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*Capital Adequacy Regulation: In Search
of a Rationale*

by
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Capital Adequacy Regulation: In Search of a Rationale

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Abstract

Capital adequacy regulation is often justified, directly or indirectly, by an appeal to the need to prevent financial crises. By contrast, we argue that, in the absence of a welfare-relevant pecuniary externality, banks will choose the socially optimal capital structure themselves,

without government coercion.

1 The flight from theory

Financial crises have become a popular academic subject since the recent events in Asia, Russia, and elsewhere. Of course, financial crises are nothing new. They are part of the long and colorful history of the development of the financial system. They are also an important part of the history of central banking. Central banks were originally established for a wide variety of reasons such as enhancing the payments system and raising money to help governments finance wars. They later took on the prevention and control of financial crises as one of their central functions. The Bank of England perfected the technique in the nineteenth century. The Federal Reserve System, founded in the early twentieth century, was a slow learner and only mastered the technique in the 1930s. (A more detailed discussion of the history of central banking is contained in Chapter 2 of Allen and Gale (2000a)).

For the most part, the development of central banking and financial regulation has been an essentially empirical process, a matter of trial and error driven by the exigencies of history, rather than formal theory. An episode that illustrates the character of this process is the Great Depression in the US.

The financial collapse in the US was widespread and deeply disruptive. It led to substantial changes, many of which shape our current regulatory framework. The SEC was established to regulate financial markets. Investment and commercial banking were segregated by the Glass-Steagall Act (subsequently repealed and replaced by the Gramm-Leach-Bliley Act of 1999). The Federal Reserve Board revised its operating procedures in the light of its failure to prevent the financial collapse. The FDIC and FSLIC were set up to provide deposit insurance to banks and savings and loan institutions.

Looking back, there is no sign of formal theory guiding these changes. Everyone seems to have agreed the experience of the Great Depression was terrible; so terrible that it must never be allowed to happen again. But why was this set of institutions and rules adopted? And why are many of them still with us today? The mind set of the 1930s continues to influence thinking about policy. According to this mind set, the financial system is extremely fragile and the purpose of prudential regulation is to prevent financial crisis at all costs. In addition, policy making continues to be an empirical exercise, with little attention to theoretical reasoning.

The Basel Accords, which impose capital adequacy requirements on the banking systems of the signatory countries around the world, are a case in point. Practitioners have become experts at the details of a highly complex

system for which there is no widely agreed rationale based in economic theory. What is the optimal capital structure? What market failure necessitates the imposition of capital adequacy requirements? Why can't the market be left to determine the appropriate level of capital? We do not find good answers to these questions in the theoretical literature.

It is not our intention to pass judgment on the practical value of any of the innovations mentioned above, but simply to point out that this empirical procedure is unusual. Indeed, the area of financial regulation is somewhat unique in the extent to which the empirical developments have so far outstripped theory. In most areas of economics, when regulation becomes an issue, economists have tried to identify some specific market failure that justifies intervention. Sometimes they have gone further to derive the optimal form of regulation. But there is no theory of optimal prudential regulation.

In the literature on capital adequacy, it is often argued that capital adequacy requirements are necessary to control the moral hazard problems generated by the existence of deposit insurance. Deposit insurance was introduced in the 1930s to prevent bank runs or, more generally, financial instability. However, deposit insurance encourages risk shifting behavior on the part of banks (see, e.g., Merton (1977)), which can be controlled by requiring the shareholders to post a "bond" in the form of adequate levels of

capital in the bank. Thus, capital adequacy requirements are indirectly justified by the desire to prevent financial crises. A large literature investigates the effect of capital adequacy requirements on risk taking. While the effect of capital adequacy requirements is usually to decrease risk taking, the reverse is also possible (see, e.g., Kim and Santomero (1988), Furlong and Keeley (1989), Gennotte and Pyle (1991), Rochet (1992) and Besanko and Kanatas (1996)).

The incentive to take risks may also be offset by the loss of charter value when a firm goes bankrupt (see, e.g., Bhattacharya (1982)). This effect will be smaller the more competitive the structure of the banking market. Keeley (1990) has provided evidence that the sharp increase in bank failures in the US in the early 1980s was due to increased competition in the banking sector and the associated fall in charter values.

Hellman, Murdock and Stiglitz (1998, 2000) develop a model that allows for the effect of both a higher charter value and capital adequacy requirements on risk-taking incentives. Controls on deposit interest rates are necessary, in addition to capital adequacy requirements, to achieve a Pareto-efficient allocation of resources. These interest-rate controls increase charter value and provide an extra instrument for controlling risk taking. A Pareto improvement is possible even without the use of deposit insurance.

It appears from our review of the literature that the justification for capital adequacy requirements is found in the existence of deposit insurance. It could be argued that an important question is being begged here: one bad policy (deposit insurance) does not justify another (capital adequacy requirements). Even if it is assumed that deposit insurance prevents financial crises, it is not clear why we should want to reduce the incidence of financial crises, still less eliminate them altogether. We have argued elsewhere that, under standard conditions, the incidence of financial crises may be socially optimal in a *laissez faire* system (Allen and Gale (1998, 2000b)). And if not, for example, if financial crises involve deadweight losses, it should be recognized that regulation also involves administrative costs and distorts economic decisions. Any analysis of optimal policy must weigh the costs and benefits of regulation. This can only be done in a model that explicitly models the possibility of crises.

Hellman, Murdoch and Stiglitz (1998) is an exception in the literature on capital adequacy requirements. Rather than simply taking the existence of deposit insurance as given, the authors also examine what happens in the absence of deposit insurance. In the rest of the literature, the rationale for deposit insurance and in particular its role in preventing financial crises is discussed but not explicitly modelled. In the absence of explicit modelling of

the costs of financial crises, it is difficult to make a case for the optimality of intervention. As a corollary, it is difficult to make a case for capital adequacy requirements as a means of offsetting the risk taking generated by deposit insurance.

