i.$$

These estimates suggest that the cost of government intervention (which reduces the ordinary cash flow independent of the probability of bankruptcy) is equal to 2.5% of the enterprise value, while the potential cost of bankruptcy is 22% of the enterprise value. These estimates appear quite reasonable and can potentially be used in the future to estimate the benefit of a government rescue of a bank.

5. The ex ante effects of the plan

Given the extreme volatility of markets during this period, it is legitimate to ask whether our estimates represent a fair assessment of the ex ante costs and benefits of the Revised Paulson Plan. For this reason, in this section we try to evaluate the plan on an ex ante basis, by using an extended version of the Merton (1974) model, where we introduce the risk of a liquidity shock/bank run. The goal of this section is twofold. On the one hand, to provide a reality check to the above results. On the other hand, to show that a simple extension of the Merton model can be used ex ante to provide accurate estimates of what the effects of various interventions will be.

5.1. The model

Since the seminal work of Black and Scholes (1973) and Merton (1974), it has been recognized that claims on a firm's assets, such as equity and debt, can be valued as options on the assets of the firm. To illustrate the logic in a simple setting, consider a bank (or a firm, more generally) with an amount $A(0)$ of assets at time zero. These assets are financed by short-term debt, long-term debt, or equity. Assume for simplicity that the principal on short-term debt and long-term debt is the same, $D_L=D_S$, and that debt carries no coupon payments. Finally, we let short-term debt be senior to long-term debt. The value of a bank's assets changes over time, due to cash inflows and outflows, as well as the willingness of market participants to purchase such assets. For instance, if some of these assets are mortgage-backed securities, then their market value may decrease in price if market participants expect higher mortgage defaults in the future.

In this simplified setting, consider the bank now at maturity of the short-term debt T_S. There are two possibilities: either the bank has a sufficient amount of assets to pay for these short-term liabilities or not. If the market value of the assets of the firm is below the principal of short-term debt D_S, the bank defaults. In this case, equity and long-term (LT) debt holders are wiped out and short-term debt holders seize the remaining assets $A(T_S)$. If assets are instead above the principal D_S, the bank pays for its short-term (ST) debt by liquidating some of its assets and proceeds on with its operations.

To take into account the possibility of a bank run or a liquidity shock, we assume that at time T_S there is probability p that the market value of assets drops to $x\%$ of its value before the shock. If $A(T_S)<D_S$, the bank defaults, equity and LT debt holders are wiped out and ST debt holders seize the remaining assets $A(T_S)$. If $A(T_S)>D_S$, the bank pays D_S and proceeds on with its operations.

At maturity of the long-term debt T_L, the situation is similar. If assets $A(T_L)$ are below the principal due at T_L, the bank defaults, equity holders receive nothing, and debt holders receive the assets $A(T_L)$. Conversely, if assets are sufficient to pay for the principal, debt holders receive their principal D_L back and equity holders obtain the remaining assets $A(T_L)-D_L$.

Fig. 3 illustrates these two scenarios: the two vertical dotted lines correspond to the maturities of the short-term and long-term debt. The solid curved line represents one hypothetical path of assets over time, while the shaded areas correspond to possible asset values at T_S and T_L from the perspective of a market participant at time zero. The solid curved line represents the case in which no default on long-term debt takes place, neither at T_S nor at T_L. In contrast, the dashed line that starts at T_S represents a hypothetical path leading to default of the bank: at T_L the bank does not have enough to pay in full its obligations to debt holders.

What is the value of debt and equity as of time zero, then? Using the option pricing methodology developed by Black and Scholes (1973) and Merton (1974), the value at time zero is the expected discounted value of the payoff at maturity, adjusted for risk. The only noteworthy point is to recall that the payoff at time T_L may be zero because default occurs at T_S. Appendix B contains more details on the model, as well a discussion on how we treat various forms of liabilities.

There are four unobservable entries in this model's formulas: the value of assets today $A(0)$, the volatility of

Table 10
Value transferred to long-term debt by equity infusion.

This table estimates the changes in the value of equity due only to the infusion of equity. The first two columns report the value in the model of long-term debt and equity before the equity infusion, columns 3 and 4 report the value of long-term debt and equity after the equity infusion reported in column 5. Columns 6 and 7 report the difference in the value of debt and equity as a result of the equity infusion. The last column reports what fraction of the equity infusion goes to increase the value of the long-term debt. All values in billions of US$, exception made for the fraction of equity infusion to debt.

	Value before equity infusion announc. LT		Value after equity infusion announc. LT		Amount of equity infusion	Difference LT		Fraction of equity infusion to debt
	Bonds	Equity	Bonds	Equity		Bonds	Equity	
Citigroup	346.3	86.4	355.7	101.7	25	9.4	15.3	0.38
Bank of America	240.1	116.0	243.4	127.6	15	3.3	11.6	0.22
JP Morgan Chase	244.8	0.5	249.1	181.2	25	4.2	180.7	0.17
Wachovia	163.9	17.0	166.4	19.5	5	2.5	2.5	0.49
Wells Fargo	103.0	94.3	105.6	111.7	20	2.6	17.3	0.13
Bank of NY Mellon								
State Street Corp								
Goldman Sachs	145.8	34.0	150.2	44.1	10	4.4	10.1	0.44
Morgan Stanley	122.8	18.3	129.6	13.3	10	6.8	-5.0	0.68
Merrill Lynch	198.9	78.3	203.7	34.7	10	4.8	-43.6	0.48
Total	1565.7	444.8	1603.7	633.8	125.0	38.0	189.1	0.29

assets σ_A, the probability of a liquidity shock p, and the loss in case of a shock x. We choose these quantities to match four observables: the market capitalization of each bank on October 10, 2008, the volatility of equity, as well as an estimate of market values of ST debt and LT debt on the same day. The estimated market value of debt is computed from CDS rates.[20] Table 2 reports the other data used in our estimations. In particular, for each bank this table reports the bank's capital structure – namely, the deposit amounts, short-term debt, long-term debt, etc. – as well as the firm market cap and equity volatility.

5.2. *The co-insurance effect*

Table 10 contains the results of the estimation. The first two columns report the estimated market value of long-term bonds and the firm market capitalization as of Friday, October 10, 2008. The next two columns report the same quantities after the $125 bn preferred equity infusion. In particular, the $125 bn preferred equity infusion increases the overall value of the equity of these ten banks by only $80 bn, reported in column 7.

This increase in the value of debt is exactly what is predicted by Myers (1977). When debt is risky, by definition there are several states of the world in which is not paid in full. An equity infusion provides a safety cushion to debt in those states of the world in which it would not have been paid in full. As a result, the value of risky debt goes up when new equity is raised. This transfer of value, which is also known in the literature as debt overhang or co-insurance effect, is what makes it so unattractive for equity holders to raise new equity.

Overall, the size of the transfer in favor of debt holders is $38 bn (see column 6), equal to 29% of the value of the money invested. However, the magnitude of this transfer varies across firms depending on the extent of their leverage and the volatility of their assets. It is highest (in relative terms) for Morgan Stanley (68%), Wachovia (49%), Merrill Lynch (48%), Goldman Sachs (44%), and Citigroup (38%). It is smaller for JP Morgan (17%), Bank of America (22%), and Wells Fargo (13%).

