Systemic Risk and Regulation*

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Abstract

Historically, much of the banking regulation that was put in place was designed to reduce systemic risk. In many countries capital regulation in the form of the Basel agreements is currently one of the most important measures to reduce systemic risk. In recent years there has been considerable growth in the transfer of credit risk across and between sectors of the financial system. In particular there is evidence that risk has been transfered from the banking sector to the insurance sector. One argument is that this is desirable and simply reflects diversification opportunities. Another is that it represents regulatory arbitrage and the concentration of risk that may result from this could

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increase systemic risk. This paper shows that both scenarios are possible depending on whether markets and contracts are complete or incomplete.

1 Introduction

The experience of banking crises in the 1930s was severe. Before this assuring financial stability was primarily the responsibility of central banks. The Bank of England had led the way. The last true panic in England was associated with the collapse of the Overend, Gurney and Company in 1866. After that the Bank avoided crises by skilful manipulation of the discount rate and supply of liquidity to the market. Many other central banks followed suit and by the end of the nineteenth century crises in Europe were rare. Although the Federal Reserve System was founded in 1914 its decentralized structure meant that it was not able to effectively prevent banking crises. The effect of the banking crises in the 1930s was so detrimental that in addition to reforming the Federal Reserve System the US also imposed many types of banking regulation to prevent systemic risk. These included capital adequacy standards, asset restrictions, liquidity requirements, reserve requirements, interest rate ceilings on deposits, and restrictions on services and product lines. Over the years many of these regulations have been removed. However, capital adequacy requirements in the form of the Basel agreements remain.

If properly designed and implemented capital regulations may reduce systemic risk. However, the growing importance of credit risk transfer has raised concerns about whether regulation as currently implemented does increase financial stability. The evidence reviewed below suggests that there is a transfer of risk from the banks to insurance companies. One view is that this credit risk transfer is desirable because it allows diversification between different sectors of the financial system that cannot be achieved in other ways. On the other hand, if the transfer arises because of ill-designed regulations it may be undesirable. For example, regulatory arbitrage between the banking and insurance sectors could conceivably lead to an increase in risk in the insurance sector which increases overall systemic risk. As Hellwig (1994, 1995, 1998) has repeatedly argued, attempts to shift risks can lead to a situation where these risks come back in the form of counterparty credit risk.

The purpose of this paper is to consider both arguments. We show firstly that diversification across sectors can lead to an optimal allocation of resources and secondly that poorly designed and implemented capital regulation can lead to an increase in systemic risk.

Our analysis builds on our previous work on financial crises (see, e.g., Allen and Gale (1998, 2000a-c, 2003, 2004a-b) and Gale (2003, 2004)). In Allen and Gale (2004a) we argued that financial regulation should be based on a careful analysis of the market failure that justifies government intervention. We developed a model of intermediaries and financial markets in which intermediaries could trade risk. It was shown that provided financial markets and financial contracts are complete the allocation is incentive efficient. When contracts are incomplete, for example, if the banks use deposit contracts with fixed promised payments, then the allocation is constrained efficient. In other words, there is no justification for regulation by the government. In order for regulation to be justified markets must be incomplete. As in standard theories of government regulation it is first necessary to identify a market failure to analyze intervention. In Allen and Gale (2003) we suggested that the standard justification for capital regulation, namely that it controls moral hazard arising from deposit insurance is not a good motivation. The two policies must be jointly justified and the literature does not do this.

There is a small but growing literature on credit risk transfer. The first part considers the impact of credit risk transfer on the allocation of resources when there is asymmetric information. Morrison (2005) shows that a market for credit derivatives can destroy the signalling role of bank debt and lead to an overall reduction in welfare as a result. He suggests that disclosure requirements for credit derivatives can help offset this effect. Nicolo and Pelizzon (2004) show that if there are banks with different abilities to screen borrowers then good banks can signal their type using first-to-default basket contracts that are often used in practice. These involve a payment to the protection buyer if any of a basket of assets defaults. Only protection sellers with very good screening abilities will be prepared to use such contracts. Chiesa (2004) considers a situation where banks have a comparative advantage in evaluating and monitoring risks but limited risk bearing capacity. Credit risk transfer improves efficiency by allowing the monitored debt of large firms to be transfered to the market while banks can use their limited risk bearing capacity for loans to small businesses. In contrast to these papers, our paper focuses on the situation where there is symmetric information and shows how credit risk transfer can improve the allocation of resources through better risk sharing.

The second part of the literature focuses on the stability aspects of credit risk transfer. Wagner and Marsh (2004) considers the transfer of risk between banking and non-banking sectors. They find that the transfer of risk out of a relatively fragile banking sector leads to an improvement in stability. Wagner (2005a) develops a model where credit risk transfer improves the liquidity of bank assets. However, this can increase the probability of crises by increasing the risks that banks are prepared to take. Wagner (2005b) shows that the increased portfolio diversification possibilities introduced by credit risk transfer can increase the probability of liquidity-based crises. The reason is that the increased diversification leads banks to reduce the amount of liquid assets they hold and increase the amount of risky assets. In contrast to these contributions, in our paper the focus is on the role of poorly designed regulation and its interaction with credit risk transfer in increasing systemic risk.

The rest of the paper proceeds as follows. We start in Section 2 by considering the institutional background of credit risk transfer. We consider the evidence on how important risk transfers are quantitatively and which entities they occur between. Section 3 develops a model with a banking sector where consumers deposit their funds and firms borrow and repay these loans with some probability. There is also an insurance sector. Some firms have an asset that may be damaged. They require insurance to allow this asset to be repaired if it is damaged. The equilibrium with complete markets and contracts is characterized. In this case complete markets allow full risk sharing. Section 4 develops an example with incomplete markets and contracts and shows how inefficient capital regulation can increase systemic risk. Finally Section 5 contains concluding remarks.

2 Institutional background on 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 tranched 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. However, BIS (2005) reports that credit risk transfer investments made up only 1 percent of insurers' total investments and their financial strength is not thereatened by their involvement in these types of investment.

As discussed in the introduction, these figures raise the important issue of why these transfers of risk are taking place. Is it the result of financial institutions seeking to diversify their risk? Alternatively, is it the result of regulatory arbitrage and if so can this arbitrage lead to a concentration of risk that increases the probability of systemic collapse?