In this paper we argue that, in the absence of a welfare-relevant pecuniary externality, banks will choose the socially optimal capital structure themselves, without government coercion. The model is simple and is intended to pose a challenge to advocates of capital adequacy requirements to do a better job of rationalizing the system that currently dominates the policy debates on prudential regulation.

In a series of related papers (Allen and Gale, 1998, 2000a-e, 2001), we have described a model that integrates intermediation and capital markets in a way that proves useful for the analysis of asset-price volatility, liquidity provision, financial crises, and related issues. The model can be briefly described as follows. There are two types of assets in the economy, short-term assets that yield an immediate but low return and long-term assets that yield a higher but delayed return. Risk averse individuals want to invest to provide for future consumption. However, they are uncertain about their preferences regarding the timing of consumption. If they invest in the long-term asset, they earn a high return, but it may not be available when they want to

consume it. If they invest in the short-term asset, they have the certainty that it will be available when they want it, but they have to forego the higher return of the long-term asset. In short, there is a trade-off between liquidity and rate of return.

Banks are modeled as institutions that provide an optimal combination of liquidity and return. In this respect we are simply following Diamond and Dybvig (1983) and a host of other writers, see e.g., Chari and Jagannathan (1988), Jacklin and Bhattacharya (1988), Postlewaite and Vives (1987), and Wallace (1988, 1990). Banks take deposits from consumers and invest them in a portfolio of long- and short-term assets. In exchange, the bank gives the individual a deposit contract, that is, an option to withdraw from the bank. The amount withdrawn depends on the date at which the option is exercised, but for a given date, liquidity is guaranteed. By pooling independent risks, the bank is able to provide a better combination of liquidity and return than an individual could achieve on his own. The aggregate demand for liquidity is less volatile than individual risks, so the bank can guarantee the same degree of liquidity while investing a smaller fraction of the portfolio in short-term assets, thus giving the depositor the benefit of the higher returns from the long-term assets.

Bank behavior can be represented as the solution of an optimal contract-

ing problem. Banks compete for customers by offering combinations of a portfolio and a deposit contract. Free entry into the banking sector guarantees that banks will earn zero profit in equilibrium and will offer the combination of portfolio and contract that maximizes the depositor's expected utility. Otherwise another bank could enter, offer a more attractive contract, and take away the first bank's customers.

Risk can take the form of shocks to asset returns or the demand for liquidity. In this paper, we focus on asset-return shocks. These shocks provide a role for financial markets. Specifically, we introduce markets for securities that allow banks to insure against aggregate shocks. We also introduce markets on which banks can buy and sell the long-term assets in order to obtain or provide liquidity.

The introduction of these two types of markets has important implications for the welfare properties of the model. First, the existence of markets on which assets can be liquidated ensures that bankruptcy involves no inefficiency ex post. Firesale prices transfer value to the buyer but do not constitute a deadweight loss. Secondly, ex ante risk sharing is optimal if there is a complete set of Arrow securities for insuring against aggregate shocks.

For a long time, policy makers have taken it as axiomatic that crises are

best avoided. By contrast, in the present framework, with complete markets, a *laisser-faire* financial system achieves the constrained-efficient allocation of risk and resources. When banks are restricted to using non-contingent deposit contracts, default introduces a degree of contingency that may be desirable from the point of view of optimal risk sharing. Far from being best avoided, financial crises can actually be *necessary* in order to achieve constrained efficiency. By contrast, avoiding default is costly. It requires either holding a very safe and liquid portfolio and earning lower returns, or reducing the liquidity promised to the depositors. In any case, the bank optimally weighs the costs and benefits and chooses the efficient level of default in equilibrium.

The important point is that avoidance of crises should not be taken as axiomatic. If regulation is required to minimize or obviate the costs of financial crises, it needs to be justified by a microeconomic welfare analysis based on standard assumptions. Furthermore, the form of the intervention should be derived from microeconomic principles. After all, financial institutions and financial markets exist to facilitate the efficient allocation of risks and resources. A policy that aims to prevent financial crises has an impact on the normal functioning of the financial system. Any government intervention may impose deadweight costs by distorting the normal functioning of

the financial system. One of the advantages of a microeconomic analysis of financial crises is that it clarifies the costs associated with these distortions.

The model described so far has no role for capital. Banks are like mutual companies, operated for the benefit of their depositors, with no investment provided and no return received by the entrepreneurs who set them up. We can add capital to the model by assuming the existence of a class of risk neutral investors who are willing to invest in the bank in return for an equity share. These investors are assumed to have a fixed opportunity cost of capital, determined by the best investment returns available to them outside the banking sector. We assume this return is at least as great as the return on the long-term asset. These investors can also speculate on the short- and long-term assets, for example, holding the short-term asset in order to buy up the long-term asset at a firesale price in the event of a default. This kind of speculation provides liquidity. It is superfluous in the case of complete Arrow securities, but plays an essential role in equilibrium with incomplete markets.

The rest of the paper is organized as follows. In Section 2 we study our model in two settings. First, we consider the classical world of Modigliani-Miller in which markets are complete and capital structure is irrelevant. This sets a benchmark in which *laissez faire* is optimal and there is no justifica-

tion for bank capital, let alone capital adequacy requirements. Secondly, we consider what happens when markets are incomplete and show that capital structure affects the risk sharing provided by the bank. However, the bank chooses the socially optimal capital structure in a *laissez-faire* equilibrium, so once again there is no rationale for government imposition of capital adequacy requirements. Our focus in Section 2 is on risk sharing under symmetric information. In Section 3 we consider asymmetric information and make a similar argument: unless there is a welfare-relevant pecuniary externality, the bank can internalize the agency problem and the private optimum is also the social optimum. There is no need for government intervention. Section 4 points out the value of continuous monitoring of capital structure as a means of avoiding risk-shifting behavior. Section 5 contains a brief conclusion.

2 A simple model of risk sharing

We use a variation of the model found in Allen and Gale (2000b). The main difference between the model presented there and the one here is that bank capital can be provided by risk-neutral investors.