5.3. *Explaining the changes in the market value of debt*

Table 11 compares the model's prediction about the changes in market value of debt and equity to the actual changes in the market. All these calculations are made under the assumption that the overall asset value does not change. As we saw in Section 4.5, however, there is strong evidence that it did change. These model-based comparisons will lead to the same answer.

Table 11, Panel A shows that the model predicts an increase in the market value of debt equal to $49 bn: $38 bn coming from the value transfer from the preferred equity infusion and $11 bn from the FDIC debt guarantee (as computed in Section 4.2). This estimate falls $72 bn short of the actual increase, equal to $120 bn. This amount is hard to rationalize without assuming an increase in the value of assets. Even if we were to assume that the government intervention eliminates the risk of a liquidity crisis (and thus, in the model, we put the probability of a run at zero), we can explain only another $19 bn of value increase, still $52 bn short of the actual amount.

5.4. *Explaining the changes in the market value of equity*

We reach similar conclusions if we look at the impact of the plan on equity holders (Table 11, Panel B). The model

[20] It is worth pointing out that the CDS implied yields underestimate the true yield of bonds (see, e.g., Longstaff, Mithal, and Neis, 2005) and thus, we overestimate the value of debt in this case. We also computed the value of debt and implied transfers by treating the principal value as a zero coupon bond itself, thereby grossly underestimating the value of debt. The transfers from equity holders to debt holders were very similar.

Table 11
Explaining the changes in the market value of debt and equity.

This table confronts the changes in the value of debt (Panel A) and equity (Panel B) predicted by the model with the actual changes observed in the market place. The changes in the value of the debt should be the value transferred as a result of the equity infusion (first column) and of the debt guarantee (second column). The changes in the value of equity after the equity infusion is announced (but before it is executed) are the sum of the expected gain from the equity infusion due to the fact that the government pays more than what it receives (see Table 6) minus the transfer to the debt holders (Table 8). The next to the last column reports the fraction of the debt guarantee that does appear to have been absorbed by debt holders (last column of Panel A). The last column is the difference between the market value changes (column 4), the total predicted value changes (column 3) and the residual benefit of debt guarantee (column 5). All the figures are in billions of US$.

Panel A: Changes in the value of debt

	Market changes	Model transfer from equity	Net insurance benefits	Total	Difference	Eliminate liquidity shock	Difference
Citigroup	21.4	9.4	3.0	12.4	9.0	3.5	5.5
Bank of America	4.2	3.3	0.2	3.5	0.7	0.6	0.1
JP Morgan Chase	3.6	4.2	0.6	4.8	−1.2	0.7	−1.9
Wachovia	7.5	2.5	0.2	2.7	4.8	0.9	3.9
Wells Fargo	1.6	2.6	0.0	2.6	−1.0	0.3	−1.3
Bank of NY Mellon		0.0		0.0			
State Street Corp		0.0		0.0			
Goldman Sachs	17.6	4.4	3.5	7.9	9.7	2.8	6.9
Morgan Stanley	51.6	6.8	2.1	8.9	42.6	7.2	35.4
Merrill Lynch	13.0	4.8	1.3	6.1	6.9	3.0	3.9
Total	120.5	38.0	10.8	48.9	71.6	19.1	52.5

Panel B: Changes in the value of equity

	Change in market value	Net gain of equity		
		Net gain from equity infusion	Transfer to debt	Total
Citigroup	7.9	4.8	9.4	−4.6
Bank of America	4.4	1.2	3.3	−2.1
JP Morgan Chase	−33.6	1.8	4.2	−2.4
Wachovia	−2.7	0.7	2.5	−1.8
Wells Fargo	−0.5	1.5	2.6	−1.1
Bank of NY Mellon	3.3	0.1	0.0	0.1
State Street Corp	2.4	0.0	0.0	0.0
Goldman Sachs	7.9	0.1	4.4	−4.3
Morgan Stanley	11.0	1.4	6.8	−5.5
Merrill Lynch	−2.8	1.7	4.8	−3.2
Total	−2.8	13.2	38.0	−24.8

predicts a loss of $25 bn, the net result of a gain of $13 bn from the preferred equity infusion and a loss of $38 bn due to the value transferred to debt holders—see Panel A, column 2. The actual change is −2.8 bn, with a difference of $25 bn. We could argue that the equity captures some of the value provided by the FDIC debt guarantee. But even if the entire value were captured by equity, this would not explain the value increase (and would make explaining the increase in the value of debt even more difficult).

5.5. Inferring the changes in the value of assets from the model

If we maintain the value of the underlying assets constant, the model is unable to account for the observed changes in the value of debt and equity. This result could imply that the model does not fit the data well or that indeed, the value of the underlying assets has increased. To distinguish between these two hypotheses we calibrate the model twice, before the announcement (October 10, 2008) and after the announcement (October 14, 2008). As in Section 3.1 and 3.2, we control for news between the two dates by exploiting the estimation results in 3.1 and 3.2 and using the adjusted increase in equity and bond values for the calibration at the later date. Table 12 reports the results.

Several factors are worth mentioning. First, the model is able to mimic very well the change in the value of the underlying assets, with a mean squared error of only 5%. Second, the volatility of the underlying assets does not seem to have changed a lot over the long weekend, but the probability of a bank run did. Before the announcement of the plan, it was on average 1.4%, after the announcement it dropped to 0.9%. The biggest beneficiary was Morgan Stanley, for whom the probability of a run went from 5.7% to 3.2%. Finally, the model estimates that the recovery rate in case of a run did not change before and after the announcement. This validates the assumption we made in Section 4.7.

6. Valuations of alternative plans

Our analysis thus far shows that the Paulson Plan created substantial value (between $84 and $107 bn), but it did so redistributing between $25 and $47 bn from the

Table 12
Change in the value of assets implied by the model.

In the extended Merton (1974) model described in Appendix B, we choose the four unobservable variables (value of assets today $A(0)$, volatility of assets σA, probability of a liquidity shock p, and loss in case of a shock x) to match the four observables: the market capitalization of each bank, the volatility of equity, the estimated of market value of ST debt, and the estimated market value of LT debt. The estimated market value of debt is computed from CDS rates. The first four columns report the value estimated by using the October 10, 2008 data, while the second four columns report the value estimated by using the October 14, 2008 data. The next to the last column reports the difference between the value of assets estimated for each of the two days and the last column reports the change in the value of assets as derived in Table 5 (common equity, preferred equity, debt). All the $ figures are in billions of US$. The volatilities and the probabilities are in percentage terms. The recovery rate is the fraction of value recovered.

	Values estimated on 10/10/2008				Values estimated on 10/14/2008				Estimated changes in asset value	Actual changes in asset value
	Asset volatility	Asset value	Prob. of run	Recovery rate	Asset volatility	Asset value	Prob. of run	Recovery rate		
Citigroup	9.5	1,915	1.00	0.25	8.8	1,945	0.69	0.29	29.8	31.4
Bank of America	11.4	1,748	0.27	0.31	11.3	1,758	0.21	0.31	10.5	10.9
JP Morgan Chase	9.3	2,202	0.28	0.30	7.7	2,172	0.22	0.31	−30.0	−29.7
Wachovia	7.3	708	0.54	0.27	5.8	713	0.31	0.33	4.6	5.1
Wells Fargo	20.1	651	0.28	0.27	19.2	652	0.21	0.27	0.9	1.1
Bank of NY Mellon										
State Street Corp										
Goldman Sachs	8.0	999	1.91	0.23	7.2	1,024	1.25	0.26	24.6	25.6
Morgan Stanley	7.0	825	5.71	0.15	5.3	887	3.17	0.16	62.3	62.9
Merrill Lynch	7.8	803	1.50	0.24	6.2	813	1.04	0.28	10.3	11.4
Average	10.1		1.4	0.3	8.9		0.9	0.3		
Total		9,851				9,964			113	119

taxpayers to the nine largest banks. In this section, we analyze whether the same objective could have been achieved in a more cost effective way and/or in a less expensive way for the taxpayers.