We turn to the role of credit risk transfer in allowing diversification between different sectors of the economy next.

3 Diversification through credit risk transfer

We use a simple Arrow-Debreu economy to illustrate the welfare properties of credit risk transfer when markets are complete. First we describe the primitives of the model, which will be used here and in following sections. Then we describe an equilibrium with complete markets. We note that the fundamental theorems of welfare economics imply that risk sharing is efficient and, hence, there is no role for government regulation in this setting. It is also worth noting that there is no role for capital. More precisely, the capital structure is irrelevant to the value of the firm, as claimed by Modigliani and Miller, and in particular there is no rationale for capital regulation. (This point has been made repeatedly by Gale, 2003, 2004; Allen and Gale, 2003; and Gale and Özgür, 2005).

The model serves two purposes. First, it serves to show how credit risk transfers can promote efficient risk sharing if we interpret the markets for contingent securities in the Arrow-Debreu model as derivatives or insurance contracts. Secondly, it provides a benchmark for the discussion of incomplete markets that follows. By contrast with the Arrow-Debreu model, there is no reason to think that the equilibrium allocation of risk bearing is efficient when markets are incomplete. So incompleteness of markets provides a potential role for regulation to improve risk sharing. However, as we shall see, a badly designed policy of capital regulation may lead to greater instability.

3.1 The basic model

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 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). This simple structure provides a tradeoff between liquidity and the rate of return (the yield curve). Banks would like to earn the higher return offered by the long asset, but that may cause problems because the banks' liabilities (demand deposits) are liquid.

In addition to these securities, banks and insurance companies have distinct profitable 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_H units of the good at date 2 if successful and B_L 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 constant-returns-to-scale investment technology for the banks). Because we are only interested in non-diversifiable risks, we assume that the loans made by an individual bank are perfectly correlated: either they all pay off or none do. This is a gross simplification that does not essentially affect the points we want to make.

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. 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 form of the depositors' preferences provides a demand for liquidity and explains why the bank must offer a contract that allows the option of withdrawing either at date 1 or date 2.

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. The risks to different firms are assumed to be independent, so the fraction of firms suffering damage in any state is equal to the probability α. More importantly, the risks faced by the insurance and banking sectors are not perfectly correlated, so there are some gains from sharing risks. This in turn provides the potential for gains from credit risk transfer.

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. This is a crucial assumption. Without it, the investors could absorb all risk and provide unlimited liquidity and the problem of achieving efficient risk sharing would be trivial. The assumption of non-negative consumption, on the other hand, implies that investors can only provide risk sharing services to banks and/or insurance companies if they invest in real assets that provide future income streams. 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 $\rho > E[R]$ represents the investor's opportunity cost of funds. For example, the investors may have access to investments that yield a very high rate of return but are very risky and very illiquid. Markets are segmented and other agents do not have access to these assets. Banks cannot include these assets in their portfolios, so they cannot earn as much on the capital invested in the bank as the investors could. This gap defines the economic cost of capital: in order to compensate the investors for the opportunity cost of the capital they invest, the depositors must take a smaller payout in order to subsidize the earnings of the investors.

We can assume without loss of generality that the role of investors is simply to provide capital to the intermediary through a 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 (unbounded) amount of the good X_0 at date 0 and nothing at dates 1 and 2. This assumption has two important implications. First, since the investors have an unbounded endowment at date 0 there is free entry into the capital market and the usual zero-profit condition implies that 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:

$$u(e_0, e_1, e_2) = \rho X_0 - \rho e_0 + e_1 + e_2.$$

The most plausible 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. For the purposes of illustration, suppose that α and β each take on two values, α_H and α_L and β_H and β_L. Nothing would change if we adopted a more general structure, but this is enough to make the essential points. Note that α and β are not perfectly correlated. We may observe any combination of values, (α_H, β_H), (α_L, β_H), (α_H, β_L), or (α_L, β_L). The uncertainty in the model is resolved at the beginning of date 1. Banks' depositors learn whether they are early or late consumers and banks learn whether the firms borrowing from them have failed. Insurance companies learn which firms' assets have suffered damage.

3.2 An Arrow-Debreu equilibrium

In this section we provide a sketch of the definition of Arrow-Debreu equilibrium for the model outlined above. (A more complete treatment of equilibrium can be found in Gale, 2004). We stress the market structure and its role in allowing economic agents to achieve an optimal allocation of risk and intertemporal consumption.

Contingent securities Aggregate uncertainty is determined by the four states of nature

$$s \in S = \{(\alpha_H, \beta_H), (\alpha_L, \beta_H), (\alpha_H, \beta_L), (\alpha_L, \beta_L)\}.$$

We denote these four states HH, LH, HL, LL. Contingent securities are defined by the date of delivery and the state on which delivery is contingent. The true aggregate state s is unknown at date 0 and is revealed at date 1, so there are nine contingent securities, a single contingent security which promises one unit of the good at date 0 and and a contingent security that promises delivery of one unit of the good at date t in state s for every $t = 1, 2$ and $s = S$. We denote the security delivering the good at date 0 by 0 and the security delivering the good at date t in state s by (t, s) for $t = 1, 2$ and $s \in S$.

The simplest way to represent complete markets is to assume there exists a separate market at date 0 for each of the contingent securities defined above. Take security 0 to be the numeraire and let $q_t(s)$ denote the price, in terms of the numeraire, of one unit of security (t, s).

It is important to realize that the Arrow security markets only allow one to hedge aggregate risks. The idiosyncratic risks presented by the damage to individual firms insured by the insurance sector and the failure of individual firms borrowing from the banking sector cannot be hedged using these markets. However, because there are large numbers of firms in the respective sectors and the insurance companies and banks, respectively, can perfectly hedge these risks by pooling, markets for all risks, aggregate and idiosyncratic, are effectively complete once we take into account the role of the intermediaries as well as the Arrow securities. An alternative approach would have been to allow firms to enter markets for idiosyncratic risk. These markets would be competitive despite the presence of a single supplier, since the risks are effectively perfect substitutes in a world with perfect diversification.