Dates. There are three dates $t = 0, 1, 2$ and a single good at each date. The good is used for consumption or investment.

Assets. There are two assets, a short-term asset (the *short asset*) and a long-term asset (the *long asset*).

- The short asset is represented by a storage technology: one unit of the good invested at date t yields one unit at date $t + 1$, for $t = 0, 1$.
- The long asset takes two periods to mature and is more productive than the short asset: one unit invested at date 0 produces a random return \tilde{R} at date 2. The long asset is more productive than the short asset: $E[\tilde{R}] > 1$.

Consumers. There is a continuum of ex ante identical consumers, whose measure is normalized to unity. Each consumer has an endowment consisting of one unit of the good at date 0 and nothing at subsequent dates. Ex post, there are two types of consumers, *early consumers*, who consume at date 1, and *late consumers*, who consume at date 2. The probability of being an early consumer is denoted by $0 < \lambda < 1$ and consumption at date $t = 1, 2$ is denoted by c_t . The consumer's ex ante utility is

$$\lambda U(c_1) + (1 - \lambda)U(c_2).$$

We adopt the usual “law of large numbers” convention and assume that the fraction of early consumers is identically equal to the probability λ . The period utility function $U : \mathbf{R}_+ \rightarrow \mathbf{R}$ is twice continuously differentiable

and satisfies the usual neoclassical properties, $U'(c) > 0, U''(c) < 0$, and $\lim_{c \searrow 0} U'(c) = \infty$.

Investors. There is a continuum of risk neutral investors who have a large endowment at date 0 and maximize expected consumption at date 2. They can invest directly in the short and long asset and they can also hold equity in financial institutions. Investors have access to the short and long assets, as do banks, but in some cases we assume they also have access to investment opportunities that are not available to the banks. The maximum expected return available to investors (measured in terms of consumption at date 2) is denoted by $\rho \geq E[\tilde{R}]$.

Uncertainty. There are two aggregate states of nature H and L . The return to the long asset \tilde{R} is a function of the state of nature:

$$\tilde{R} = \begin{cases} R_H & \text{w.pr. } 1 - \varepsilon \\ R_L & \text{w.pr. } \varepsilon \end{cases}$$

where $0 < R_L < R_H$.

Information. All uncertainty is resolved at date 1. The true state H or L is revealed and each consumer learns his ex post type, i.e., whether he is an early consumer or a late consumer. Note that knowledge of the true return \tilde{R} is available one period before the return itself is available.

Banking. A bank is a cooperative enterprise that provides insurance to consumers. At date 0, consumers deposit their initial endowments in a bank, which offers them a deposit contract promising d_t units of consumption if they withdraw at date $t = 1, 2$. The bank holds a portfolio (x, y) consisting of x units of the long asset and y units of the short asset. The bank can also obtain e units of capital from risk-neutral investors, in exchange for a claim on the bank's profits.

2.1 Equilibrium with Arrow securities

Suppose that there are default-free Arrow securities for the two states H and L at date 0 and a capital market at date 1. One unit of an Arrow security corresponding to state $s = H, L$ pays one unit of the good at date 1 if state s occurs and nothing otherwise. The capital market at date 1 allows goods at date 2 to be exchanged for goods at date 1. Let q_s denote the price of one unit of the Arrow security for state s measured in terms of the good at date 0. Let p_s denote the price of one unit of the good at date 2, measured in terms of the good at date 1. Then $q_s p_s$ is the price, in terms of the good at date 0, of one unit of the good at date 2 in state s . Clearly, there are complete markets for hedging aggregate uncertainty.

In this version of the model, we assume that investors and banks have

access to the same assets, that is, the short asset and the long asset. In fact, with complete markets, it does not make sense to distinguish the set of assets available to banks and markets. If investors had access to a third type of asset not available to banks, the returns to this asset would be reflected in the prices of Arrow securities. Trading Arrow securities would be equivalent to investing in the assets available to investors. In that sense, there is no loss of generality in assuming that $\rho = \bar{R}$.

Suppose that a risk-neutral investor had the opportunity to purchase a security that pays z_s units of the good at date 2 in state $s = H, L$. The investor would be indifferent between this security and one that paid the expected value $\bar{z} = (1 - \varepsilon)z_H + \varepsilon z_L$ in each state at date 2. In equilibrium, the price of these securities must be the same. Otherwise, there would be an opportunity for arbitrage. Thus,

$$q_{HPH}z_H + q_{LPL}z_L = (q_{HPH} + q_{LPL})\bar{z}.$$

The no-arbitrage condition holds for any payoffs (z_H, z_L) , which will only be true if

$$(q_{HPH}, q_{LPL}) = \alpha(1 - \varepsilon, \varepsilon)$$

for some constant $\alpha > 0$. Since one unit of the good at date 0 produces (R_H, R_L) at date 2, if anyone holds the long asset at date 0 it must be the

case that

$$\begin{aligned} 1 &= q_H p_H R_H + q_L p_L R_L \\ &= (q_H p_H + q_L p_L) \bar{R} \\ &= \alpha \bar{R}, \end{aligned}$$

so $\alpha = \bar{R}^{-1}$. Thus, the prices of contingent commodities at date 2 are completely determined and, moreover, allow any agent with access to the market to convert an arbitrary security into one paying its expected value in each state.

A similar argument concerning securities paying off at date 1 proves that

$$(q_H, q_L) = \beta(1 - \varepsilon, \varepsilon)$$

and if anyone holds the short asset at date 0 it can be shown that $\beta = 1$.

We assume that banks and investors can participate directly in these markets, but that consumers cannot.

