

Credit Risk Transfer, Fragility, and Contagion*

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1 Introduction

It is often argued that financial innovation in the form of creating new instruments and the opening up of new markets is desirable because it creates opportunities for diversification and potentially promotes liquidity. Although this argument appears to be a powerful one, practical experience of financial liberalization such as the introduction of new instruments and the creation of new markets has not always been positive particularly in emerging markets. Such changes have often led to financial crises.

This paper illustrates how financial innovation can lead to a fall in welfare despite the fact that it allows beneficial diversification. The reason is that it can also cause fragility and contagion. A model with a banking sector and an insurance sector based on Allen and Gale (2005a) is developed. Initially there is no way to diversify across the two sectors because of a lack of instruments

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to do so. The financial innovation of credit risk transfer is then introduced. It is shown how this allows diversification and can improve welfare. However, this improvement relies on there being no markets for liquidating assets. If such markets are introduced then the financial system can become fragile. In order to induce some market participants to hold liquidity to purchase the assets being liquidated, there must be states in which asset prices are “low” so the participants can make a profit and cover the opportunity cost of holding cash in the other states. The low prices are determined by the amount of cash in the market rather than the future earning power of the asset. If assets are marked to the market then these low prices can cause a problem of contagion. In the example presented there can be contagion from the insurance sector to the banking sector. The overall effect of this contagion is to lower welfare compared to the autarkic solution.

The paper thus contributes to the literature on credit risk transfer by illustrating that even though it allows diversification it can lower welfare because of its effect on systemic risk. Section 2 discusses the institutional details of credit risk transfer. This has grown significantly in the last few years. The results obtained below suggest that this is not necessarily desirable because it can increase the breadth of financial crises.

In recent years there has been a considerable debate on the advantages and disadvantages of moving away from the historic cost accounting that has traditionally been used for financial institutions such as banks and insurance companies towards a mark-to-market system. This debate has been triggered by the move of the International Accounting Standards Board (IASB) and the US Financial Accounting Standards Board (FASB) to make changes in this direction as part of an attempt to globalize accounting standards (Hansen 2004).

Planta, Sapra, and Shin (2004) show that while an historical cost regime can lead to some inefficiencies, the feedback effects of mark-to-market pricing can lead to increased price volatility and suboptimal real decisions. Their analysis suggests the problems with mark-to-market accounting are particularly severe when claims are (i) long-lived, (ii) illiquid, and (iii) senior. The assets of banks and insurance companies are particularly characterized by these traits. This provides an explanation of why banks and insurance companies have been so vocal against the move to mark-to-market accounting.

In the current paper an additional reason for banks and insurance companies to be disturbed by mark-to-market accounting is provided. When markets are complete, prices reflect future earning power and it is appropri-

ate to use them to measure values. However, if markets are incomplete and liquidity plays an important role this is not the case in times of crisis. Here asset prices reflect the amount of liquidity available in the market not the future earning power of the asset. This means that mark-to-market accounting is not a desirable way to assess the solvency of a financial institution. It is shown that the current value of assets can be less than the current value of liabilities so the bank is insolvent. However, if the bank is allowed to continue, which would be the case if historic cost accounting is used, then the bank can meet all its future liabilities. More generally, this result illustrates that in times of financial crisis it may not be a good idea to use market prices to value assets.

Section 3 develops a model to analyze the effects discussed. Section 4 considers the autarkic equilibrium. Section 5 shows how credit risk transfer can improve welfare. The example given relies on there being no market for liquidating the long asset for a welfare improvement to occur. Section 6 shows how the introduction of such a market can lead to a Pareto reduction in welfare compared to the autarkic equilibrium because of fragility and contagion. Finally, Section 7 contains concluding remarks.

2 Credit risk transfer

Credit risk has been transferred between parties for many years. Bank guarantees and credit insurance provided by insurance companies, for example, have a long history. Securitization of mortgages occurred in the 1970s. Bank loans were syndicated in the 1970s and secondary markets for bank loans developed in the 1980s. In recent years a number of other methods of risk transfer have come to be widely used.

Table 1 (BIS (2003)) shows the size of credit risk transfer markets using various instruments from 1995-2002. Institutions transferring risk out are referred to as "risk shedders" while institutions taking on risk on are referred to as "risk buyers". One important class of instrument is credit derivatives. An example of these is credit default swaps. These are bilateral contracts where the risk shedder pays a fixed periodic fee in exchange for a payment contingent on an event such as default on a reference asset or assets. The contingent payment is provided by the risk buyer. With asset-backed securities, loans, bonds, or other receivables are transferred to a special purpose vehicle (SPV). The payoffs from these assets are then paid out to investors.