No-arbitrage conditions Because markets are complete, economic agents do not need to hold assets for the purpose of hedging risks or smoothing consumption. In fact, assets are redundant securities in the sense that they can be synthesized by trading contingent securities. Assets play an important role in equilibrium, however, because their existence places constraints on equilibrium prices and they are necessary to clear the goods market by altering the supply of contingent securities.

The short asset converts one unit of the good at date t into one unit of the good at date $t+1$, independently of the state. Since the state is unknown at date 0, the storage technology converts one unit of the good at date 0 into one unit of the good at date 1, independently of the state. So investing one unit of the good in the storage technology at date 0 produces one unit of each of the contingent securities $(1, s)$ at date 1. If the cost of the inputs is less than the value of the outputs, there is a riskless arbitrage, so equilibrium requires

$$\sum_{s \in S} q_1(s) \leq 1.$$

At date 1, the state is known so it possible to invest one unit in the short asset in state s and produce one unit of the contingent security $(2, s)$ at date 2. Then the no-arbitrage condition requires

$$q_2(s) \leq q_1(s)$$

for each state s. To see why this condition must hold, consider the following example, which violates the condition:

$$q_1(s) = 0.2 < 0.3 = q_2(s).$$

A riskless arbitrage profit can be achieved as follows. At date 0, buy one unit of the $(1, s)$ contingent security and sell one unit of the $(2, s)$ security for a profit of $0.3 - 0.2 = 0.1$. At date 1, if state s occurs the $(1, s)$ contingent security yields one unit of the good. Investing this unit of the good in the short asset produces one unit of the good at date 2 in state s, which can be used to redeem the unit of the $(2, s)$ contingent security issued at date 0.

Investment in the long asset is only possible at date 0, when the state is unknown, so the long asset only gives rise to one no-arbitrage condition. One unit of the good at date 0 yields R units of the good at date 2, independently of the state, in other words, R units of the contingent security $(2, s)$ for each state s. Then the no-arbitrage condition that the cost of the inputs is greater than or equal to the value of the outputs is

$$\sum_{s \in S} q_2(s) R \leq 1.$$

These no-arbitrage conditions can also be thought of as zero profit conditions. If the profit is negative, no one invests in the asset at that date and state; if someone does invest, the profit is zero. In either case, investments in the assets do not affect an economic agent's wealth (in the case of an individual) or market value (in the case of a firm). In the aggregate, some investment in these assets may be necessary in order to transform goods at one date into goods at a future date, but it is a matter of indifference which economic agent undertakes the investment activity. In particular, this implies a separation property holds for every agent's decision problem: the optimal investment in the short and long asset is independent of the agent's optimal choice of other variables, such as consumption or loan and insurance contracts.

Banking As in the standard Diamond and Dybvig (1983) model, banks provide liquidity insurance for consumers who are uncertain about the optimal timing of their consumption. Consumers deposit their endowments of one unit of the good with the bank at date 0 and are promised future consumption payments conditional on their types, early or late. An early consumer is promised $c_1(s)$ of the contingent security $(1, s)$ for each state s; a late consumer is promised $c_2(s)$ units of the contingent security $(2, s)$ for each state s. Thus, the contracts the banks offer are complete in the sense that they allow the payments made to vary acoss the aggregate states s. Free entry and competition in the banking sector force banks to offer contracts that maximize the expected utility of the typical depositor subject to the constraint that the bank break even on the deal. If a bank did not maximize the expected utility of depositors another bank would enter, offer a better contract and take away all its customers. The break-even condition is equivalent to a budget constraint that says the value of promised consumption is less than or equal to the value of the deposits. The deposits are one unit per capita and the per capita demand for consumption is $\lambda c_1(s)$ at date 1 in state s and $(1-\lambda)\, c_2(s)$ at date 2 in state s. The budget constraint can be written

$$\sum_{s \in S} \{q_1(s)\lambda c_1(s) + q_2(s)(1-\lambda)c_2(s)\} \leq 1.$$

Recall that we can ignore the bank's investments since they yield zero profits. The expected utility of the typical depositor can be constructed as follows. In each state s, the depositor has a probability λ of being an early consumer and $1-\lambda$ of being a late consumer, so his expected utility conditional on s is $\lambda U(c_1(s)) + (1-\lambda)U(c_2(s))$. Then the expected utility at date 0, before the state is known, is obtained by taking expectations over states:

$$E\left\{\lambda U(c_1(s)) + (1-\lambda)U(c_2(s))\right\}.$$

It is important to note that the depositors cannot trade directly in the markets for contingent securities or assets. As Cone (1983) and Jacklin (1986) have shown, it is not possible for depositors to obtain liquidity insurance from a bank if they can directly trade the securities the banks hold.

In addition to providing consumption smoothing for consumers, the banks can invest in loans to firms. Because we assume that entrepreneurs with projects are in perfectly elastic supply and banks have access to a limited amount of deposits, equilibrium requires that entrepreneurs earn zero profits. In other words, all the surplus goes to the banks. Since one unit of the good at date 0 produces B_H when the payoff is high and B_L when the payoff is low, the zero-profit condition requires that the face value of a loan of one unit to the firm is $D = B_H$. In the high-payoff state the firm can repay the loan but in the low payoff-state it defaults and the bank seizes the remaining value of the firm B_L. Because entrepreneurs are indifferent between borrowing to fund a project and not undertaking the project at all, the number of projects undertaken is determined by the supply of loanable funds from the bank. Although banks are earning a positive return on each loan, they are indifferent about the number of loans they offer because they can replicate these loans through the markets for Arrow securities (after pooling the idiosyncratic risks).

Insurance Insurance companies provide two services to firms. Note that these firms are different from the firms that borrow from banks. The insurance companies insure the firm's assets against damage (if it is efficient to do so) and they provide consumption smoothing to the owner of the firm. We make this assumption for convenience, but it is not necessary. The firms could provide the same consumption-smoothing services for themselves by trading contingent securities. Recall that in order for banks to provide insurance to their depositors it was necessary to exclude the depositors from the asset markets. By contrast, there is no need to limit the market participation of the insurance companies' customers. Since the damage to assets is observed by the insurance companies, there is no incentive constraint to worry about. We will allow firms to participate in markets when we consider the case of incomplete markets in the sequel.