Suppose that a planner, with access to these markets, was given the task of allocating investments and consumption to maximize the expected utility of the depositors. It does not matter what assets the planner invests in at date 0 because the existence of complete markets and the absence of arbitrage opportunities means that the planner's wealth is independent of his investment decisions. Given one unit of the good per depositor at date 0, the

planner's task is to allocate consumption so as to maximize expected utility subject to a budget constraint. If c_s^t denotes the consumption of the typical depositor in state s at date t , then the planner's problem can be written as follows:

$$\begin{aligned} \max \quad & E[\lambda U(c_s^1) + (1 - \lambda)U(c_s^2)] \\ \text{s.t.} \quad & \sum_s (q_s \lambda c_s^1 + q_s p_s (1 - \lambda) c_s^2) \leq 1. \end{aligned}$$

The budget constraint can be explained as follows. In state s , each early consumer receives c_s^1 and each late consumer receives c_s^2 . There are λ early consumers, so the total demand for the good at date 1 is λc_s^1 and the cost, measured in terms of the good at date 0, is $q_s \lambda c_s^1$. Similarly, there are $1 - \lambda$ late consumers so the total demand for the good at date 2 is $(1 - \lambda) c_s^2$ and the cost, measured in terms of the good at date 0, is $q_s p_s (1 - \lambda) c_s^2$. Summing these terms over dates and states gives the total cost of consumption in terms of the good at date 0, which is the left hand side of the budget constraint. The right hand side is the initial endowment of goods at date 0.

The no-arbitrage restrictions on the prices of contingent commodities allow us to exchange a random consumption bundle for its expected value. For example, the value of (c_H^1, c_L^1) is the same as (\bar{c}^1, \bar{c}^1) , where $\bar{c}^1 = (1 - \varepsilon)c_H^1 + \varepsilon c_L^1$. Since depositors are risk averse, it is always optimal to substitute (\bar{c}^1, \bar{c}^1) for (c_H^1, c_L^1) . A similar argument holds for consumption at date 2.

Thus, the planner's problem reduces to

$$\begin{aligned} \max \quad & \lambda U(c^1) + (1 - \lambda)U(c^2) \\ \text{s.t.} \quad & \lambda c^1 + \bar{R}^{-1}(1 - \lambda)c^2 \leq 1. \end{aligned}$$

The first-order conditions for an optimum are

$$U'(c^1) = \bar{R}U'(c^2),$$

which implies that $c^1 < c^2$. Thus, the optimal consumption allocation is non-stochastic and gives more consumption to the late consumers than to the early consumers.

Now consider what a bank could achieve on behalf of its depositors. The first-best consumption allocation (c^1, c^2) can be implemented by a deposit contract (d_1, d_2) , where d_1 is the payoff promised to early consumers and d_2 is the payoff promised to late consumers. Note that this deposit contract is incentive-compatible. If the bank cannot distinguish early consumers from late consumers and $d_1 > d_2$, the late consumers have an incentive to withdraw d_1 at date 1, store it until date 2 and then consume it. So the deposit contract is incentive-compatible if and only if $d_1 \leq d_2$, which is the case here. Since the solution to the planner's problem is the first best, the bank cannot do any better. Thus, $(d_1, d_2) = (c^1, c^2)$ is the solution to the bank's decision problem.

Proposition 1 *If there exist complete markets for insuring aggregate risks, the bank can achieve first-best (Pareto-efficient) risk sharing, without the introduction of bank capital.*

In this model, the only function of capital is to improve cross-sectional risk sharing between investors (shareholders) and depositors in the bank. This can be achieved just as well using Arrow securities. So bank capital is redundant.

To see this, consider what would happen if bank capital were introduced. Suppose that risk neutral investors subscribe e units of capital at date 0 to buy shares in the bank. The profits are all paid at date 2. Let π_s denote the profits in state $s = H, L$. The bank's budget constraint can be written as follows:

$$\sum_s (q_s \lambda c_s^1 + q_s p_s \{(1 - \lambda)c_s^2 + \pi_s\}) \leq 1 + e$$

We assume that the investors have access to the same assets as the banks, that is, the short and long assets. Then the opportunity cost of capital ρ is exactly \bar{R} . The supply of capital is perfectly elastic as long as investors receive the opportunity cost of capital. In equilibrium, this means that

$$e = \sum_s q_s p_s \pi_s.$$

Substituting this into the bank's budget constraint, we get the same budget constraint as before:

$$\sum_s (q_s \lambda c_s^1 + q_s p_s (1 - \lambda) c_s^2) \leq 1.$$

Thus, capital makes no difference to the feasible set of consumption allocations available to depositors. This proves the following Modigliani-Miller-type result:

Proposition 2 *Capital structure is irrelevant because Arrow securities can be used to undo any changes in the debt to equity ratio. Any capital ratio (including zero) is optimal for the bank.*

The assumption of a complete set of Arrow securities is quite restrictive. In practice, such securities do not exist. However, the use of dynamic trading strategies or derivatives may achieve an equivalent allocation of risk. In that case, Proposition 2 can be interpreted as saying that capital adequacy requirements impose no economic costs on the banking system.

Finally, we note that what is optimal for a bank is not necessarily socially optimal. However, in this model the banks operate like a representative agent. (The risk-neutral investors serve to fix the prices of contingent commodities, but do not play any other role in equilibrium). In equilibrium, what is optimal for the bank (and its depositors) is optimal for society as a

whole. There is no scope for welfare-improving intervention by the banking authorities and, in particular, no role for capital adequacy regulation. We state this corollary of Proposition 2 as a proposition.

Proposition 3 *Whatever level of capital is chosen, the laissez-faire equilibrium is Pareto-efficient. The imposition of capital adequacy requirements cannot improve economic welfare.*

2.2 Equilibrium without Arrow securities

In order to provide an opportunity for welfare-improving intervention, some kind of friction or market failure must be introduced. Here we assume that markets for liquidity services are incomplete. Specifically, there are no markets for Arrow securities (or their equivalent).

In this case, there is a role for capital in promoting improved risk sharing. If banks use non-contingent liabilities to finance investment in risky assets, there is a risk of bankruptcy in bad states where asset returns are low. Even if bankruptcy involves no deadweight costs ex post, depositors end up bearing risk and the allocation of this risk may be suboptimal in the absence of Arrow securities. By using capital to finance investment, the bank increases the total value of its portfolio in each state. The depositors (debt holders) receive all the value in bad states, where the bank is bankrupt, and the shareholders

receive the excess returns (total value minus debt) in good states. From the point of view of depositors, there has been a shift in returns from the good states to the bad states, equalizing consumption across states and improving risk sharing.