The credit risk of the instruments in the SPV is borne by the investors. The underlying pool of assets in asset-backed securities is relatively homogeneous. Collateralized debt obligations also use an SPV but have more heterogeneous assets. Payouts are tranching with claims on the pools separated into different degrees of seniority in bankruptcy and timing of default. The equity tranche is the residual claim and has the highest risk. The mezzanine tranche comes next in priority. The senior tranche has the highest priority and is often AAA rated.

It can be seen from Table 1 that the use of all types of credit risk transfer has increased substantially. The growth has been particularly rapid in credit derivatives and collateralized debt obligations, however. Despite this rapid growth a comparison of the outstanding amounts of credit risk transfer instruments with the total outstanding amounts of bank credit and corporate debt securities shows that they remain small in relative terms.

Table 2 (BBA (2002)) shows the buyers of credit protection in Panel A and the sellers in Panel B. From Panel A it can be seen that the buyers are primarily banks. Securities houses also play an important role. Hedge funds went from being fairly insignificant in 1999 to being significant in 2001. Corporates, insurance companies and the other buyers do not constitute an important part of demand in the market. From Panel B, it can be seen that banks are also important sellers of credit protection. In contrast to their involvement as buyers, the role of insurance companies as sellers is significant. Securities houses also sell significant amounts while the remaining institutions play a fairly limited role. The results of a survey contained in Fitch (2003) are consistent with Table 2. They found that the global insurance sector had a net seller position after deducting protection bought of \$283 billion. The global banking industry purchased \$97 billion of credit protection. A significant amount of risk is thus being transferred into the insurance industry from banks and other financial institutions.

As discussed in the introduction, these figures raise the important issue of whether these transfers of risk are desirable. We turn to developing a model to consider these issues.

3 The model

The model is based on the analyses of crises and systemic risk Allen and Gale (1998, 2000a-c, 2004a-b) and Gale (2003, 2004) and particularly Allen

and Gale (2005a). A familiar model of intermediation is extended by adding an insurance sector. Since the risks faced by the insurance sector are not perfectly correlated with the risks faced by the banking sector, there is scope for diversification. This is the basic motive for credit risk transfer.

There are three dates $t = 0, 1, 2$ and a single, all-purpose good that can be used for consumption or investment at each date.

There are two sectors in the financial system, the banking sector and the insurance sector. Each sector consists of a large number of competitive firms and their lines of business do not overlap. This is a strong assumption but a necessary one, since the combination of insurance and intermediation activities in a single financial institution would obviate the need for credit risk transfer.

There are two securities, one *short* and one *long*. The short security is represented by a storage technology: one unit at date t produces one unit at date $t + 1$. The long security is represented by a constant-returns-to-scale investment technology that takes two periods to mature: one unit invested in the long security at date 0 produces $R > 1$ units of the good at date 2 (and nothing at date 1).

In addition to these securities, banks and insurance companies have distinct direct-investment opportunities. Banks can make loans to firms which succeed with probability β . More precisely, each firm borrows one unit at date 0 and invests in a risky venture that produces B units of the good at date 2 if successful and 0 if unsuccessful. There is assumed to be an infinite supply of such firms, so the banks take all the surplus. (In effect, these “firms” simply represent a risky, constant-returns-to-scale, investment technology for the banks).

The bank’s other customers are depositors, who have one unit of the good at date 0 and none at dates 1 and 2. Depositors are uncertain of their preferences: with probability λ they are *early consumers*, who only value the good at date 1 and with probability $1 - \lambda$ they are *late consumers*, who only value the good at date 2. Uncertainty about time preferences generates a preference for liquidity and a role for the intermediary as a provider of liquidity insurance. The utility of consumption is represented by a utility function $U(c)$ with the usual properties. We normalize the number of consumers to 1.

The insurance companies have access to a large number of firms, whose measure is normalized to one. Each firm owns an asset that produces A units of the good at date 2. With probability α the asset suffers some damage at date 1. Unless this damage is repaired, at a cost of C , the asset becomes

worthless and will produce nothing at date 2. The firms also have a unit endowment at date 0 which the insurance company invests in the short and long securities in order to pay the firms' damages at date 1.

Finally, we introduce a class of risk neutral investors who provide "capital" to the insurance and banking sectors. Although investors are risk neutral, we assume that their consumption must be non-negative at each date. Otherwise, the investors could absorb all risk and provide unlimited liquidity. The investor's utility function is defined by

$$u(c_0, c_1, c_2) = \rho c_0 + c_1 + c_2,$$

where $c_t \geq 0$ denotes the investor's consumption at date $t = 0, 1, 2$. The constant $\rho > R$ represents the investors' opportunity cost of funds. An investor's endowment consists of a large (unbounded) amount of the good at date 0 and nothing at dates 1 and 2.