It is efficient to repair the damage to the firm's asset if the cost of doing so is less than or equal to the value of the asset's output, that is, if $q_1(s)C \leq q_2(s)A$. An optimal insurance contract will make the decision to pay the damages contingent on the state. Contracts are again complete. The insurance company will also promise the firm owner consumption $a_2(s)$ at date 2 in state s. Free entry and competition in the insurance sector imply that the insurance companies offer firms a contract that maximizes the utility of the firm's owner subject to a break-even constraint. The break-even constraint is equivalent to the following budget constraint:

$$\sum_{s \in S} q_2(s)a_2(s) \leq 1 + \sum_{s \in S} \{\alpha(s) \max\{q_2(s)A - q_1(s)C, 0\} + (1 - \alpha(s))\, q_2(s)A\}.$$

The left hand side is the value of consumption promised to the owner; the right hand side is the value of the owner's endowment at date 0 plus the value of outputs from the firm's assets at date 2 net of damage payments at date 1. Note that we assume here that the insurance company can perfectly diversify across firms, so that exactly a fraction $\alpha(s)$ of its customers suffer damage in state s and $1 - \alpha(s)$ suffer no damage. Since the insurance companies are competitive their objective is to maximize the firm owner's expected utility

$$E\left[U\left(a_2(s)\right]\right.$$

subject to the budget constraint above.

Investors We can describe the investors' decision problem in a similar way, although it adds relatively little to our understanding of the model when markets are complete. Since there are a large number of investors with very large endowments, their consumption at date 0 is assumed to be positive. This implies that, unless they make zero profits by trading in markets for contingent securities, there will be an excess supply of investment. The only important implication for equilibrium takes the form of a no-arbitrage condition: any feasible consumption plan that requires the investor to sell e_0 units at date 0 and purchase $e_t(s) \geq 0$ units of the contingent security (t, s) that increases expected utility, must also cost a positive amount. Formally, if there exists a trade $\{e_0, e_t(s)\}$ such that

$$E\left[e_1(s) + e_2(s)\right] > \rho e_0$$

then it must be the case that

$$\sum_{s \in S} \{q_1(s)e_1(s) + q_2(s)e_2(s)\} > e_0.$$

Conversely, if $\{e_0, e_t(s)\}$ is a trade that occurs in equilibrium, then it must be the case that it leaves expected utility unchanged

$$E\left[e_1(s) + e_2(s)\right] = \rho e_0$$

and it leaves the budget constraint unchanged

$$\sum_{s \in S} \{q_1(s)e_1(s) + q_2(s)e_2(s)\} = e_0.$$

Otherwise, the trade would violate the no-arbitrage condition. Again, the no-arbitrage condition constrains equilibrium prices but does not otherwise affect equilibrium.

Investors may share some of the risks born by consumers and firms, but they do so indirectly through the markets for contingent securities rather than through explicit risk sharing contracts with individual consumers and firms. They perform this function by supplying e_0 at date 0 which can be invested in short or long assets or can be used to finance loans by the banks, and then take their earnings in states where consumers and owners have a high marginal utility of consumption. By doing this, they allow consumers and owners to reduce the variation in their consumption across states.

Welfare The first theorem of welfare economics tells us that, under very weak assumptions about non-satiation, every equilibrium of an Arrow-Debreu economy has a Pareto-efficient allocation of goods and services. So in the equilibrium sketched above, it is impossible to make some economic agents better off without making others worse off. In particular, risk sharing is efficient and there is no scope for government intervention or regulation to increase efficiency.

Absence of bank runs, bankruptcy, and systemic risk One important thing to note about the case of complete markets and contracts is that there is no bankruptcy for banks or insurance companies. Since it is possible to trade contingent securities for every state and contract payments can be varied in every state, assets and liabilities can always be matched so bank runs and bankruptcy do not occur. Since banks runs and bankruptcy do not occur there is no systemic risk with complete markets. As we will see when markets and contracts are incomplete this is no longer the case and this has important implications for the characteristics of equilibrium.

3.3 The Modigliani-Miller theorem for risk sharing

In an Arrow-Debreu world, risk sharing is mediated by markets. In particular, the capital is provided to the market and not to any specific individual financial institution. Similarly, there are no OTC derivatives traded between banks and insurance companies. Instead, they trade contingent securities with "the market". One could introduce specific capital contracts between investors and bank or insurers, but these would be redundant securities. In fact, we can establish a Modigliani-Miller theorem for banks and insurers along the lines of Gale (2004). For example, suppose that a bank wants to raise an amount of capital e_0. It will offer investors a contract (e_0, e_1, e_2) under which it promises to pay investors $e_t(s)$ in state s at date t in exchange for the contribution of e_0 at date 0. In order to be acceptable to the investors, the capital contract (e_0, e_1, e_2) will have to satisfy the participation constraint

$$E\left[-\rho e_0 + e_1(s) + e_2(s)\right] \geq 0.$$

The bank's objective function remains the same as before, but now the value of the capital contract is added to its budget constraint. Clearly, the bank will want to minimize the cost of the contract in order to maximize the "market value" of the bank. Thus, an optimal contract will minimize

$$E[-e_0 + q_1(s)e_1(s) + q_2(s)e_2(s)]$$

subject to the participation constraint above. This problem is the dual of the investor's decision problem in the preceding section. Because of the linearity of the problem, in equilibrium the market value of the contract is zero and the participation constraint is binding. In other words, the capital contract will have no effect on the bank's budget constraint and no effect on its objective function. Furthermore, the introduction of an explicit capital structure has no effect on the endogenous variables we care about (the allocation of consumption and investment in assets) because the trades implied by the contract are offset in the contingent security markets.

In an exactly similar way, we can show that any insurance contract between banks and insurance companies would be redundant. This does not mean that risk is not being shared between the insurance and banking sectors. To the extent that there is any scope for sharing risk between the two sectors (credit risk transfer), it is exploited fully and efficiently using the markets for contingent securities.