How far can this process go? It depends on the cost of capital, that is, the difference between the return on external investments and the bank's portfolio. So far, we have assumed that the risk-neutral investors have access to the same set of investments as the banks, that is, the long asset and the short asset. In that case, there is no cost to the bank of acquiring more capital and the first best can be achieved.

Suppose the bank acquires e units of capital at date 0 and chooses a portfolio (x, y) , where x is the investment in the long asset and y is the investment in the short asset and the budget constraint

$$x + y = 1 + e$$

is satisfied. The investment in the short asset is chosen to satisfy the bank's budget constraint at date 1:

$$\lambda d_1 = y,$$

where (d_1, d_2) is the first-best deposit contract achievable with complete markets. The investment in the long asset is chosen to satisfy the bank's budget

constraint at date 2 in the low state:

$$(1 - \lambda)d_2 = R_L x.$$

In the high state, there will be a surplus that goes to the shareholders as profit:

$$(1 - \lambda)d_2 + \pi_H = R_H x.$$

Clearly, we can choose e , x , and y to satisfy these constraints for the given contract of (d_1, d_2) . We need to check that the shareholders are receiving their opportunity cost of capital. Recall that the bank's complete-markets budget constraint assures us that

$$\lambda d_1 + \bar{R}^{-1}(1 - \lambda)d_2 = 1.$$

This implies that

$$(1 - \varepsilon)\pi_H = \bar{R}e$$

as required.

As long as the returns on assets held by the bank are equal to the best returns available to the investors elsewhere in the economy, there is no (net) cost to the bank of acquiring capital. The bank invests capital in the long asset. The returns on the investment in the long asset are just enough to

cover the investors' opportunity cost of capital. However, the bank's portfolio is now larger and this enables the bank to pay the depositors the same amount (d_1, d_2) in both states without risk of default. This is just what an efficient allocation of risk requires: there is no risk of default and the depositors' consumption is equalized in all states. In this case, capital provides the same services as complete markets.

Note that in the preceding discussion we have focused on the *smallest* amount of capital that allows the bank to achieve the first best. A higher level of capital would do just as well and would allow shareholders to receive positive profits in the low state as well as in the high state, but the depositors' welfare would be unchanged.

The introduction of capital allows optimal risk sharing with incomplete markets, as long as the net cost of capital is zero. However, as every CEO knows, capital is expensive. A more realistic assumption is that capital is costly, that is, the return on bank assets is not as high as the opportunity cost of capital. In the rest of this section, we consider the case $\rho > \bar{R}$. We discuss the motivation for this assumption in Section 2.3.

When capital is costly, risk sharing may be incomplete. Banks, which are forced to use non-contingent deposit contracts as liabilities, find it costly to avoid default. They either have to raise a large amount of capital, or hold

a large amount of the short asset, or distort the deposit contract. may find it optimal to default. The possibility of default allows greater flexibility and superior risk sharing. In some cases, banks that seek to maximize depositors' expected utility will find it optimal to default.

The model is easily adapted to allow for the possibility of default, which can occur if the level of capital is less than the first best. If there is no default in equilibrium at date 1, the representative bank offers a deposit contract (d_1, d_2) , early consumers at date 1 receive the promised payment d_1 and the late consumers are the residual claimants at date 2. The bank must pay the late consumers d_2 if possible, and the liquidated value of the portfolio otherwise. Without loss of generality we can put $c_L \leq c_H = d_2$. In one case, there is no default at date 2 and the late consumers receive d_2 in both states. In the other case there is default in state L (only) and consumers receive d_2 in state H and the liquidated value of the portfolio in state L . In the first

case, the bank's decision problem (DP) can be written as

$$\begin{aligned}
& \max \quad \lambda U(d_1) + (1 - \lambda)U(d_2) \\
& \text{s.t.} \quad x + y \leq 1 + e \\
& \quad \lambda d_1 + (1 - \lambda)p_H d_2 + p_H \pi_H \leq y + p_H R_H x \\
& \quad \lambda d_1 + (1 - \lambda)p_L d_2 + p_L \pi_L \leq y + p_L R_L x \\
& \quad d_1 \leq d_2 \\
& \quad (1 - \varepsilon)\pi_H + \varepsilon\pi_L \geq \rho e,
\end{aligned}$$

where π_s is profits in state s . Note that profits are assumed to be paid at date 2. The first constraint is the budget constraint at date 0: the investment in assets is bounded by the depositors' endowment and the capital provided by investors. The second and third constraints are the date-1 budget constraints corresponding to states H and L respectively: the left hand side is the present value of depositors' consumption and profits and the right hand side is the value of the bank's portfolio. The fourth constraint is the incentive constraint: late consumers have no incentive to imitate early consumers. The final constraint ensures that investors earn the rate ρ on the capital invested in the bank.

In this case, the demand for consumption at date 1 is the same in both states, as is the supply. Excess supply implies that $p_s = 1$, for $s = H, L$, which is inconsistent with equilibrium (the short asset is dominated). Thus,

demand must equal supply and there is a single price $p_H = p_L = p$ that clears the asset market at date 2. Investors will only hold the short asset if $p\rho = 1$, but in that case $p\bar{R} < 1$, so no one will be willing to hold the long asset. This cannot be an equilibrium. So there is no provision of liquidity by the investors. Since capital is costly, we want to minimize the amount holding constant the consumption of the depositors. Thus, $\pi_L = 0$. Further, since there is no liquidity provision by investors, we can assume without loss of generality that the bank holds enough of the short asset to pay the consumers at date 1 and enough of the long asset to provide consumption for the late consumers at date 2. The bank's DP reduces to

$$\begin{aligned}
& \max \quad \lambda U(d_1) + (1 - \lambda)U(d_2) \\
& \text{s.t.} \quad x + y \leq 1 + e \\
& \quad \quad \lambda d_1 \leq y \\
& \quad \quad (1 - \lambda)d_2 \leq R_L x \\
& \quad \quad d_1 \leq d_2 \\
& \quad \quad (1 - \varepsilon)(R_H - R_L)x \geq \rho e.
\end{aligned}$$