We can assume without loss of generality that the role of investors is simply to provide capital to the intermediary through the contract $e = (e_0, e_1, e_2)$ where $e_0 \geq 0$ denotes the investor's supply of capital at date $t = 0$, and $e_t \geq 0$ denotes the investor's consumption at dates $t = 1, 2$. While it is feasible for the investors to invest in assets at date 0 and trade them at date 1, it can never be profitable for them to do so in equilibrium. More precisely, the no-arbitrage conditions ensure that profits from trading assets are zero or negative at any admissible prices and the investor's preferences for consumption at date 0 imply that the investors will never want to invest in assets at date 0 and consume the returns at dates 1 and 2. An investor's endowment consists of a large amount of the good W_0 at date 0 and nothing at dates 1 and 2. This assumption has two important implications. First, since the investors have a large endowment at date 0 and the capital market is competitive, there will be excess supply of capital unless the investors receive no surplus in equilibrium. Secondly, the fact that investors have no endowment (and non-negative consumption) at dates 1 and 2 implies that their capital must be converted into assets in order to provide risk sharing at dates 1 and 2.

We can then write the investors' utility in the form:

$$u(e_0, e_1, e_2) = \rho W_0 - \rho e_0 + e_1 + e_2.$$

For the purposes of illustrating the scope for diversification, the structure of uncertainty is one that allows for some diversification and some aggregate

risk. This is achieved by assuming that the proportions of damaged firms for the insurance sector and failing firms for the banking sector equal the probabilities α and β , respectively, and that these probabilities are themselves random. All uncertainty is resolved at the beginning of date 1. Banks' depositors learn whether they are early or late consumers and insurance companies learn which firms have damaged assets. Whether loans will pay off or not at date 2 is also determined at date 1.

4 Autarkic equilibrium

The purpose of this and subsequent sections is to illustrate the potential benefits of financial innovation but also the costs. The easiest way to do this is using numerical examples. The first case considered is when the banking sector and the insurance sector are autarkic and operate separately. It is initially assumed that the long asset and the loans cannot be liquidated for a positive amount at date 1. Hence if a bank or insurance company goes bankrupt at date 1, the proceeds from the long asset and the loans are 0. It will be seen below that this assumption plays a crucial role but perhaps not in the way that might be expected.

4.1 The banking sector

The return on the long asset is $R = 1.05$.

For the investors providing equity capital for banks $\rho = 1.1$. For depositors in the banks $\lambda = 0.5$; $U(c) = Ln(c)$. For banks' loans $B = 3$. The probability of state H = the probability of state $L = 0.5$. In state H the probability of the high payoff B on firms' loans is $\beta_H = 1$; in state L it is $\beta_L = 0.4$. Overall, the probability that the banks loans pay off 3 is 0.7 and the probability they pay off 0 is 0.3.

There are investors who can make capital available to the banks. Since the investors are indifferent between consumption at date 1 and date 2 it is optimal to set $e_1 = 0$ and invest any capital e_0 that is contributed in the long asset or loans since these have a higher return than the short asset. Banks investment in the short asset is denoted x and their investment in loans is denoted y . They receive an endowment of 1 from depositors so their investment in the long asset is $1 + e_0 - x - y$. In the case where the loans pay off B it is possible to make a payout e_2 to investors.

Since banks are competitive they choose the contracts they offer to maximize the expected utility of the depositors. If they failed to maximize their expected utility then another bank could step in and offer a better contract to attract way all their customers.

$$\text{Max } 0.5U(x/0.5)+0.5[0.7U(((1+e_0-x-y)R+By-e_2)/0.5)+0.3U((1+e_0-x-y)R/0.5)]$$

In order for the investors to be willing to supply the capital it is necessary that

$$e_0\rho = 0.7e_2.$$

Hence the banks' problem becomes to choose e_0 , x and y to

$$\text{Max } 0.5U(x/0.5)+0.35U(((1-x-y)R+By-e_0(\frac{\rho}{0.7}-R))/0.5)+0.15U((1+e_0-x-y)R/0.5)$$

The first order conditions are now

$$\frac{dEU}{dx} = \frac{0.5}{x} - \frac{0.35R}{(1-x-y)R + By - e_0(\frac{\rho}{0.7} - R)} - \frac{0.15}{(1+e_0-x-y)} = 0$$

$$\frac{dEU}{dy} = \frac{0.35(B-R)}{(1-x-y)R + By - e_0(\frac{\rho}{0.7} - R)} - \frac{0.15}{(1+e_0-x-y)} = 0$$

$$\frac{dEU}{de_0} = -\frac{0.35(\frac{\rho}{0.7} - R)}{(1-x-y)R + By - e_0(\frac{\rho}{0.7} - R)} + \frac{0.15}{(1+e_0-x-y)} = 0$$