3.4 Derivatives and contracts

In practice, we do not observe markets for contingent securities as such. Instead, we observe markets for spot trading of assets, a variety of derivative securities whose purpose is to allow hedging of risk from the underlying securities, and a variety of risk sharing contracts such as insurance contracts. Regardless of the form which risk sharing takes, similarly to Ross (1976), if there are enough derivatives and contracts, markets will effectively be complete and the allocation of risk will be the same as in the Arrow-Debreu equilibrium. This is the sense in which credit risk transfer is desirable. If the instruments that transfer risk allow markets to be effectively complete then they ensure a Pareto-efficient allocation of resources is achieved. This is the first main result of the paper, that credit risk transfer is desirable when markets and contracts are effectively complete.

This argument assumes there is no capital regulation and indeed this is optimal. What happens if there is capital regulation? Suppose next we get rid of all contingent securities so markets are no longer complete but allow a spot market for assets at date 1 (equivalent to a forward market for consumption at date 2). If we still allow banks and insurers to write complete contracts, then markets are effectively complete because there are only two representative agents (plus the risk neutral investors who receive no surplus). However, in this case, the net effect of risk sharing between investors and the banks or insurance companies must be mediated by an explicit contract and it is this contract that is controlled by capital adequacy regulation. If the bank is required to increase e_0, this will have a real impact on its feasible set and on the value of its objective function. It cannot be offset by side trades because we assume that all trades are governed by pairwise contracts and those between the investors and banks are explicitly regulated. Markets are no longer effectively complete and the properties of equilibrium change significantly.

We next develop a simple numerical example to show that, when markets and contracts are incomplete, there can be an increase in systemic risk as a result of capital regulation that forces banks to hold too much capital.

4 Increased systemic risk from capital regulation

In this section we present simple numerical examples to illustrate our second result that capital regulation can increase systemic risk when markets and contracts are incomplete. In contrast to the previous section, we assume there are no state contingent securities. Whereas with complete markets it was possible to trade securities that paid off 1 unit of the consumption good in aggregate states HH, LH, HL, and LL at dates $t = 1, 2$ now this is not the case. There are only markets for the long and short assets. Contracts are also incomplete. Whereas before payoffs could be made explicitly contingent on states HH, LH, HL, and LL, this is no longer possible.

We start by considering the banking sector on its own and then go on to consider the insurance sector in isolation. Without capital regulation we show that in the example there is no incentive to have credit risk transfer between the two sectors. However, with capital regulation where capital can be reduced when there is credit risk transfer between the sectors, we show that the transfer will take place. Moreover, this credit risk transfer can increase systemic risk in the banking sector.

4.1 The banking sector

No capital

To start with we consider what happens if there is no capital available for banks from investors.

Example 1

The return on the long asset is $R = 1.4$.

For depositors in the banks $\lambda = 0.5$; and $U(c) = Ln(c)$. In state β_H for banks, which occurs with probability 0.7, the loans pay off $B_H = 1.7$ with probability $\beta_H = 1$. The probability of state β_L is 0.3 and in this state the loans pay off $B_L = 0.9$ with probability $1 - \beta_L = 1$.

Banks' investment in the short asset is denoted x, their investment in the long asset is denoted y, and their loans to firms are denoted z. They receive an endowment of 1 from depositors so $x + y + z = 1$.

The contract the banks use with their depositors are incomplete in the following sense. The banks cannot make the payment at date 1 contingent on the aggregate state. The aggregate state at date 1 is now observable but not verifiable and hence contracts cannot be made contingent on it. Instead the deposit contract banks use promises a fixed amount c_1 to any depositor wishing to withdraw. Since the banking industry is competitive, then as before each bank's objective is to maximize the expected utility of its depositors. If a bank did not do this then another bank would enter, offer a better contract, and take away all its customers. The implication of this is that the banks will pay out all their remaining funds to late consumers at date 2. The amount the late consumers will receive will depend on whether or not firms' loans are repaid in full. Hence there are two possible payouts, c_{2H} in state β_H, and c_{2L} in state β_L.

Banks are unable to distinguish between early and late consumers. If late consumers deduce that they will be better off withdrawing at date 1 then all depositors will attempt to withdraw. If a bank is unable to meet the demands of its depositors then it goes bankrupt, its assets are liquidated, and the proceeds are distributed to the depositors in proportion to their deposits. When markets and contracts were complete assets and liabilities could be balanced state by state and bankruptcy never occurred. Now, however, bankruptcy may occur if late consumers have an incentive to pretend to be early consumers so there is a run on the bank.

At date 0, the banks choose their portfolio, x, y, and z and the deposit contract c_1, c_{2H}, and c_{2L} to maximize the expected utility of the depositors. In equilibrium, x, y, and z must be non-negative. We will suppose initially that there are no runs and check to see that this assumption is satisfied. Since in this case there is no uncertainty about the banks' needs for liquidity at date 1, they will use the short term asset to provide consumption at date 1. The optimization problem of the banks is to choose x, y and z to

$$\text{Max } 0.5U(c_1) + 0.5[0.7U(c_{2H}) + 0.3U(c_{2L})]$$

$$\text{subject to } x + y + z = 1,$$

$$c_1 = \frac{x}{0.5},$$

$$c_{2H} = \frac{yR + zB_H}{0.5},$$

$$c_{2L} = \frac{yR + zB_L}{0.5}.$$

The first constraint is the budget constraint at date 0. The second constraint gives the per capita consumption of the early consumers. Since there is 1 depositor and 0.5 of these are early consumers and 0.5 are late consumers, we need to divide the total consumption produced by the investment in the short asset at date 1 by 0.5 to get the per capita consumption. The third and fourth constraints give the per capita consumption of the late consumers in states β_H and β_L respectively. Clearly, $c_{2H} \geq c_{2L}$. In order for a run to be avoided, we also need $c_{2L} \geq c_1$ otherwise late consumers will pretend to be early consumers and will withdraw their money at date 1.

Denoting the Lagrange multiplier for the constraint μ, the first order conditions are:

$$\frac{0.5}{x} - \mu \leq 0,$$

$$\frac{0.35R}{yR + zB_H} + \frac{0.15R}{yR + zB_L} - \mu \leq 0,$$

$$\frac{0.35B_H}{yR + zB_H} + \frac{0.15B_L}{yR + zB_L} - \mu \leq 0.$$

The solution for the equilibrium is

$$\begin{gathered} x = 0.5; y = 0.22; z = 0.28 \\ c_1 = 1; c_{2H} = 1.568; c_{2L} = 1.12 \\ EU = 0.1744 \end{gathered}$$

It can be seen directly that $c_{2L} > c_1$ so in state β_L late consumers will not have an incentive to withdraw their money and cause a run. As a result there will be no systemic risk in the banking industry.