This leads to first-best risk sharing, but the depositors' expected utility is reduced relative to the equilibrium with Arrow securities because of the cost of capital. To see this, consider the first-order conditions for this problem (as usual ignoring the incentive constraint, which turns out not to be a binding

constraint at the optimum):

$$U'(d_1) = \mu_2$$

$$U'(d_2) = \mu_3$$

$$\mu_1 = \mu_2$$

$$\mu_1 = \mu_3 R_L + \mu_4 (1 - \varepsilon)(R_H - R_L)$$

$$\mu_1 = \rho \mu_4$$

or

$$U'(d_1) = U'(d_2) R_L + \frac{U'(d_1)}{\rho} (1 - \varepsilon)(R_H - R_L),$$

which implies

$$\rho = \rho \frac{U'(d_2)}{U'(d_1)} R_L + (1 - \varepsilon)(R_H - R_L). \quad (1)$$

To check our earlier analysis of the first-best, suppose that $\rho = \bar{R}$. Then the first-order condition reduces to $\rho U'(d_2) = U'(d_1)$ and we have the first-best allocation once again.

If the opportunity cost of funds to investors is greater than the return on bank assets, $\rho > \bar{R}$, increasing capital imposes a real cost on the bank depositors. They will have to give up part of the return on their investments in order to compensate the shareholders for the lower average return of bank assets. This trade-off between cost of capital and improved risk sharing will limit the extent to which it is optimal to share risk between shareholders and depositors.

Assuming $\rho > \bar{R}$ in (1) gives $\rho U'(d_2) > U'(d_1)$. Risk sharing is no longer complete. As ρ increases, d_1 and d_2 draw closer together until at last the incentive constraint is binding. A further increase in ρ will make default in state L an optimal response.

Default occurs in state L at date 2 when the value of bank assets is sufficient to allow the bank to make the payment promised to early consumers at date 1 but not the payment promised to late consumers at date 2. Although the late consumers receive less than d_2 , they will not run on the bank if they are still receiving more than d_1 . The representative bank will sell the long asset in exchange for liquidity in the bad state, so investors must be willing to hold the short asset. The demand for liquidity in the good state is lower than the demand in the bad state, so the prices of future consumption at date 1 are $p_H = 1$ and $p_L = p$. In order to induce investors to hold the short asset, we must have

$$\rho = (1 - \varepsilon) + \varepsilon \frac{1}{p}$$

The decision problem of the representative bank can be written as follows:

$$\begin{aligned}
\max \quad & \lambda U(d_1) + (1 - \lambda) \{(1 - \varepsilon)U(d_2) + \varepsilon U(c_L)\} \\
\text{s.t.} \quad & x + y \leq 1 + e \\
& \lambda d_1 + (1 - \lambda)d_2 + \pi_H \leq y + R_H x \\
& \lambda d_1 + (1 - \lambda)pc_L \leq y + pR_L x \\
& d_1 \leq c_L \\
& (1 - \varepsilon)\pi_H \geq \rho e.
\end{aligned}$$

If ρ gets even higher, it may be optimal to consider default at date 1 in state L .

Default at date 1 is different from default at date 2. At date 2, default simply means that the depositors receive less than was promised, but they still receive the total value of the remaining bank assets. The default event has no other equilibrium implications. Default at date 1 requires the bank to cease operating and liquidate all its assets in an attempt to meet its obligations. This has two important implications. First, the late consumers must withdraw at date 1; if they delay, there will be no assets left for them at date 2. Secondly, the sale of long assets will depress the asset price (raise the short-term interest rate), which in turn affects the liquidity of other banks. (Note that the asset price is affected only if a non-negligible number of banks defaults simultaneously). Thus, default at date 1 constitutes a crisis in a way

that the comparatively benign default at date 2 does not.

In each of the cases studied, it can be shown that capital is reduced when the cost of capital $\rho - \bar{R}$ is increased. When the difference between ρ and \bar{R} is sufficiently large, the optimal level of capital is zero.

Proposition 4 *If the cost of capital is high, the optimal level of capital may be positive, but it will not guarantee complete (first-best) risk sharing. For a sufficiently high cost of capital, the optimal (for the bank) level of capital is zero.*

It is worth stopping to ask why first-best risk sharing cannot be achieved between risk neutral equity holders and risk-averse debt holders. Technically, the reason is limited liability. If the shareholder's liability is limited to their investment, so is the depositors' insurance in the worst states. Because the cost of capital is positive, the liability constraint may be binding and risk sharing will be less than complete. If the equity holders and debt holders could write a complete contingent contract, they would replicate the effect of complete Arrow securities, but this would require payments from the equity holders to the debt holders in the worst states. As we have seen, complete Arrow securities effectively imply the (net) cost of capital is zero.

This suggests an interesting way that risk sharing could be improved: multiple liability has been discussed recently by Macey and O'Hara (2000).

Double or higher multiple liability was common in the United States until the introduction of deposit insurance in the 1930s. Absent collection and liquidity costs, multiple liability provides a way of increasing effective capital without increasing capital costs. For example, with double liability, the debt holders receive the same insurance indemnity in bad states with half the capital cost. In the limit, no capital is required, only liability.

Proposition 5 *If shareholder liability is a multiple m of their investment, first-best risk sharing is achieved in the limit as m diverges to infinity.*

This is like the situation at Lloyd's of London, where names invest their capital in various ways to get the highest rate of return and simultaneously use it as collateral to underwrite insurance contracts. There are two drawbacks to this solution, illiquidity and collection costs.