6.1. Efficiency of the plan

Philippon and Schnabl (2009) analyze the trade-offs of different intervention strategies from a theoretical point of view. Here, we want to perform this analysis from an empirical point of view. This exercise is clearly speculative, since the counterfactuals are difficult to assess. Nevertheless, the extended Merton model we used has been very successful in matching the observed variations; thus, we feel reasonably confident to use it as a benchmark to evaluate the counterfactuals.

To evaluate these counterfactuals we need to impose one constraint and make one assumption. The constraint is that we only consider plans that achieve the same goal as the Paulson Plan. Since Paulson's Plan objective was to recapitalize the banking system so that the risk of default of a financial institution became sufficiently low, we evaluate alternative plans with the constraint that they reach this objective: i.e., a reduction in the CDS rates of each bank equivalent to the one observed in the data (see Table 3). Since there are multiple CDS rates, depending on the maturity, we impose in particular that the alternative matches the drop in the one-year CDS rates, since these are the ones that indicate the imminent risk of a run, and the five-year CDS rates, which instead mainly depend on the current value of assets $A(0)$.

As in the event study, we want to consider the direct impact of the plan on CDS, and not the systemic effect. For this reason, Table 3 reports two declines in CDS rates: the actual decline and the adjusted decline, where the latter is adjusted for the decline in GE Capital CDS rates. Since we do not know whether the general decline, captured in the decline of GE Capital CDS rates, is due to the plan or to the other events, for completeness we consider two possibilities: that the plan achieves the adjusted decline in CDS or that the plan achieves the unadjusted decline in CDS. Clearly, the second hypothesis puts a much higher hurdle on the plan.

Conditional on achieving this objective, we rate the different plans along several dimensions, which are important both economically and politically: the investment required, the net cost, the value at risk, and the percentage of bank's equity capital the government will end up owning. The need to evaluate the amount of funds required separately from the net cost arises from two considerations. First, there are some political constraints on the amount of funds employed, regardless of whether they are invested or given away as subsidies, as shown by the fact that the entire debate on the original Paulson Plan (to buy distressed assets from banks) was about the amount of money invested, not on the actual cost for taxpayers of this investment. Second, the expected cost of debt guarantee does not appear in the government budget as a cost simply because of the way government accounting is done. Third, since large government losses may have disproportionate negative effects, we

Table 13
Cost of alternative plans.

This table measures the Revised Paulson Plan along five dimensions and compares it along these dimensions with four alternatives. The five dimensions are: the amount of funds required by the plan, the ex ante cost of the plan for taxpayers, the *statistical* value at risk for taxpayers (5% probability of a loss in three years under the actual probability), the *economic* value at risk for taxpayers (5% probability of a loss in three years under the risk neutral probability, which subsumes the fact that the costs of funds in certain states of the world is higher), and the percentage of ownership the Government would have acquired if it invested in straight equity. All the plans in Panel A are constrained to deliver a reduction in CDS rates at least as big as the adjusted decline reported in Table 3. All the plans in Panel B are constrained to deliver a reduction in CDS rates at least as big as the raw decline reported in Table 3. All the figures are in billions of US$.

Panel A: Target=adjusted reduction in CDS rates

	Revised Paulson Plan	Original Paulson Plan: asset purchase		Pure equity infusion	Long-term debt-for-equity swap
		No over-payment	20% over-payment		
Investment required	125	3,084	953	261	0
Net cost to taxpayers	49	0	191	65	0
5% Three-year statistical value at risk	97	123	47	189	0
5% Three-year economic value at risk	114	373	147	236	0
% of banks owned by government	20	0	0	40	0

Panel B: Target=raw reduction in CDS rates

	Revised Paulson Plan	Original Paulson Plan: asset purchase		Pure equity infusion	Long-term debt-for-equity swap
		No over-payment	20% over-payment		
Investment required	125	4,585	1,654	495	0
Net cost to taxpayers	49	0	331	139	0
5% Three-year statistical value at risk	93	197	86	341	0
5% Three-year economic value at risk	112	568	257	426	0
% of banks owned by government	20	0	0	52	0

calculate the value at risk. In fact, we use two definitions of Value-at-Risk (VaR). The first one is the standard statistical measure of the maximum dollar losses that the taxpayer will suffer over three years with 95% probability. This measure is informative as it can be directly compared with the (dollar) size of the investments. However, the statistical VaR measure does not reveal the marginal costs to the economy from such potential losses. If these losses occur during recessions, for instance, they have a marginal cost that is higher than in the case in which these losses occur during booms. A simple way to compute a risk measure for the government that takes into account the marginal costs of these losses is to compute the Value-at-Risk under the risk-neutral (or risk-adjusted) probabilities, which by construction weight the probability of each future state of nature by the proper state price density (marginal utility) of those states (see Ait-Sahalia and Lo, 2000). Because the state price density is implicit in the CDS rates we used in the calibration of the model, a VaR computed under risk-neutral probabilities takes implicitly into account the marginal cost of future losses. As in Ait-Sahalia and Lo (2000), we refer to this VaR number as Economic VaR. Finally, we compute the percentage ownership of the large banks acquired by the US government has both political and economic consequences in the short- and the long-run.

For comparison, in the first column of Table 13 we report the values of these criteria for the Revised Paulson Plan analyzed so far. The only two parameters we have not discussed yet are the two values at risk and the overall government ownership of banks. The statistical value at risk is just below $100 bn, while the economic one is slightly higher ($114 bn).[21] A more interesting dimension is the percentage of ownership acquired by the government. We compute this as the amount of money invested divided by the sum of the market capitalization of the common equity and the preferred equity before the plan is announced (i.e., the October 10, 2008) plus the amount of money invested. This is the fraction of equity the government should have taken, not necessarily what it will take since the warrant will be priced at the moment of the infusion. With this plan, the government would own on average 20% of the top ten banks, with a maximum of 48% ownership in Morgan Stanley.

[21] If we assume that the effect of the plan is to reduce not just the adjusted CDS, but also the raw CDS rates (Table 13, Panel B), the 5% VaR is slightly lower, because the initial value of the assets is higher, to match the higher value of debt. Appendix D elaborates on the methodologies we use to calculate the VaR under the various alternative plans.

We are now in the position to compare the Revised Paulson Plan with some alternatives. The first one we analyze is the original Paulson Plan, with no overpayment. The idea of this plan was to substitute risky assets of dubious value with assets of certain value (cash) on the banks' balance sheets. Even if these transactions occurred at market prices, this plan would have reduced the riskiness of banks' underlying assets and in so doing reduced their risk of default.

By using the model described above, we calculate that it would have been necessary to purchase $3.1 trillion of banks' assets to achieve the same adjusted drop in CDS rates achieved by the Revised Paulson Plan (see Table 13, Panel A). If we want to achieve the same unadjusted drop, we would need $4.6 trillion. This is clearly a theoretical exercise since purchases of this entity would certainly alter market prices. Nevertheless, it gives a sense of the order of magnitude of the intervention required to achieve the stated goal only with asset purchases. The magnitudes involved suggest that even if it were possible not to overpay for the assets, it would have been unfeasible to reach the objective with the money requested under TARP.