The role of capital

Next consider what happens if there are investors who can make capital available to the banks.

For the investors providing equity capital, the opportunity cost is $\rho = 1.5$.

Since the investors are indifferent between consumption at date 1and date 2 it is optimal to set $e_1 = 0$ and not invest any of the capital e_0 that is contributed at date 0 in the short asset. In state β_H when depositors' marginal utility of consumption is the lowest it is possible to make a payout e_2 to investors. The banks optimization problem is the same as before except now the date 0 budget constraint is

$$x + y + z + e_0 = 1.$$

and

$$c_{2H} = \frac{yR + zB_H - e_2}{0.5}.$$

In order for the investors to be willing to supply the capital e_0 it is necessary that

$$e_0\rho = 0.7e_2$$

so

$$c_{2H} = \frac{yR + zB_H - e_0\rho/0.7}{0.5}.$$

The first order conditions for x, y, z, and e_0 are now

$$\frac{0.5}{x} - \mu \leq 0,$$

$$\frac{0.35R}{yR + zB_H - e_0\rho/0.7} + \frac{0.15R}{yR + zB_L} - \mu \leq 0,$$

$$\frac{0.35B_H}{yR + zB_H - e_0\rho/0.7} + \frac{0.15B_L}{yR + zB_L} - \mu \leq 0,$$

$$-\frac{0.35\rho/0.7}{yR + zB_H - e_0\rho/0.7} + \mu \leq 0.$$

The solution for the equilibrium in this case is

$$x = 0.5; y = 0; z = 0.726; e_0 = 0.226$$
$$c_1 = 1; c_{2H} = 1.5; c_{2L} = 1.306$$
$$EU = 0.1820$$

Once again there is no danger of runs and hence no systemic risk since $c_{2L} > c_1$.

Comparing the case without capital to the case with, it can be seen that expected utility is increased from 0.174 to 0.182. Capital allows the depositors to share risk with the investors. This improves welfare directly but it also allows the bank to invest more in loans and less in the long asset, which has a lower expected return (1.4) than the loans (1.46). This increases expected consumption for the late consumers from $0.7 \times 1.568 + 0.3 \times 1.12 = 1.434$ to $0.7 \times 1.5 + 0.3 \times 1.306 = 1.442$. In addition to this increase in expected consumption there is also clearly a reduction in the variability of consumption (1.568 and 1.12 before versus 1.5 and 1.306 now) because the repayment to investors occurs only in the good state. Risk is not eliminated from the depositors' consumption even though the investors providing the capital are risk neutral because capital is costly. The investors' opportunity cost of capital is $\rho = 1.5$ while the expected return on the loans is only 1.46 and on the long asset 1.4. It is only the increase in expected utility from smoothing consumption that makes it worthwhile using investors' capital and only up to the point where the marginal benefit is equal to the marginal cost. This is why depositors continue to bear risk.

This is not the only kind of situation that can occur. In some cases the bank will not want to use capital at all. To see this consider the following example.

Example 2

This is exactly the same as Example 1 except that $R = 1.28$, $B_H = 1.6$, and $B_L = 0.8$ so $EB = 1.36$.

It can be shown that the equilibrium whether capital is available or not is the same.

$$x = 0.5; y = 0.190; z = 0.314; e_0 = 0$$
$$c_1 = 0.990; c_{2H} = 1.494; c_{2L} = 0.990$$
$$EU = 0.1341$$

There is no role for capital at all in this example. Any capital regulation that imposes a positive minimum requirement will lead to inefficiency.

We will use Example 2 when we consider the banking and insurance sectors together.

4.2 The insurance sector

We next turn to the insurance sector and consider it on its own. As explained above there are firms that own assets that produce A at $t = 2$ if they are undamaged. For our example, we assume that $A = 1.3$. The owners of these firms consume at date 2 and have $U = Ln(c)$.

With some probability $\alpha(s)$ a firm's asset is damaged at date $t = 1$. It costs $C = 0.8$ to repair the asset in which case it produces A at $t = 2$. Without repair the asset produces nothing. Insurance companies insure the firms and allow the risk to be pooled. As before the firms that the insurance companies insure are different from the firms that the banks make loans to.

The parameters for Example 2 are used so $R = 1.28$.

State α_H occurs with probability 0.9 and in this case $\alpha_H = 0.5$ firms have damaged machines. State α_L occurs with probability 0.1 and $\alpha_L = 1$ firms have damaged machines.

Similarly to the banking sector, the insurance companies cannot access complete markets with securities contingent on aggregate states. They can only buy the long and short assets. They also cannot write state contingent contracts. They can promise to insure the firms' machines irrespective of state s. This means that an insurance company may go bankrupt. In this case its assets are liquidated and distributed to the firms it was insuring.

The costs of an insurance company liquidating long term assets at date $t = 1$ if it goes bankrupt is such that the proceeds are zero. Grace, Klein and Phillips (2003) have found that for a large sample of insurers that went bankrupt from 1986-1999 the average cost of insolvent firms accessing the guarantee funds was \$1.10 per \$1 of pre-insolvency assets. By way of contrast James (1991) found that the figure for banks for the late 1980s was \$0.30.

Each firm has an endowment of 0.8 at date $t = 0$ that it can use to buy insurance or invest itself. As mentioned in the previous section, it will be assumed that the firms just buy insurance from the insurance companies. The firms can use the markets for the long and the short assets to smooth consumption for their owners.