If the shareholders' liability is limited to the capital invested in the bank's portfolio, the receiver can easily dispose of those assets, assuming no fraud on the part of the bank's management. If the shareholders' liability extends to assets they own, it may be very costly for the receiver to pursue the shareholders and enforce their liability. Again, Lloyd's of London provides a useful illustration. These costs limit the effectiveness of multiple liability as a source of inexpensive insurance.

Illiquidity is another problem. If the best returns achieved by shareholders outside the bank are generated by illiquid investments, the shareholders may have difficulty meeting their liability to the bank when the bank defaults. Another way of putting the same point is that part of the cost of capital is the need to maintain a certain portion of the bank's portfolio in liquid investments.

What can government intervention accomplish? Because markets are incomplete, the equilibrium allocation may not be Pareto-efficient. However, the bank chooses its portfolio and deposit contract to maximize the welfare of the depositors, taking as given the prices in the market. So there is a market failure only if banks are facing the "wrong" prices. There are two possible ways in which prudential regulation can improve economic welfare. First, it could execute intertemporal trades that banks, investors, and depositors cannot achieve, effectively replacing missing markets. Secondly, it could alter the allocation of resources in a way that changes prices and causes economic decision makers to change their own intertemporal decisions. The first kind of intervention is not as interesting as the second. If regulatory authorities can replace missing markets, there is an obvious welfare gain; but it is not obvious what technological advantage the authorities have over the market when it comes to executing intertemporal trades. For example, if there are

missing markets because transaction costs are high, the regulatory authorities will be subject to the same transaction costs. It is unrealistic to assume that they have a technological advantage in this activity. In any case, even if regulators have a superior technology available, we cannot really argue that there is a market failure if the market allocation is efficient relative to the available technology. The market must be judged relative to the technology available to it.

The second possibility is more interesting. We say that an equilibrium is *constrained-efficient* if it is impossible to make every agent better off (or some better off and no one worse off), by changing the allocation of goods and services at the first date, while relying on the existing (incomplete) markets at the second and subsequent dates. Constrained inefficiency does imply that markets have failed to produce the most efficient allocation possible relative to that technology. The pecuniary externality created by intervention does not require a superior transaction technology, just a manipulation of agents' incentives by changing prices. This is the idea that lies behind a famous result of Geanakoplos and Polemarchakis (1986), who show that in a model of perfectly competitive general equilibrium with incomplete markets, the equilibrium allocation is generically constrained inefficient. A welfare-improving intervention does not require the regulator to make intertemporal

trades that are impossible for the market. The regulator only needs to affect the allocation of resources at a single point in time and leave it to the market to respond intertemporally to the changed incentives.

In the present model, there is no welfare-relevant pecuniary externality. Asset prices at the second date are uniquely determined by the opportunity cost of capital and the investors' first-order conditions for an optimal portfolio. An increase in the required capital adequacy ratio or reserve ratio may change the bank's portfolio, but it will not change asset prices. Since the bank is already maximizing the expected utility of the depositors taking prices as given, there is no feasible welfare improvement.

Proposition 6 *Equilibrium is constrained-efficient. There is no scope for using capital adequacy requirements to improve economic welfare.*

To see why this result holds consider the welfare impact of imposing a capital requirement \bar{e} above the equilibrium level. Each case considered above requires a different argument.

If there is no default at date 2, the banks do not use the asset market at date 1. At the market-clearing price, the investors do not want to hold the short asset, so there will be no trade at date 1 in the new equilibrium. Forcing the banks to hold more capital by imposing a constraint $e \geq \bar{e}$ reduces expected utility.

If there is default in the bad state at date 2, the investors provide liquidity by holding speculative balances of the short asset. It is optimal for the investors to hold the short asset only if $p_H = 1$, $p_L = p$ and

$$\rho = (1 - \varepsilon) + \varepsilon \frac{1}{p}.$$

This condition uniquely determines the price p . Thus, forcing the banks to hold more capital by imposing a constraint $e \geq \bar{e}$ does not change the prices at which banks can sell the long asset. At these prices, the banks can sell as much as they wish, just as they could in the original equilibrium. Thus, the maximum expected utility they can achieve is the solution to the DP given above with the added constraint $e \geq \bar{e}$. Obviously, adding a constraint to the problem will not increase expected utility.

A similar argument applies if there is default at date 1.

The conditions under which Proposition 6 holds are non-generic. Still, it makes the point that without a welfare-relevant pecuniary externality, intervention cannot be justified. If there were a welfare-relevant payoff externality, the Geanakoplos-Polemarchakis theorem suggests that there will typically be some intervention that can make everyone better off, but it does not identify the nature of the intervention and in general it is very hard to say what the intervention will look like. Even in simple examples, the general equilibrium effects of a regulatory intervention can contradict our intuition about

the policy's likely impact (cf. Allen and Gale, 2000b). Without a theory of optimal policy, intervention is a shot in the dark.

2.3 The cost of capital

Before leaving the issue of risk sharing, we need to say something in defense of the assumption that the opportunity cost of capital ρ is greater than the return on the long asset. One rationalization, pointed out above, is that investors have access to assets that are not available to the banks. There are various other ways in which this assumption could be rationalized. Here, a simple story will suffice. Suppose that there is a third asset, which pays a return $\rho/(1 - \varepsilon)$ in the high state and nothing in the low state. Risk neutral investors will choose to invest all of their wealth in this asset because it offers the highest expected return $\rho > \bar{R}$. Thus, ρ is the opportunity cost of capital. Now suppose some investors are persuaded to become shareholders and provide capital for the bank. The bank gains nothing from investing this capital in the risky asset. The risky asset provides no returns in the low state and the entire marginal return in the high state has to be paid to the shareholders in order to cover their opportunity cost of capital. An investment in the risky asset cannot improve risk sharing. In order to improve risk sharing (change the feasible set of consumption allocations), the bank

will have to invest some of the capital in the original two assets. Thus, without loss of generality we can restrict the bank's investments to the short and long asset. Then we are back to the model analyzed in this paper.