The first thing to notice is that these cannot all be satisfied. Since $B > \frac{\rho}{0.7}$ the last two conditions cannot be simultaneously satisfied. What is happening is that the risk neutral investors are supplying the funds for loans and the cost of these funds is less than the return from loans. Banks have an incentive to raise an infinite amount of equity capital and fund loans with this. We assume there is a limited number of loans $y = 0.3$ and the owners of the firms taking the loans therefore obtain the surplus. The amount paid

on loans instead of being B will be $\frac{\rho}{0.7}$ in equilibrium. Hence the relevant first order conditions become

$$\frac{0.5}{x} = \frac{0.35R}{(1-x-y)R + \frac{\rho}{0.7}y - e_0(\frac{\rho}{0.7} - R)} + \frac{0.15}{(1+e_0-x-y)} = 0$$

$$\frac{0.35(\frac{\rho}{0.7} - R)}{(1-x-y)R + \frac{\rho}{0.7}y - e_0(\frac{\rho}{0.7} - R)} = \frac{0.15}{(1+e_0-x-y)}$$

Solving these and using the values of the example together with $y = 0.3$ we get

$$\begin{aligned} e_0 &= 0.25; e_1 = 0; e_2 = 0.40; \\ x &= 0.5; 1 + e_0 - x - y = 0.45 \\ (1 + e_0 - x - y)R + \frac{\rho}{0.7}y - e_2 &= 0.55; (1 + e_0 - x - y)R = 0.47. \end{aligned}$$

The condition for not having a run at date 1 in the state where it is learned the loans don't pay off is

$$U(x/0.5) \leq U((1 + e_0 - x - y)R/0.5)$$

Putting $x = 0.5$ and $(1 + e_0 - x - y)R = 0.47$, it can be seen that this condition is not satisfied. Since when there is a run the bank goes bankrupt all the 0.45 units of the long asset are liquidated for 0, this cannot be optimal. In order to ensure that there is not a run at date 1 we need that

$$x \leq (1 + e_0 - x - y)R.$$

Solving the banks problem with this constraint binding gives the following solution.

$$\begin{aligned} e_0 &= 0.26; e_1 = 0; e_2 = 0.42; \\ x &= (1 + e_0 - x - y)R = 0.49; 1 + e_0 - x - y = 0.47; \\ (1 + e_0 - x - y)R + \frac{\rho}{0.7}y - e_2 &= 0.55; \\ EU &= 0.025. \end{aligned}$$

This is the autarkic solution for the bank. Its depositors get expected utility of 0.025. There are no runs in this equilibrium and this is optimal.

One important thing concerns the role that capital is playing in the banking sector. Since the providers of capital are risk neutral they provide risk smoothing to the depositors in the bank. The assets their capital provides

pay off when the loans do not and they only receive a payment when the loans pay off. The reason that the providers of capital do not bear all the risk is that capital is costly. In other words their opportunity cost of capital is higher than the return on the long asset. If it was the same there would be full risk smoothing and the depositors would consume the same in every state.

4.2 The insurance sector

The insurance sector is considered next on its own. As explained above there are firms that own assets that produce A at $t = 2$. For our example, we assume that $A = 1.15$. The owners of these firms have $V = Ln(c)$.

With some probability $\alpha(s)$ a firm's asset is damaged at date $t = 1$. It costs $C = 1$ to repair the asset in which case it produces A at $t = 2$. Without repair the asset produces nothing. Insurance companies insure these firms.

In state l the probability $\alpha(l) = 0.5$ and this state occurs with probability 0.9. In state h the probability $\alpha(h) = 1$ and this state occurs with probability 0.1.

Each firm has an endowment of 1 at date $t = 0$ that it can use to buy insurance or invest itself.

The insurance industry is competitive so the companies do not earn any profits. Like the banks they maximize the expected utility of the owners of the firms they insure. If they did not do this, their customers would be taken away by another insurance company. The insurance companies can offer partial or full insurance to firms. If they offer partial insurance they charge 0.5 at date 0. Suppose the firms put the other 0.5 of their endowment in the long term asset (it will be shown this is optimal shortly). In order to have funds to repair the damaged assets the insurance companies must invest in the short asset so that they have liquidity at date 1. In state l the funds they need for claims to repair the damaged assets are $\alpha(l)C = 0.5$. They have funds of 0.5 and can pay all the claims to repair the damaged assets. The utility of the owners of the firms is therefore $V(A + 0.5R)$. In state h the insurance companies receive claims of $\alpha(h)C = 1$. They don't have sufficient funds to pay these so they go bankrupt. With partial insurance there is thus systemic risk in the insurance industry. When the insurance companies go bankrupt their assets are distributed equally among the claimants. The firms receive 0.5 from the insurance companies' liquidation of its short term assets. The firms can't repair their assets so these produce nothing. In state h the

utility of the owners of the firm is therefore $V(0.5 + 0.5R)$. Their expected utility with partial insurance is

$$EV_{\text{partial}} = 0.9V(A + 0.5R) + 0.1V(0.5 + 0.5R) = 0.467.$$

Notice that if the firms put the other 0.5 of the endowment in the short rather than the long asset they would be able to repair their assets in state h but they would only receive 0.5 in state l from their investment. Hence their expected utility would be

$$EV = 0.9V(A + 0.5) + 0.1V(A) = 0.465,$$

so they would be worse off.