Since by definition these transactions are done at the fair value, the expected cost of this strategy is zero. Nevertheless, it subjects taxpayers to an enormous risk. In Panel A Table 13, the 5% statistical value at risk for this alternative is $123 bn, while the corresponding figure for the economic value at risk is $373 bn. This clearly shows the risk implicit in this strategy. The situation is even worse when we target the raw reduction in CDS rates (Panel B): the statistical value at risk is $197 bn, while the economic one $568 bn! The only advantage of this approach is that it does not require any government ownership of banks.

The second alternative plan we consider is a variation of the original Paulson Plan, with the difference that the government has an explicit mandate to overpay. We fix this overpayment at 20%. This overpayment could be the result of an explicit government decision or the result of a surge in prices due to the massive purchases made by the government under this plan.

In this case, the amount of investment needed decreases significantly: $953 billion if we target the adjusted reduction in CDS rates, and $1.7 trillion if we target the raw reduction. Note that the amount necessary to achieve the required reduction in adjusted CDS is similar to, but falls short of, the amount Secretary Paulson requested to buy toxic assets. This reduction in the funds needed comes at a high price for the taxpayers: they have to pay $191 bn up front. In addition to this cost, the statistical value at risk predicts a $47 bn additional loss in three years, while the economic value at risk $147 bn. Once again, one benefit of this approach is that the government does not end up owning any share in the banking sector. The only additional benefit of this strategy is reducing the amount of funds needed, at the cost of a very significant up-front cost for taxpayers: almost $200 bn.

The third hypothesis we consider is a pure equity infusion, with no debt guarantee. This is the proposal advanced by several economists (Diamond, Kaplan, Kashyap, Rajan, and Thaler, 2008; Stiglitz, 2008). If the goal is simply to achieve the adjusted reduction in the CDS rates, the preferred equity infusion achieves it at twice the upfront investment of the Revised Paulson Plan: $261 bn vs $125 bn. The cost of this option, $65 bn, is represented by the transfer in value from equity holders to debt holders that occurs when equity is injected in a very highly levered firm. We attribute this share to the government in proportion to the equity acquired at the price before the announcement. Clearly, the government could have imposed all these costs on the existing equity holders buying at a lower price, but this would have required a forced recapitalization, not a voluntary one. The VaR would also have been significantly higher than the Revised Paulson Plan: $189 bn for the statistical VaR and $236 bn for the economic one.

This approach would have had very adverse effects in terms of government ownership of banks. On average, the government would have ended up owning 40% of the top ten banks. This ownership would have been very unequally distributed. As Fig. 5 shows, the equity infusion plan will concentrate the investment in the three former investment banks and Citigroup. Such investment would have given the government 61% of Citigroup, 50% of Morgan Stanley, and 39% of Goldman Sachs. The scenario is worse if we want to target the raw reduction in CDS rates. In this case, the equity infusion required would be $495 bn, with a cost for the taxpayers of $139 bn and a government ownership of banks of 52% (Panel B of Table 13).

This analysis suggests that the original Paulson Plan not only would have been extremely costly for taxpayers, but it would have also been unfeasible in the terms proposed by Paulson. Even ignoring the fact that it would have been difficult to limit the purchase of assets from banks alone and assuming a generous overpayment (20%), the entire TARP money would not have been sufficient to rescue the ten largest banks alone. Had it been implemented, this plan would have exposed taxpayers to a significant amount of risk.

By contrast, the Revised Paulson Plan seems to perform the best, among the options considered at the time and analyzed by Philippon and Schnabl (2009). It has the lowest up-front investment need, the lowest up-front cost, and the lowest sum of the immediate cost plus VaR cost. This advantage stems from the cost effectiveness of the debt guarantee. A debt guarantee on unsecured debt provides the necessary access to funds in a crucial moment, making all the debt safer, while not guaranteeing it all. The only drawback of the Revised Paulson Plan vis-à-vis alternatives is the higher government ownership of banks it generates.

While the Revised Paulson plan performs best within this set of options, it is clearly dominated by a debt-for-equity swap along the lines proposed by Zingales (2008a, 2008b). The idea aims at eliminating the threat of default by converting long-term debt into equity. To protect the value of the existing equity holders, such a plan would grant them the option to buy back their claim from the old debt holders (now transformed into equity holders) at the face value of debt. The beauty of this scheme, first devised by Bebchuk (1988), is that it does not require any valuation

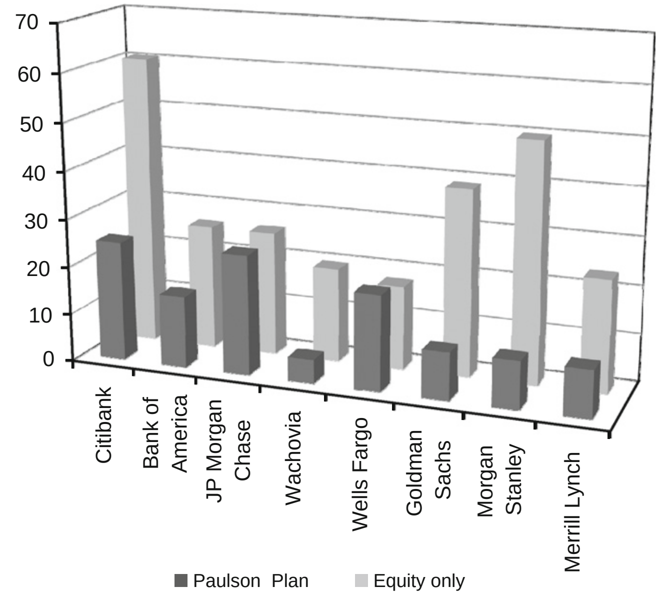

Fig. 5. Difference in equity infusion. This figure compares the equity infusion under the Revised Paulson Plan and the equity infusion needed to match the observed adjusted reduction in the CDS rates observed after the announcement of the Revised Paulson Plan (see Table 3). All the numbers are in billions.

Table 14
The Paulson Plan using the Warren Buffet terms.

This table measures what would have happened if the Revised Paulson Plan had been implemented by using the terms that Warren Buffett obtained from Goldman Sachs when he invested $5 billion on the 14th of September 2008. The first column reports the value of the perpetual preferred with a 10% coupon rate, which can be called back at any time at a 10% premium. The second and third columns report the value of the warrants under two assumptions: that they were issued with a strike price 8% below the price on 10/10/2008 and on 10/14/2008. The fourth and fifth columns report the sum of the packages the government would have obtained under the two hypotheses. Columns 6 and 7 report the ex ante gain the government would have obtained by applying the Warren Buffet terms, computed as the difference between the value of the package and the amount of the investment made. Columns 8 and 9 report the net gain captured by the government as a fraction of the net gain in enterprise value experienced by each company during the event window. Columns 10 and 11 do the same as a fraction of the net gain in equity value (common plus preferred) experienced by each company during the event window. "neg" means that the denominator was negative.