There are other stories we could tell. We could assume that the opportunity cost of capital is set by an asset that is more illiquid than the long asset, for example, one that only yields a return after date 2. Like the risky asset that yields nothing in state L , this asset will not help the bank improve risk sharing for the depositors and we can assume without loss of generality that the bank does not hold it. This again yields a wedge between the opportunity cost of capital and the return on bank assets.

Risk aversion would provide another justification for an opportunity cost of capital higher than \bar{R} . If investors are risk averse they have to be compensated for taking on the risk that depositors shed. In this case, it may not be possible to represent the opportunity cost by an exogenous parameter ρ , but there will be an economic cost of increasing capital and the optimal capital ratio may be incompatible with first-best risk sharing.

2.4 Costly crises

We have not emphasized the costs of financial crises, but they are obviously an important part of any rationalization of prudential regulation. In

the present model, the intertemporal allocation of consumption is distorted when a bank goes ceases to operate because the depositors lose their access to financial markets and hence to the highest equilibrium returns. This is a cost of crises but it seems a rather small one compared with the real effects of major financial upheavals. As Bernanke and Gertler (1989) have argued, financial crises have (negative) wealth effects that increase the cost of intermediation, reduce investment in real capital, and so reduce activity throughout the economy. This and other transmission mechanisms from the financial to the real sector are known as *financial accelerators*. Their absence is perhaps the most glaring limitation of our model. There is a large amount of empirical evidence about the destructive effects of financial crises on the real economy and, as we noted at the beginning of this paper, these seem to be the motivation for much of the concern with financial stability and prudential regulation. Introducing non-trivial costs of financial crises is clearly the best way to provide a foundation for prudential regulation. However, as with everything else, there will be costs and benefits of financial crises, and it is not obvious until we have analyzed these issues carefully that eliminating crises is optimal or that there are not better ways of reducing the deadweight costs of crises. What we need (and what we do not have) are models of financial crises in which it is possible to derive the optimal prudential regulation

policy, whether it be in the form of regulation of capital adequacy or some other.

3 Asymmetric information and capital structure

The risk-sharing example makes the point that, under certain circumstances, capital adequacy requirements are, at best, unnecessary and, at worst, harmful. Banks, left to themselves, will choose the optimal capital structure. If regulation forces them to increase capital ratios, the result will be a reduction of economic welfare. Of course, this example ignores a number of other ways in which capital structure may influence bank behavior and economic welfare, particularly those associated with asymmetric information (moral hazard, adverse selection).

In the presence of moral hazard, debt finance may be associated with risk shifting. Banks are financed by debt-like liabilities (deposits) and this can produce an incentive to take excessive risk. Capital, like collateral, counteracts this tendency, because it increases the shareholders' sensitivity to downside risk. One rationale that is given for capital adequacy regulation is to reduce the incentive for banks to take risks.

However, in the absence of capital adequacy regulation reputation may ensure that banks do not take excessive risks in a situation of moral hazard. Bhattacharya (1982) points to the work of Klein and Leffler (1981) on reputation and quality and suggests its applicability in this context. Depositors will infer the incentives of banks to take risk and realize that the value of a reputation for prudence makes it incentive-compatible for the bank to adopt a low risk strategy. Hellman, Murdock, and Stiglitz (1998) also mention this incentive.

The assumption that adequate capital is necessary to prevent excessive risk taking does not by itself provide an argument for capital adequacy requirements. The bank can internalize this agency cost and adopt the optimal capital structure without any assistance from the regulator. In the absence of a pecuniary externality, there is no reason to think that the privately optimal capital structure is not socially optimal.

The same argument can be made in connection with other determinants of optimal capital structure. If there are deadweight losses from bankruptcy, for example because illiquid markets imply that an orderly liquidation is difficult to achieve or because there is loss of charter value or assets cannot be managed as efficiently by other banks, these costs should be internalized in the bank's choice of the optimal capital structure. Only if there is a

pecuniary externality and markets are incomplete will there be an argument for regulation.

It is not clear that any of these considerations are actually the ones that motivate the regulators who set capital adequacy requirements. But whatever the motivation, the onus seems to be on the regulator to identify the pecuniary externality so that we can assess the importance of the market failure and the effectiveness of capital adequacy requirements as a solution. Financial fragility, the idea that one bank failure may trigger others and bring down the whole financial system, would be an example of a pecuniary externality on a very large scale. Perhaps this is what motivates the system of capital adequacy requirements. If so, we need better models of financial fragility before we can provide a theoretical basis for the current system.

4 Monitoring and survival strategies in a volatile environment

Another function of capital is to make continuous monitoring unnecessary.

Imagine a world in which the following assumptions are satisfied:

- Monitoring is continuous;
- Portfolio is marked to market;

- Portfolio value changes continuously;
- Markets are perfectly liquid.

In this world, banks would never make losses without the forbearance of the regulator. When the net worth of the bank reaches zero, the assets and liabilities will be liquidated and the bank closed without loss to depositors. There is no need for capital to act as a buffer for creditors (depositors) since the creditors are always paid in full. Similarly, there is no incentive for risk shifting. The problem of moral hazard is resolved by continuous monitoring. Now, of course, these are strong assumptions. If monitoring is not continuous, if asset returns are not continuous, or if asset markets are illiquid, there may be deadweight losses associated with bankruptcy. But, again, that is not necessarily a market failure that can be rectified by setting high capital adequacy requirements. The bank will internalize these costs and choose the optimal capital structure to maximize shareholder value. Again, in the absence of a pecuniary externality, the private optimum will be the social optimum.

5 Concluding remarks

We began by noting the lack of theory in the practice of financial regulation. In this paper we have argued that theoretical analysis should be an important component of policy analysis. In the area of banking regulation little theory has typically been used. Instead historical experience has been the guide. Capital adequacy regulations are one of the most important aspects of banking regulation. We have suggested that the theoretical rationale for their existence is not as straightforward as might be expected at first sight. Much work remains to be done in this area.

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