If the insurance company offered full insurance they would charge 1 at $t = 0$ and could meet all of their claims in both states. At $t = 1$ in state l they would have 0.5 left over. Since the industry is competitive they would pay this out to the insured firms. In this case

$$EV_{\text{full}} = 0.9V(A + 0.5) + 0.1V(A) = 0.465.$$

Again this is worse than partial insurance.

Thus the optimal scheme is for the insurance industry to partially insure firms and to charge 0.5 at $t = 0$. The firms put the remaining part of their endowment in the long asset. The role of the assumption that the long asset cannot be liquidated at date 1 for a positive amount is again important here. This ensures that the firms do not pay any excess into the insurance companies. All their surplus funds are invested within the firm in the long asset. This ensures that when the insurance companies go bankrupt in state h completely inefficient liquidation of the long asset is eliminated.

In this case there is no role for capital in the insurance sector. Capital providers charge a premium. Their funds would have to be invested in the short asset since it is not optimal to hold any long assets. There are already potentially enough funds from customers to hold more of the short asset but it is not worth it. If there is a premium to be paid for the capital it is even less worth it. Capital will not be used in the insurance industry unless they are regulated to do so.

5 Credit risk transfer

In the previous sections the banking and insurance sectors have been considered in isolation. Suppose next that the risks in the two sectors are independent. Then the four possible states and their payoffs are as follows.

State	Bank loans	Depositors (Late)	Insurance claims	Firms	Probability
1	3	1.10	50 percent	1.68	$0.7 \times 0.9 = 0.63$
2	3	1.10	100 percent	1.03	$0.7 \times 0.1 = 0.07$
3	0	0.98	50 percent	1.68	$0.3 \times 0.9 = 0.27$
4	0	0.98	100 percent	1.03	$0.3 \times 0.1 = 0.03$

It can be seen that the depositors in the banks who are late consumers have different payoffs in states 1 and 2 compared to states 3 and 4. The payoffs to the owners of the firms being insured are also different in states 1 and 3 as compared to 2 and 4. These differences mean that there is potential for risk sharing between the two groups. Credit risk transfer between the two sectors provides one way of providing this risk sharing. For the moment the assumption that the long asset cannot be liquidated for a positive amount in a market at date 1 is maintained. In the event of bankruptcy long assets are liquidated for zero.

For simplicity the focus is on a particularly simple form of risk transfer. The banks make a payment to the insurance companies in state 2. The insurance companies make a payment to the banks in state 3. Notice that markets are still not complete with this credit risk transfer. There is only one contract, not state-contingent securities which would be required for complete markets. For simplicity it is assumed that the banks' depositors obtain the surplus from the credit risk transfer. The insurance companies will compete to provide the credit risk transfer that maximizes the utility of the banks' depositors at the lowest cost to themselves. In equilibrium they will obtain their reservation utility, which is what they would receive in autarky.

How can such transfers be implemented? In state 2 the banks' loans pay off so they have excess funds and they can simply transfer these to the insurance companies. In state 3 the owners of the firms that insure their assets with the insurance companies have plenty of funds. However, the insurance companies themselves do not. They are only holding enough to meet claims in states 1 and 3. In order for them to be able to make a payout on the credit risk transfer in state 3 at date 2 to the banks at date they must

hold extra assets. They must charge the firms more initially and the firms will reduce their holdings of the long asset. If the insurance companies hold the short asset there is an opportunity cost of $R - 1$ in all states. Let the transfer from the banks to the insurance companies in state 2 be $Z2$ and the transfer from the insurance companies to the banks in state 3 be $Z3$. The amount they must hold in the short asset to be able to fulfil their side of the contract in state 3 is $Z3$ and the opportunity cost in each state is $Z3(R - 1)$. The expected utility of the customers of the insurance company, which is ultimately the objective function of the insurance companies, is then

$$EV_{short} = 0.63V(A + 0.5R - Z3(R - 1)) + 0.07V(0.5 + 0.5R + Z2 - Z3(R - 1)) + 0.27V(A + 0.5R - Z3 - Z3(R - 1)) + 0.03V(0.5 + 0.5R - Z3(R - 1)).$$