	Pref.	Warrant at 8% discount at		Total		Net gain		Net gain as fraction of change in enterprise value		Net gain as fraction of change in equity value	
		10/10	10/14	10/10	10/14	10/10	10/14	10/10	10/14	10/10	10/14
Citigroup	18.1	14.4	10.8	32.5	28.9	7.5	3.9	0.30	0.16	0.74	0.39
Bank of America	13.4	8.9	6.7	22.2	20.1	7.2	5.1	0.74	0.52	1.09	0.76
JP Morgan Chase	23.9	10.1	10.4	34.0	34.3	9.0	9.3	neg.	neg.	neg.	neg.
Wachovia	3.8	2.8	2.3	6.6	6.1	1.6	1.1	0.32	0.22	neg.	neg.
Wells Fargo	19.9	9.9	7.9	29.8	27.8	9.8	7.8	neg.	neg.	neg.	neg.
Bank of NY Mellon	2.8	2.6	1.9	5.4	4.7	2.4	1.7	0.72	0.52	0.72	0.52
State Street Corp	2.0	1.6	1.1	3.6	3.2	1.6	1.2	0.68	0.49	0.68	0.49
Goldman Sachs	10.0	7.5	5.2	17.5	15.2	7.5	5.2	0.32	0.22	0.94	0.65
Morgan Stanley	7.6	8.4	4.5	16.0	12.1	6.0	2.1	0.10	0.03	0.53	0.19
Merrill Lynch	7.5	4.7	4.1	12.2	11.6	2.2	1.6	0.23	0.17	neg.	neg.
Total	108.9	70.8	55.0	179.7	163.9	54.7	38.9				
Average								0.4	0.3	0.8	0.5

of the existing assets, which is the biggest problem any plan is facing given the uncertainty in the value of the underlying assets. Since this plan does not involve any government money, all the entries are obviously zero. We did compute, however, whether the conversion of the long-term debt would have been sufficient to achieve the stated goals. In fact, it is more than sufficient. Converting the long-term debt insures a dramatic drop of the CDS rates to 7–8 basis points, the level most banks had at the beginning of 2007. So this plan was economically feasible, but it would have required new legislation to be implemented (Swagel, 2009).

6.2. *Redistributive effects of the plan*

Even accepting the idea that the strategy used was the most cost-effective given the existing legal constraints, we need to explain why the government left so much money on the table: not only did the government not capture any of the value increase it generated, but it also subsidized it with a gift estimated between \$21 and \$44 bn. Could the government have done better? Only three weeks before, when Warren Buffett invested in Goldman Sachs, he obtained much better terms: a 10% coupon on the preferred and a warrant with a strike price 8% below the closing price before the announcement (not a 5% coupon and a warrant with a strike price at the market price after the announcement of the injection) (Craig, Karnitscnig, and Lucchetti, 2008). In Table 14 we report what the cost for the various banks would have been if the Treasury had applied the Warren Buffett terms to all ten banks.[22] Given the huge surge in absolute (not just market-adjusted) prices that took place at the announcement of the plan, we consider two hypotheses: a warrant with a strike price 8% below the market price of October 10 and a warrant with a strike price 8% below the market price of October 14. Columns 6 and 7 of Table 14 report the net gain the government would have obtained had it asked for the same terms as Warren Buffett. Columns 8 and 9 relate this gain to the increase in enterprise value experienced by each company as a result of the plan (Table 5, column 6). Except for JP Morgan and Wells Fargo (where the gain was negative), the government would have captured between 30% and 40% of the gain (i.e., between \$39 and \$55 bn), instead of losing between \$21 bn and \$44 billion. The relevant question, though, is whether all the banks would have accepted these terms.

To answer this question, a more relevant comparison is with the gain experienced by equity holders. Since the claims offered to the government are junior with respect to debt, the gain captured by the government would have been mostly at the expense of equity holders.[23] As columns 10 and 11 show, four out of ten experienced a negative change in the value of equity (adjusted for market movements). For the rest, the government would have captured between 50% and 80% of the benefits of the plan enjoyed by equity holders. Therefore, if the goal of the plan was to achieve 100% participation by all top ten banks (to avoid signaling effects), tougher terms might have gotten in the way.

7. Conclusions

By analyzing the market response to the Revised Paulson Plan we show that, systemic effects aside, this plan "gifted" \$130 bn to the ten largest banks. This gift was made of two components: a transfer of between \$21 and \$44 bn from taxpayers to banks' investors and an efficiency gain of between \$86 and \$109 bn. From a purely economic point of view, the plan could be considered a success because it created value. It did, however, achieve this objective via a massive redistribution of resources from taxpayers to banks, in particular to banks' bondholders who gained \$121 bn as a result of the plan. This redistribution had and will have significant political costs. Most importantly, it did not need to be done that way. The government could have asked for significantly more, both for the equity infusion and the debt guarantee. For instance, if the government had applied the same terms Warren Buffett obtained from Goldman Sachs, taxpayers would have gained between \$39 and \$55 bn, instead of losing between \$21 and \$44 bn. However, we find that such terms may not have been accepted by four of the ten banks. An open question is how much power did the government have to coerce firms to participate (after all, it did exercise some "moral suasion"), and how important as a goal was 100% participation. Even accepting that nothing could be done at that time, it remains unanswered why the government did not try to extract some of these benefits on the way out, i.e., when these banks asked to get out of TARP.

By looking at the limited cross section we can infer that the net benefit created is the combination of two factors. On the one hand, a government intervention reduces the enterprise value by 2.5%, possibly due to the inefficient restrictions the government will impose. On the other hand, the government money infusion reduces the probability of bankruptcy, which – we estimate – could cause a dissipation of 22% of the enterprise value.

We then study the cost of alternative plans that would have achieved the same effects in terms of reduction of the default risk of existing banks. The Revised Paulson Plan vastly dominates the original Paulson Plan and performs better than the most popular alternatives advanced at the time. Only a debt-for-equity swap would have done better, but this would have required specific legislation to be implemented.

Appendix A. Bootstrapping risk-neutral default probabilities from CDS rates

Denote by $r(\tau)$ the riskless rate at time τ and by $p(\tau)$ the risk-neutral default intensity for time τ. We assume for simplicity that both $r(\tau)$ and $p(\tau)$ are simple deterministic functions of time. Assuming continuous payments, the no-arbitrage formula for a CDS rate on a contract with maturity T is given by

$$CDS(T) = \frac{(1-\delta)\int_0^T p(\tau)e^{-\int_0^\tau r(u)+p(u)\,du}\,d\tau}{\int_0^T e^{-\int_0^\tau r(u)+p(u)\,du}\,d\tau}, \tag{A.1}$$

where δ is the recovery rate. Note that if the default intensity $p(\tau)=p$ is constant, then $CDS(T)=p(1-\delta)$. When $p(\tau)$ is not constant, we can use CDS rates for various maturities T to bootstrap out $p(\tau)$ for every τ. For simplicity, we assume that $p(\tau)$ is a step function with one-year step size. To implement the procedure, we need

[22] To approximate the lower bound value of a perpetual callable preferred, we calculated the value of the perpetual non-callable preferred as the perpetuity value of the 10% dividend discounted at the rate of existing preferred securities, and subtract the value of a standard American call option with a 15-year maturity and a volatility equal to the implied volatility at that time. Since the volatility of common stock is much higher than the volatility of the preferred, this is a lower bound of the value of the perpetual callable preferred.