No capital

The insurance industry is competitive so the companies do not earn any profits - all funds are paid out to the firms they insure. At date 0 the insurance companies' objective is to maximize the expected utility of the firms' owners. If they did not do this another insurance company would enter and take their business away. The insurance companies can offer partial or full insurance to firms. If they offer partial insurance they charge $0.5 * C = 0.4$ at date $t = 0$. Suppose the firms put the other 0.4 of their endowment in the long term asset (it will be shown this is optimal shortly). In order to have funds to allow firms' damaged assets to be repaired, the insurance companies must invest in the short asset so that they have liquidity at date $t = 1$. In state α_H the funds they need for claims to repair the damaged assets are $\alpha_H C = 0.4$. They have funds of 0.4 and can pay all the claims to repair the damaged assets. The amount the owners of the firms obtain is therefore $A + 0.4R = 1.812$. In state α_L the insurance companies receive claims of $\alpha_L C = 0.8$. 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 0.4 from the insurance companies' liquidation of its short term assets. The firms can't repair their assets so these produce nothing. In state α_L the amount the owners of the firm receive is therefore $0.4 + 0.4R = 0.912$. Their expected utility with partial insurance is

$$EU_{partial} = 0.9U(A + 0.4R) + 0.1U(0.4 + 0.4R) = 0.5258.$$

If the insurance company offered full insurance they would charge 0.8 at $t = 0$ and could meet all of their claims in both states. At $t = 1$ in state α_H they would have 0.4 left over. Since the industry is competitive they would pay this out to the insured firms. In this case

$$EU_{full} = 0.9U(A + 0.4) + 0.1U(A) = 0.5038.$$

This is worse than partial insurance.

If the firms decide not to have insurance then they would invest their endowment in the long asset. Their expected utility would be

$$EU_{none} = 0.9[0.5U(0.8R) + 0.5U(A + 0.8R)] + 0.1U(0.8R) = 0.3925.$$

Finally, if they decided to self-insure and hold their endowment in the short asset so they could repair their machines when necessary they would obtain

$$EU_{self} = 0.9[0.5U(A) + 0.5U(A + 0.8)] + 0.1U(A) = 0.4782.$$

Thus the optimal scheme is for the insurance industry to partially insure firms and to charge 0.4 at $t = 0$. The firms put the remaining part of their endowment in the long asset.

The role of capital

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. There are already potentially enough funds from customers to do this but it is simply 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 if they are not regulated to do so.

4.3 Bringing together the banking and insurance sectors

Now consider what happens if we consider the two sectors together and look at possible interactions. We start with the situation where there is no regulation and then go on to consider what happens with regulation.

No regulation

Without any regulation both sectors have the same equilibrium as when they are considered on their own. Given that markets and contracts are incomplete, there are no incentives for the insurance sector to insure the banking sector and have credit risk transfer. All the insurance sector could do is to hold the long term asset and pay off when the loans default. But the banking sector can do this on its own. In fact with insurance the systemic risk means that there would be a strict loss in this case. The value of the long term assets held in the insurance companies would be lost.

There is also no gain for the banking sector to bear the risk of the insurance sector. They would have to hold the short term asset but the insurance sector can do this just as efficiently.

Of course, if markets and contracts were complete then there would be an incentive to share risk. The consumption at date 2 of the bank depositors and insured firms' owners are as follows.

State	HH	LH	HL	LL
Bank depositors	1.494	1.494	0.990	0.990
Insured firm owners	1.812	0.912	1.812	0.912

By, for example, transfering consumption from the bank depositors to the insured firms' owners in state LH in the amount of 0.0386 and vice-versa in state HL in the amount of 0.01 it is possible to make both groups better off.

If the shocks to the two sectors are independent then the expected value of this transfer is

$$0.07 \times 0.0386 - 0.27 \times 0.01 = 0.$$

The expected utility of the bank depositors is improved from 0.1341 to 0.1394 and the expected utility of the insured firms' owners goes from 0.5258 to 0.5272. With complete markets and contracts optimal risk sharing would ensure that the ratios of marginal utilities of consumption of the bank depositors and the owners of the insured firms across states would be equated. This is clearly far from being the case here. The incomplete markets and contracts that are actually in place in this section prevent improved risk sharing of this type and in fact there is no possibility of an improvement through credit risk transfer in the absence of capital regulation.

Equilibrium with inefficient capital regulation in the banking sector

Now suppose that the government requires banks to have a certain minimum amount of capital. There is no role for capital regulation in our model so it can have no benefit. It may be harmless if the required level is below the optimal level. The more interesting case is when it is set at too high a level.

Suppose in Example 2 that the government requires banks to have $e_0 = 0.2$ compared to the optimal level of 0. The solution to the banks' problem then becomes

$$\begin{gathered} e_0 = 0.2; e_1 = 0; e_2 = 0.429; \\ x = 0.494; y = 0; z = 0.706 \\ c_1 = 0.988; c_{2H} = 1.401; c_{2L} = 1.129 \\ EU = 0.1305 \end{gathered}$$

The capital improves risk sharing and allows more funds to be invested in loans both from the extra capital and from the lower return long asset. However, the high cost of capital means that this is inefficient and welfare is reduced from the case with no regulation.

Inefficient capital regulation in banking and credit risk transfer to the insurance sector

Next consider what happens if we allow for the possibility of credit risk transfer from the banking sector to the insurance sector. It is supposed that the shocks to the two sectors are independent. The regulation is such that the existence of hedging of credit risk allows a reduction in the capital requirement. By purchasing an insurance contract with cost of $G = 0.02$ at date 0 and a payoff of $0.02 \times R = 0.026$ at date 2 when loans do not pay off it is possible for a bank to reduce its capital requirement to the optimal level of 0. The idea here is that the regulation does not work effectively since under Basel II banks can use their own risk models. They can therefore construct their risk models to make it look as if the hedging instument reduces risk the right amount to allow them to reduce capital to the optimal level. Notice that in order for this insurance contract to be such that the insurance companies break even, which is necessary because of competition, they will also provide a payment of 0.026 when the loans do pay off if they are able to. The insurance companies use the initial payment from the banks at date 0 to buy the long term asset and then pay out the proceeds when they are solvent. When they are not solvent the long term asset is wasted because of the inefficient liquidation in the insurance sector. The only point of the credit risk transfer is to arbitrage the inefficient capital regulation in the banking sector. The key issue is whether the gain from this inefficient risk transfer outweighs the inefficiency of the capital regulation. It can be shown that in the example it does. The bank chooses its portfolio x, y, and z to maximize the depositors' expected utility taking $G = 0.02$ and $e_0 = 0$ as given.