Now with $Z2 = 0.16$ and $Z3 = 0.05$, which maximizes the expected utility of the banks and keeps the insurance companies at the same level as they would receive in autarky, the expected utility of the latter is

$$EV_{short} = 0.467.$$

Now if the insurance companies were instead to invest the extra money they raise in the long asset rather than the short asset they would not suffer an opportunity cost $Z3(R - 1)$ in each state. On the other hand they suffer a loss of $Z3$ in states 2 and 4 when they go bankrupt since it is not possible to liquidate the long asset for a positive amount. Their expected utility in this case is

$$\begin{aligned} EV_{long} &= 0.63V(A + 0.5R) + 0.07V(0.5 + 0.5R + Z2 - Z3) + \\ &\quad 0.27V(A + 0.5R - Z3) + 0.03V(0.5 + 0.5R - Z3) \\ &= 0.464. \end{aligned}$$

Thus the insurance company is better off to use the short asset rather than the long asset to fund its credit risk transfer payment in state 3. The amount needed to do this, $Z3$, is raised at date 0 from the firms that are insured as part of the premium they pay.

As far as the banks are concerned, their expected utility is increased relative to autarky by this credit risk transfer. They receive

$$\begin{aligned}
EU &= 0.5U(x/0.5) + 0.5[0.63U(((1-x-y)R + \frac{\rho}{0.7}y - e_0(\frac{\rho}{0.7} - R))/0.5) + \\
&\quad 0.07U(((1-x-y)R + \frac{\rho}{0.7}y - e_0(\frac{\rho}{0.7} - R) - Z2)/0.5) + \\
&\quad 0.27U(((1+e_0-x-y)R + Z3)/0.5) + 0.03U(((1+e_0-x-y)R)/0.5) \\
&= 0.027.
\end{aligned}$$

This compares with $EU = 0.025$ in autarky. The overall result of credit risk transfer is therefore beneficial. Limited credit risk transfer has been considered here because it is only in states 2 and 3 but nevertheless it allows a Pareto improvement. If credit risk transfer was allowed in more states a further improvement would be possible.

6 Financial fragility and contagion

Although credit risk transfer has allowed an improvement in welfare the potential benefits have at first sight been smaller than they potentially might be because the insurance companies are unable to liquidate the long asset for a positive amount when they go bankrupt in states 2 and 4. This is clearly wasteful and it would seem that it limits the benefits that can be obtained from credit risk transfer. If instead of being unable to liquidate the long asset, the insurance companies could receive the full value this would improve welfare. In this case the expected utility of the insurance companies customers when the company uses the long asset goes from 0.464 to

$$\begin{aligned}
EV_{long} &= 0.63U(A + 0.5R) + 0.07U(0.5 + 0.5R + Z2) + \\
&\quad 0.27U(A + 0.5R - Z3) + 0.03U(0.5 + 0.5R) \\
&= 0.469.
\end{aligned}$$

This would suggest that the financial innovation of creating a market for the long asset to enable the insurance companies to sell their holdings when they go bankrupt would improve welfare since it would eliminate waste. However, it will be seen below that in fact the fragility of the financial system and the possibility of contagion means that this may not be the case.

Financial fragility is defined to be a situation where a small event can have a large impact. A crucial role is played by the incompleteness of markets. In order to understand this, it is helpful to start by considering the complete markets case. Allen and Gale (2004a) investigates the sufficient conditions for efficient risk sharing. When (a) markets for aggregate risk are complete, (b) participation is incomplete, and (c) contracts are complete, a *laissez-faire* equilibrium is incentive-efficient. The risk sharing contracts intermediaries offer consumers may be incomplete: for example, a demand deposit offers consumers a fixed amount of money independently of the aggregate state of nature. Nonetheless, incompleteness of contracts does not lead to market failure. When (a) markets for aggregate risk are complete, (b) participation is incomplete, and (c) contracts are incomplete, a *laissez-faire* equilibrium is constrained-efficient.

Complete markets also have important implications for asset pricing. When markets are complete, intermediaries trade contingent securities to provide liquidity in each state. There is no need to sell assets to obtain liquidity and asset pricing is independent of liquidity needs. When markets are incomplete, however, intermediaries are forced to sell assets in order to obtain liquidity. An increase in liquidity demand increases the quantity of assets supplied to the market, which reduces asset prices. The fall in asset prices may necessitate the supply of an even greater quantity of assets. This “backward bending supply curve of assets” lies behind the phenomenon of financial fragility.

Allen and Gale (2004b, 2005b) investigate the relationship between incomplete markets and asset-price volatility, which provides the key to understanding financial fragility in this model. If an aggregate shock requires several intermediaries to sell assets at the same time, the attempt to obtain liquidity may be self-defeating: as the asset sales push asset prices lower, intermediaries are forced to sell even more assets, which exacerbates the decline in prices. In extreme cases, the fall in asset prices may make it impossible for intermediaries to meet their short-term commitments, forcing a default. Because of this “multiplier effect”, very small shocks can have large effects on asset prices and financial stability.