[23] The dividend paid on the preferred is de facto junior to the principal repayment of long-term debt. Thus, the value of the debt would be lower with a higher dividend payment. We expect this effect to be small, though.

the spot rates $r(\tau)$, which we bootstrap out from plain-vanilla swap rates data, available on the Federal Reserve Board Web site. Fixed-for-floating swap rates implicitly embed the London Interbank Offered Rate (LIBOR) discount curve, which is used by dealers to price CDS contracts and other derivatives. The LIBOR curve implicitly embeds the risk of default of derivative security dealers. In this bootstrap procedure, we assume a recovery rate δ=0, 20%, or 40%, depending on cases discussed in the text. Note that δ=40% is the standard assumption in the pricing of CDS (see, e.g., the Bloomberg description of CDS).

Given intensities $p(\tau)$, we can finally compute the probability to survive up to time T as

$$Q(T) = e^{-\int_0^T p(\tau)\, d\tau}. \tag{A.2}$$

The conditional probability of defaulting in year n conditional on not defaulting earlier, $P(n)$=*Prob*(*Default in year n*|*No Default before year n*), can be computed from $Q(t)$ from Bayes' rule:

$$P(n) = \frac{Q(n-1)-Q(n)}{Q(n-1)}, \tag{A.3}$$

where $Q(0)$=1.

Appendix B. The Merton model of equity as an option

In order to take into account the possibility of a short-term default, we modify the Merton (1974) model to consider two possible maturities of debt, short-term (ST) and long-term (LT). Consider a bank with an amount $A(0)$ of assets at time zero. To illustrate the simple model, assume for simplicity that the principal on ST debt and LT debt is the same, D_L=D_S, that debt carries no coupon payments, and that short-term debt is senior to long-term debt. The value of $A(t)$ changes over time, due to cash inflows and outflows, as well as the willingness of market participants to purchase such assets. For instance, if some of these assets are mortgage-backed-securities, then their market value may decrease in price if market participants expect higher mortgage defaults in the future.

In this simplified setting, consider the bank is now at maturity of the short-term debt T_S. In order to cover its liabilities, the bank has to sell some of its assets $A(T_S)$, or, equivalently, roll-over ST debt. To take into account the possibility of a bank run or a liquidity shock, we assume that at time T_S there is a risk-neutral probability p that the market value of assets drops by x%. If $A(T_S) < D_S$, the bank defaults, equity and LT debt holders are wiped out, and ST debt holders seize the remaining assets $A(T_S)$. If $A(T_S) > D_S$, the bank pays D_S and proceeds on with its operations. At maturity of the long-term debt T_L, the situation is similar. If assets $A(T_L) < D_L$, the bank defaults, equity holders receive nothing, and debt holders receive the assets $A(T_L)$. Otherwise, debt holders receive their principal D_L and equity holders obtain the remaining assets $A(T_L) - D_L$.

Fig. 3 illustrates the model: the two vertical dotted lines correspond to the maturities of the short-term and long-term debt. The solid curved line represents one hypothetical path of assets over time, while the shaded areas correspond to possible asset values at T_S and T_L from the perspective of a market participant at time zero. The solid curved line represents the case in which no default on long-term debt takes place, neither at T_S nor at T_L. In contrast, the dashed line that starts at T_S represents a hypothetical path leading to default of the bank: at T_L the bank does not have enough to pay in full its obligations to debt holders.

More specifically, now, consider a bank at time zero, with assets $A(0)$, financed by short-term deposits *Dep*, unsecured and secured short-term debt, denoted by D_S and D_S^{Sec}, respectively, and long-term debt D_L. We make the simplifying assumption that deposits, short-term debt, and long-term debt are all zero coupon instruments, maturing at T_S (deposits and short-term debt) and at T_L (long-term debt). The balance sheet also reports "other liabilities" among the long-term liabilities. We assume that these liabilities also mature at T_L, and are senior to long-term debt. Finally, we assume secured short-term debt is senior to everything else, including deposits (which are instead partly insured by the FDIC).

As in Black and Scholes (1973) and Merton (1974), the market value of assets $A(t)$ follows a geometric Brownian motion. Under the pricing probability distribution, we then have that

$$\log(A(T_{S^-})) \sim N(\log(A(0)) + (r-0.5\sigma_A^2)T_S, \sigma_A^2 T_S),$$

where r is the riskless rate. At T_S, there is a (risk-neutral) probability p that the asset value will drop to $A(T_S) = xA(T_{S^-})$. Because deposits are senior to unsecured short-term debt holders (and are insured by FDIC), the payoff to short-term debt holders at T_S is

$$\textit{ST Deb Payoff} = \max(A(T_S)-(Dep+D_S^{Sec}),0) - \max(A(T_S) - (Dep+D_S^{Sec}+D_S),0).$$

That is, the payoff is zero if $A(T_S) < Dep + D_S^{Sec}$, while it is $A(T_S)-(Dep+D_S^{Sec})$ if $A(T_S) > Dep+D_S^{Sec}$ but $A(T_S) < Dep + D_S^{Sec}+D_S$, and it is finally equal to D_S if $A(T_S) > (Dep + D_S^{Sec}+D_S)$. Note that in the former two cases, equity holders and debt holders get zero. It follows that by the usual option pricing arguments, the value of short-term debt under the two scenarios of no liquidity shock or with a liquidity shock at T_S are

$$V^S(A(0)|\textit{no shock at } T_S) = BSC(A(0), Dep+D_S^{Sec}, \sigma_A, r, T_S) - BSC(A(0), Dep+D_S^{Sec}+D_S, \sigma_A, r, T_S)$$

$$V^S(A(0)|\textit{shock at TS}) = BSC(A(0)x, Dep+D_S^{Sec}, \sigma_A, r, T_S) - BSC(A(0)x, Dep+D_S^{Sec}+D_S, \sigma_A, r, T_S),$$

where BSC denotes the Black and Scholes option pricing formula. Thus, the value of short-term debt is

$$V^S(A(0)) = V^S(A(0)|\textit{no shock at } T_S)(1-p) + V^S(A(0)|\textit{shock at } T_S)p.$$

Conditional on the bank surviving at T_S, we can compute then the value of long-term claims. In particular, if the firm survives at T_S, its assets will be reset at

$$A*(T_S) = A(T_S) - (Dep + D_S^{Sec} + D_S)$$

For simplicity, after paying the short-term liabilities, we assume that assets are still log-normally distributed going forward. In particular, conditioning on a given $A(T_S) > Dep + D_S^{Sec} + D_S$, we assume

$$log(A*(T_L))|_{A(Ts)} \sim N(log(A*(T_s)+(r-0.5\sigma_A^2)(T_L-T_S),\sigma_A^2(T_L-T_S)).$$

Given this, we can value the equity at T_S conditional on $A(T_S) > Dep + D_S^{Sec} + D_S$ again by Black and Scholes formula. In particular, under this condition the payoff to equity is given by

$$Equity\ Payoff = max(A*(T_L)-(D_L+D_O),0),$$

where D_O are the other liabilities in the balance sheet, and D_L is the face value of long-term debt, computed in such a way to make the value of the zero coupon bond equal to the estimated market value of debt of the bank (see below). Assuming the other liabilities are senior to long-term debt, the payoff to long-term debt holders is then

$$LT\ Debt\ Payoff = max(A*(T_L)-D_O,0)-max(A*(T_L)-(D_L+D_O),0).$$

It follows that conditional on $A(T_S) > Dep + D_S^{Sec} + D_S$, the value at T_S of equity and LT debt are, respectively:

$$V^E(A*(T_S)) = BSC(A*(T_S),D_L+D_O,\sigma_A,r,T_L-T_S)$$

and

$$V^{LT}(A*(T_S)) = BSC(A*(T_S),D_O,\sigma_A,r,T_L-T_S)-BSC(A*(T_S),D_L+D_O,\sigma_A,r,T_L-T_S).$$