$$\text{Max } EU = 0.5U(c_1) + 0.5[0.7(0.9U(c_{2HH}) + 0.1U(c_{2LH})) + 0.3(0.9U(c_{2HL}) + 0.1U(c_{2LL}))]$$

$$\text{subject to } 1 + e_0 = x + y + z + G.$$

$$c_1 = \frac{x}{0.5},$$

$$c_{2HH} = \frac{yR + zB_H - e_0\rho/0.7 + GR}{0.5},$$

$$c_{2LH} = \frac{yR + zB_H - e_0\rho/0.7}{0.5},$$

$$c_{2HL} = \frac{yR + zB_L + GR}{0.5},$$

$$c_{2LL} = \frac{yR + zB_L}{0.5}.$$

Solving this gives the following.

$$x = 0.5; y = 0.15; z = 0.33; e_0 = 0$$
$$c_1 = 1; c_{2HH} = 1.491; c_{2LH} = 1.440; c_{2HL} = 0.963; c_{2LL} = 0.912$$
$$EU = 0.1322$$

So the expected utility of the banks depositors is improved relative to the case with no credit risk transfer ($EU = 0.1305$) but, of course, they are not as well off as in the case with no regulation ($EU = 0.1341$) because the credit risk transfer has costs associated with it. However, all this is beside the point because the solution assumes there will be no runs but in fact there will be runs in states HL and LL. In state HL $c_{2HL} = 0.963 < c_1 = 1$ and in state LL $c_{2LL} = 0.912 < c_1 = 1$. In both cases the late consumers as well as the early consumers will attempt to withdraw their funds. The banks will anticipate this and will optimize taking this into account.

A key issue is what happens if there is a run on the bank in terms of the liquidation value of the long asset and loans it holds. For simplicity, we assume the bank can liquidate its assets for their full value. As mentioned above, James (1991) found that the cost of liquidating bank assets in the late 1980s was \$0.30 per dollar of assets which is much lower than the \$1.10 per dollar cost of liquidating insurance assets that Grace, Klein and Phillips (2003) found. We could allow for some small loss of asset value and all the results above would hold. The more inefficient the banking regulation the greater this loss can be.

In the optimal solution taking into account bankruptcy the banks go bankrupt in state LL and both the early and late consumers receive the same amount

$$c_{1LL} = c_{2LL} = x + yR + zB_L.$$

The full solution is

$$x = 0.492; y = 0.188; z = 0.300; e_0 = 0$$

In states HH, LH, and HL the banks avoid bankruptcy:

$$c_1 = 0.984; c_{2HH} = 1.493; c_{2LH} = 1.441; c_{2HL} = 1.012$$

In state LL the banks go bankrupt:

$$c_{1LL} = c_{2LL} = 0.973$$
$$EU = 0.1318$$

We have thus shown the second result of the paper, namely that with inefficient banking regulation credit risk transfer can increase overall systemic risk. The insurance industry is hit by a large shock where it has high claims from the firms' it insures. At the same time the banking industry has low returns on it loans. Whereas without credit risk transfer the banks avoided bankruptcy, this is not optimal any longer. They go bankrupt and there is contagion from the insurance industry to the banking industry. The credit risk transfer has created links between the industries and this allows contagion.

5 Concluding remarks

In this paper we have developed a model of a financial system with both banking and insurance sectors. Banks and insurance companies do different things. Banks provide liquidity insurance to depositors while insurance companies pool risks. The first result was to show that with complete markets and contracts for aggregate risks intersectoral transfers are desirable. They allow risk to be shared efficiently between the different industries. The second result was to show that with incomplete markets and contracts for aggregate risks credit risk transfer can occur as the result of regulatory arbitrage and this can increase overall systemic risk.

The key question going forward, of course, is which view of credit risk transfer is empirically relevant. As documented in Section 2, the amount of credit risk transfer between the two industries is currently relatively small. Even if one were to take the view that this credit risk transfer is the result of regulatory arbitrage then the systemic risk may be slight. However, going forward, transfers between sectors may increase and if they are the result of regulatory arbitrage may lead to an increase in systemic risk.

Perhaps more importantly, although the model can be interpreted literally as being about banking and insurance, it can also be viewed more generally. The other group of institutions that in recent years has been playing an increasingly important role in the transfer of credit and the repackaging of risk in general has been hedge funds (BIS (2005)). If markets function well in the sense that risk sharing opportunities are complete then these transfers of risk around the economy are desirable. However, if they are the result of inefficient regulation and regulatory arbitrage they may not be. Since hedge funds are unregulated while a large part of the financial services industry is regulated, much of this activity may well be the result of regulatory arbitrage. More empirical work analyzing the nature of risk reallocation in the economy is required to understand the full consequences on systemic risk.

In the model presented systemic risk was not particularly damaging. Assets could be liquidated in the banking system for the full amount of their value. In practice, systemic risk can be extremely damaging. Augmenting the model to allow for endogenous liquidation values and spillovers to the real economy mean that the kind of effect modeled here with incomplete markets may be quite damaging.

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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	34	40	61	78	79	102	118	117[1]
(Loan Pricing Corporation)								
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)	315	403	517	684	816	947	1,114	1,258[6]
(Bond Market Association)[5]								
- European market (issuance)								
(Moody's)[7]					68	80	134	50[8]
- Australian market (outstanding)	7	10	15	19	27	33	38	54
(Australian Bureau of Statistics)								
Collateralised debt obligations								
- US market (outstanding)	1	1	19	48	85	125	167	232[6]
(Bond Market Association)								
- European market (issuance)								
(Moody's)					42	71	114	70[8]
Total bank credit	23,424	23,576	23,309	26,018	26,904	27,221	27,442	29,435[9]
(outstanding)[10]								
- IMF								
Corporate debt securities[11]	3,241	3,373	3,444	4,042	4,584	4,939	5,233	5,505[9]
(outstanding)								
- BIS								

Footnotes: [1]First three quarters of 2002, annualised. [2]Holdings of US commercial banks. [3] Second Quarter of 2002. [4]Forecast for 2002. [5]Excluding CB)os/CDOs. [6] September 2002. [7] ABSs and MBSs. [8]First 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: [1]Includes mono-line companies and reinsurers.

Source: BBA Credit Derivatives Report 2001/2002