Although a stylized example is used to illustrate these ideas, it can be argued that the lessons are applicable to many areas of the financial system. Liquidity plays a crucial role in a world in which markets and contracts are incomplete. Whenever a firm or financial institution has to make a fixed payment, independently of the state of nature, it runs the risk of having

insufficient liquidity. When firms and financial institutions are forced to obtain liquidity by selling assets, the suppliers of liquidity will demand a premium in the form of low asset prices in states where the demand for liquidity is high. This general principle, that the supply of liquidity must always be insufficient to prevent asset price volatility in equilibrium, is valid throughout the financial system. It applies whenever there are incomplete contracts and incomplete markets.

In the current context, the creation of a market for the long asset to allow the insurance companies to sell the long asset when they go bankrupt can create fragility. The first issue is that somebody must supply liquidity to this market. In other words they must hold the short asset in order to have the funds to purchase the long asset supplied to the market by the insurance companies when they go bankrupt in states 2 and 4. To see this suppose nobody did hold liquidity. Then there would be nobody on the other side of the market and the price of the long asset would fall to zero at date 1. This can't be an equilibrium though because by holding a very small amount of cash somebody would be able to enter and make a large profit.

In the framework considered in this paper, the group that will supply the liquidity is the investors who provide the capital to the banks. In order to be willing to hold this liquidity they must be able to recoup their opportunity cost. Since in states 1 and 3 when there is no liquidation of assets they end up holding the low-return short asset throughout, they must make a significant profit in at least one of the states 2 and 4 when the insurance companies go bankrupt. In other words, the price of the long asset must be low in at least one of these states.

In equilibrium, it turns out that what happens is that in state 4 when the insurance companies have high claims and go bankrupt and the banks' loans don't pay off the price of the long asset falls to

$$P4 = 0.20.$$

This low price provides the incentive that is needed for the investors to provide the liquidity needed for the market. However, it also causes **contagion**. If the banks' assets are marked to the market then the problem is that the banks become insolvent. The banks have 0.49 in the short asset and 0.47 in the long asset. The market value of these assets in state 4 when $P4 = 0.20$ is

$$0.49 + 0.47 \times 0.20 = 0.58.$$

The banks' liabilities to all their depositors are $0.49/0.5 = 0.98$. Since this is less than the value of their assets then if they are forced to mark assets to the market they will be declared insolvent and liquidated. Thus in addition to the insurance companies' long assets of $Z3/R = 0.08$ the banks' long assets of 0.47 are also liquidated.

In equilibrium the investors will hold 0.11 in the short asset, or in other words in cash, at date 0. This is the amount of cash that in equilibrium ensures that

$$P4 = \frac{0.11}{0.08 + 0.47} = 0.2.$$

There is cash in the market pricing where the bankrupt insurance companies and banks sell their assets and the investors who are the only ones with cash buy the assets up. The market clearing price is 0.2. This of course means that in state 4 the investors make a significant profit because the assets will pay off 1.05 with certainty. However, overall given the costs of holding cash they only just recoup their opportunity cost of $\rho = 1.1$. The price of the long asset at date 1 in the other three states will be

$$P1 = P2 = P3 = R = 1.05.$$

In states 1 and 3 the reason for this is straightforward. In these states there is no bankruptcy and no sale of assets. Given that the banks and the insurance companies hold the long asset between dates 1 and 2 the equilibrium price must be R . This ensures that both cash and the long asset will be held and markets will clear. If $P < R$ then the investors would want to buy the asset since it would provide a higher return than cash. If $P > R$ then the banks and insurance companies would sell the long asset and then hold cash until date 2 instead. The only price at which both cash and the long asset will be held between dates 1 and 2, which is necessary for equilibrium, is $P = R$. In state 2 it is slightly more complicated. Here the insurance companies go bankrupt and sell their $Z3/R = 0.08$ of the long asset. The investors will be able to buy this amount of the long asset and still have cash left over. Again this surplus of cash means that $P2 = R$ by the same argument as for $P1$ and $P3$. At this price there is cash left over because $0.08 \times 1.05 = 0.084 < 0.11$.

To see that the investors just recover their opportunity cost note that

$$1.1 \times 0.11 = 0.97 \times 1 \times 0.11 + (1.05 - 0.20) \times \frac{0.11}{0.20}.$$

The term on the left hand side is the investors' opportunity cost of holding 0.11 in cash. The first term on the right hand side is the payoff from holding

cash in states 1, 2, and 3. The second term is the profit from buying the long asset at the low price of P_4 .