If $A(T_S) < Dep + D_S^{Sec} + D_S$, instead, the value of both equity and LT debt is zero. In order to compute the value today (i.e., time zero) for LT debt and equity, we must take their discounted expected value of the payoff at T_S, under the pricing probability distribution. Given the log-normality assumption, we therefore obtain

$$V^E(A(0)) = \int_{Dep+D_S^{Sec}+D_S}^{\infty} e^{-rT_S} V^E(A-(Dep+D_S^{Sec}+D_S))f(A)\,dA$$
$$V^{LT}(A(0)) = \int_{Dep+D_S^{Sec}+D_S}^{\infty} e^{-rT_S} V^{LT}(A-(Dep+D_S^{Sec}+D_S))f(A)\,dA$$

where $f(A)$ is a mixture of log-normal distributions, weighted by the probabilities p and $(1-p)$ that a liquidity shock occurs at T_S.

Finally, the calculations above also allow us to compute the value of the FDIC deposit guarantee. Let $Dep^{Ins} < Dep$ be the total amount of deposits that are insured by the FDIC. The same argument as above implies that the cost of the guarantee is given by the spread put option

$$V^G(A(0)) = V^G(A(0)|no\ shock\ at\ T_S)(1-p) + V^G(A(0)|shock\ at\ T_S)p,$$

where

$$V^G(A(0)|no\ shock\ at\ T_S) = BSP(A(0),\ Dep+D_S^{Sec},\sigma_A,r,T_S) - BSP(A(0),\ Dep+D_S^{Sec}-Dep^{Ins},\sigma_A,r,T_S)$$

and

$$V^G(A(0)|shock\ at\ T_S) = BSP(A(0)x,Dep+D_S^{Sec},\sigma_A,r,T_S) - BSP(A(0)x,Dep+D_S^{Sec}-Dep^{Ins},\sigma_A,r,T_S).$$

There are four unobservable entries in these formulas: the value of assets today $A(0)$, the volatility of assets σ_A, the probability of a liquidity shock p, and the loss in case of a shock x. We choose these quantities to match four observables: the market capitalization of each bank on October 10, 2008, the volatility of equity, as well as an estimate of market values of ST debt and LT debt on the same day. The estimated market value of debt is computed from CDS rates. First, we compute the average coupon and average maturity of debt, using data from Bloomberg (see Table 2). Second, we compute the present value of future (average) coupons and principal up to the (average) maturity, discounting them at the CDS implied yield

$$Yield = Risk\ Free\ Rate + CDS\ Rate.$$

Given the value of LT debt, we compute the principal value of an equivalent zero coupon bond with five year to maturity (the maturity of CDS) as

$$D_L = Value\ of\ Debt*(1+Yield)^5.$$

For ST debt we apply the same methodology, although we do not have coupons in this case. Since we are interested in very short-term probability of default, we considered a maturity of only three months in the calibration, and used the shortest maturity CDS (one year) to compute the implied yield.

It is worth pointing out that the CDS implied yields underestimate the true yield of bonds (see, e.g., Longstaff, Mithal, and Neis, 2005) and thus, we overestimate the value of debt in this case. We also computed the value of debt and implied transfers by treating the principal value as a zero coupon bond itself, thereby grossly under-estimating the value of debt. The transfers from equity holders to debt holders were very similar.

For the calibration after the announcement on October 14, 2008, we control for other confounding news between October 10 and 14, 2008 by exploiting the estimation results in Sections 3.1 and 3.2, which provide the increase in the values of equity and debt that control for the market variation and the variation in GE Capital, respectively. In particular, we impose that the values of equity and debt on October 14, 2008 are equal to the respective values on October 10, 2008 plus the adjusted values. Because these adjustments do not regard the value of short-term debt, we perform a similar adjustment to the one-year CDS rates of banks on October 14, 2008, in which we control for the percentage decline in the CDS rate of GE Capital. The remaining part of the calibration on October 14, 2008 is the same as at the previous date.

Appendix C. More robustness calculations

C.1. Recovery rates and discounts

Another robustness check has to do with the assumptions we made about the recovery rates, a key assumption to compute the risk-neutral probabilities of default, used then to compute the value of debt insurance. In the body of the text we assume 20%, which is below the standard value assumed for single-name CDSs, which is 40% instead. Table 8 shows that changing the value of recovery rate from 20% to 0% or to 40% changes the result, but not the conclusion. In particular, with 0% recovery, the best (optimistic with Morgan Stanley) and worst (pessimistic without Morgan Stanley) cases are \$116 and \$25 bn, respectively. With 40% recovery, instead, the best and worst cases are \$98 and \$20 bn, respectively.

One additional concern pertains to the discount rate used to compute the present value of insurance. In the body of the paper we use the US Treasury curve. However, since security dealers may default, it is customary to use the LIBOR curve to price CDS contracts. Using the LIBOR curve also does not change our conclusions, as the best and worst possible cases are now \$107 and \$24 bn, respectively.

C.2. Beta estimates

To compute the change in value of common stock, we controlled for the change in the stock market. The resulting adjusted equity values are therefore just an estimate, and we must consider their standard errors in our analysis. We check the robustness of our results to these estimation errors by computing the total costs and benefits after shifting of the regression coefficients by plus/minus two standard errors, which amounts to assuming that all regression coefficients are perfectly correlated, a strong, but conservative assumption. Once again, Table 8 shows that our conclusions remain the same: a two-standard deviation decrease in betas leads to a best and worst case of \$120 and \$35 bn, respectively, while these numbers are \$100 and \$16 bn when we increase the betas by two standard errors.

Appendix D. Taxpayers VaR calculations

For the Revised Paulson Plan, we compute the VaR from the perspective of taxpayers as follows: First, we estimate the correlation structure of banks' assets from the correlation of changes of short-term and long-term CDS rates. Second, we use these correlation structures to simulate the joint "liquidity shock" at T_S as well as the joint assets realization at T=3. More specifically, we compute the liquidity shock at T_S as follows: for each bank i, given a probability p_i of a liquidity shock, we compute a cutoff level e_i=$N^{-1}(p_i)$, where $N(\cdot)$ denotes the cumulative standard normal distribution. We then simulate a vector $\varepsilon \sim \varphi(0, R)$, where $\varphi(0, R)$ denotes the multivariate normal density with correlation matrix R. A liquidity shock for bank i is declared if $\varepsilon_i < e_i$. The correlation structure for liquidity shocks R is obtained from the variance covariance of the changes in short-term CDS rates. We simulate the value of assets $A*(T) = (A_1^*(T), \ldots, A_n^*(T))$ at T jointly according to the model

$$\log(A*(T))|_{A(T_S)} \sim N(\log(A*(T_s) + (\mu - 0.5\sigma_A^2)(T - T_S), \Sigma_A(T - T_S)),$$

where Σ_A is the joint covariance matrix obtained from the correlation of CDS rate changes and the calibrated asset volatilities σ_A, and μ is the risk-natural drift rate of assets, discussed further below. In this formula, for each bank i we have that its assets at T_S are given by

$$A_i^*(T_S) = max(A_i(T_S) + D_{Si}^* 1.25 - (Dep_i + DS_i + D_{Si}^{Sec}), 0).$$