When this contagion and inefficiency is taken account of then in fact there is a Pareto reduction in welfare. The investors and the insurance companies have the same levels of utility as in autarky. The banks however are worse off since their assets are liquidated at a low level in state 4 and this makes them worse off. Of course, taking prices as given everybody keeps doing the credit risk transfer. However, the financial fragility and contagion mean that what would apparently be welfare improving, namely the credit risk transfer and the creation of a market for liquidating the long asset in fact make some worse off and leave everybody else at the same welfare as in autarky.

An important role in this mechanism is played by marking to market. If assets were valued at historic costs then there would not be contagion. The assets' value would be recorded as being the same as they cost and this would cover the liabilities. At date 2 the banks could cover their liabilities and everybody would be paid off in full. The reason for the failure of mark-to-market accounting is that when prices are determined by liquidity rather than future payoffs they no longer are appropriate for valuing financial institutions' assets. This point has important implications for the debate on mark-to-market accounting versus historic accounting for financial institutions. It suggests that mark-to-market accounting may increase the possibility of contagion which has negative effects for welfare.

7 Concluding remarks

This paper has shown that financial innovations such as credit risk transfer can be beneficial. However, if markets for liquidating assets are introduced and there is mark-to-market accounting then there can be fragility and contagion which lead to a Pareto reduction in welfare. Hence financial innovation can have somewhat unexpected results. It is necessary to consider all the systemic effects when deciding whether or not it is beneficial.

The counterexample presented in this paper was developed in the context of banking and insurance. It is clear that these are not crucial for innovations to have systemic effects. It is the interaction of incomplete markets and incentives to provide liquidity that are key. These can occur in the context of many financial institutions.

This paper has focused on the private provision of liquidity in markets

and has not analyzed the role of central banks in liquidity provision. In markets with limited participation it is likely that central banks will have problems injecting liquidity into the financial system that will reach the required markets and prevent the kind of fragility and contagion considered here. The justification used by the Federal Reserve Bank of New York for their intervention in arranging a private sector bailout of Long Term Capital Management in 1998 explicitly used this rationale. The issue of what the precise role of central banks in this kind of situation should be is an interesting question for future research.

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Table 1: Size of Credit Risk Transfer Markets (in billions of US \$)

Instrument	1995	1996	1997	1998	1999	2000	2001	2002
Loan trading (turnover)								
- US Market (Loan Pricing Corporation)	34	40	61	78	79	102	118	117 ¹
Credit Derivatives (outstanding)								
- BIS triennial survey				108			693	
- US OCC ²				144	287	426	395	492 ³
- British Bankers Association			180	350	586	893	1,189	1,952 ⁴
- Risk Magazine						810	1,398	
- ISDA							919	1,600 ⁴
Asset-backed securities								
- US market (outstanding) (Bond Market Association) ⁵	315	403	517	684	816	947	1,114	1,258 ⁶
- European market (issuance) (Moody's) ⁷					68	80	134	50 ⁸
- Australian market (outstanding) (Australian Bureau of Statistics)	7	10	15	19	27	33	38	54
Collateralised debt obligations								
- US market (outstanding) (Bond Market Association)	1	1	19	48	85	125	167	232 ⁶
- European market (issuance) (Moody's)					42	71	114	70 ⁸
Total bank credit (outstanding)¹⁰	23,424	23,576	23,309	26,018	26,904	27,221	27,442	29,435 ⁹
- IMF								
Corporate debt securities¹¹ (outstanding)	3,241	3,373	3,444	4,042	4,584	4,939	5,233	5,505 ⁹
- BIS								

Footnotes: ¹First three quarters of 2002, annualised. ²Holdings of US commercial banks. ³ Second Quarter of 2002. ⁴Forecast for 2002. ⁵Excluding CB)os/CDOs. ⁶ September 2002. ⁷ ABSs and MBSs. ⁸First half of 2002. ⁹ June 2002. ¹⁰ Domestic and international credit to non-bank borrowers (United States, United Kingdom, Japan, Canada, Euro area). ¹¹ Debt securities issued in international and domestic markets, non-financial corporates.

Table 2
The Buyers and Sellers of Credit Protection
(% of market)

Panel A: The Buyers of Credit Protection

	End of 1999	End of 2001
Banks	63	52
Securities Houses	18	21
Hedge Funds	3	12
Corporates	6	4
Insurance Companies ¹	7	6
Mutual Funds	1	2
Pension Funds	1	1
Government/Export credit agencies	1	2

Panel B: Sellers of Credit Protection

	End of 1999	End of 2001
Banks	47	39
Securities Houses	16	16
Hedge Funds	5	5
Corporates	3	2
Insurance Companies ¹	23	33
Mutual Funds	2	3
Pension Funds	3	2
Government/Export credit agencies	1	0

Footnote: ¹Includes mono-line companies and reinsurers.

Source: BBA Credit Derivatives Report 2001/2002