To explain this formula, $A_i(T_S)$ denotes the amount of assets at T_S, when the short-term liabilities become "due." This is given by $(A_i(T_S)) = x_i A_i(T_{S^-})$ with a probability π_i and $(A_i(T_S)) = A_i(T_{S^-})$ with probability $(1-\pi_i)$, where π_i denotes the risk-natural probability of a shock, discussed below. To compute the three-year VaR, we need to take into account the ability of banks to issue new debt (as part of the FDIC plan), therefore, we augment the asset value by the amount that the bank can issue at T_S minus the total liabilities that become due at T_S, according to the model, namely, deposits Dep, unsecured ST debt D_S, and secured ST debt D_{Si}^{Sec}. If the bank total net assets at T_S are smaller than zero, the bank fails. As before, we simulate the vector $A(T_S)$=$(A_1(T_S), \ldots, A_n(T_S))$ jointly according to the model

$$\log(A(T_S)) \sim N(\log(A(0) + (\mu_0 - 0.5\sigma_A^2)T_S, \Sigma_A T_S),$$

where μ_0 is the drift rate of assets before T_S is discussed further below.

For each bank i we then compute the government disbursement at T=3 as the difference between D–$A(T)$, if any, where D equals the total LT debt maturing by T plus the new guaranteed debt D_S*1.25 issued at T_S, capitalized at the risk-free rate to T (because it is government guaranteed), up to the maximum guaranteed debt. To be conservative, we do not include "other liabilities" in D. On top of this, we compute the value of the investment in equity for the government, by using the Black and Scholes (1973) option pricing formula to compute the value of equity defined on the simulated assets at time T, minus of course the maturing guaranteed debt D_S*1.25, capitalized at the risk-free rate to T. This approach ensures the correct correlation between losses from the guarantee and equity investment, as if a bank needs a government intervention because of losses on assets, its equity value ought to be small as well, implying a double loss for the government. The potential losses are given by the sum of losses from the guarantee and from the equity position.

We compute the VaR for the other three cases (purchase of assets with and without overpayment, and pure capital infusion without guarantee) in an analogous manner. In particular, consider the scenario in which the government purchases the banks' assets (with or without overpayment). As mentioned, we calibrate the amount of the purchase, and the risk-neutral probability p, as of October 14, 2008 to match the decline in the one-year and five-year CDS rates. Because we assume the government buys assets with cash, we assume that both the asset volatility σ_A and the losses in case of a liquidity shock x decline proportionally with the fraction of total assets purchased by the government. Let $A_i(0)$ be the total amount purchased from bank i. We then simulate the value at T=3 of these assets $A_i(T)$ as above. For symmetry, we also consider in this case a shock at T_S for the value of assets held by the government. In particular, we define the after-shock value of assets as $A_i^*(T_S) = A_i(T_S)$ if no shock occurs, and $A_i^*(T_S) = xA_i(T_S)$ if a shock occurs. The remaining calculations are the same, noting that in this case there is no guarantee in place, and thus, all of the VaR is coming from the devaluation of the assets purchased.

Finally, for the case of a pure capital infusion, we follow the same approach of simulating the value of assets at T=3. From the calibration we obtain the capital infusion necessary at aero to yield a reduction in the value of CDS rates comparable to the ones in the data. From the capital infusion, we then obtain the percentage of government ownership of the bank and the value of initial assets of the bank (equal to old assets plus additional capital). We then simulate the value of assets at T as in the previous cases, taking into account that at T_S the bank can fail if its assets are below the total amount of short-term liabilities D. Recall that there is no guarantee in this case. At T, we compute the value of equity using the Black and Scholes formula for equity, and compute the profits/loss for the government as the difference from the initial capital infusion. We obtain the VaR number from the distribution of profits/losses at T.

One final important issue in the simulation of the asset value of each bank i, $A_i(T)$, is how to move from the risk-neutral dynamics to the risk-natural (physical) dynamics, which is needed for VaR calculations. To move from risk-neutral to risk-natural probability measures, it suffices to make an assumption about the risk premium on traded assets. We assume that the market value of these assets has a relatively generous Sharpe Ratio of 35%. Note that the higher the Sharpe Ratio, the higher is the expected value of future assets and thus, the lower is the VaR. Given the assumed Sharpe Ratio λ=35%, the annual drift rate of assets after T_S is then given by

$$\text{drift rate of assets} = \mu = \text{risk free rate} + \lambda\sigma_A,$$

where σ_A is the volatility of assets. This transformation must hold for $t > T_S$. At T_S there is also the liquidity shock, and thus, the drift rate of assets before T_S must be adjusted to ensure that the ex ante Sharpe Ratio is consistent with the possible crash. In particular, we proceed as follows: Let π denote the risk-natural probability of a drop at T_S. Then, we first require that the return on assets over T_S must still be μ, that is $E[A(T_S)]=A(0)\exp(\mu T_S)$, which in turn implies

$$E[A(T_S)] = (1-\pi)A(0)\exp(\mu_0 T_S) + \pi x A(0)\exp(\mu_0 T_S)$$
$$= A(0)\exp(\mu T_S)$$

or

$$\mu_0(\pi) = \mu - \log((1-\pi)+\pi x)/T_S.$$

That is, for a given π we can compute the drift μ_0 which ensures the proper expected return. We can then pin down π by imposing a Sharpe Ratio also on the ex ante investment. In particular, we can compute the variance of $A(T_S)$. The second moment is

$$E[A(T_S)^2] = [(1-\pi)+\pi x^2]E[A(T_S)^2] = [(1-\pi)+\pi x^2]E[A(T_S)^2]$$
$$= [(1-\pi)+\pi x^2]A(0)^2\, exp((2\mu_0+\sigma_A^2)T_S)$$

yielding

$$V(A(T_S)) = E[A(T_S)^2] - E[A(T_S)]^2$$
$$= [(1-\pi)+\pi x^2]A(0)^2\, exp((2\mu_0+\sigma_A^2)T_S)$$
$$-[(1-\pi)+\pi x]^2 A(0)^2\, exp(2\mu_0 T_S)$$
$$= \{[(1-\pi)+\pi x^2]\, exp(\sigma_A^2 T_S) - [(1-\pi)+\pi x]^2\}$$
$$\times A(0)^2\, exp(2\mu_0 T_S).$$

The T_S Sharpe Ratio (SR) is then the expected excess return $E[A(T_S)/A(0)-\exp(rT_S)]$ divided by the standard deviation $STD(A(T_S)/A(0))=V(A(T_S)/A(0))^{1/2}$, that is

$$SR = E[A(T_S)/A(0) - exp(rT_S)]/STD(A(T_S)/A(0))$$
$$= [(1-\pi)+\pi x - exp(-(\mu_0(\pi)-r)T_S)]/\{[(1-\pi)+\pi x^2]$$
$$\times \exp(\sigma_A^2 T_S) - [(1-\pi)+\pi x]^2\}^{1/2}$$

We obtain the probability π by imposing SR=0.35 $\sqrt{T_S}$ [in random-walk types of models, the Sharpe Ratio is increased as a square root of time, as the expected return at the numerator increases linearly, but the standard deviation increases as a square root of time].

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