A Unified Approach to Credit Crunches, Financial Instability, and Banking Crises

Goetz von Peter*
Columbia University

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Abstract

We link banking and asset prices in a simple monetary macroeconomic model. Our main innovation is to consider how wide-spread default affects the banking system. We find that the interaction of credit, asset prices, and loan losses explains a complete spectrum of outcomes, including financial extremes for which separate theories were thought to apply.

When fundamentals deteriorate, an asset price decline causes default among leveraged firms, and banks suffer loan losses. Their size determines whether a capital crunch, financial instability, or a banking crisis occurs. But self-fulfilling capital crunches and banking crises are also possible when loan losses force a credit contraction that feeds back onto asset prices.

This model, unlike others, distinguishes between financial and macroeconomic stability, and derives explicit solutions and balance sheet effects even far from the steady state. It is applied to Japan's Lost Decade and to the US Great Depression. It also sheds light on the role of asset prices in monetary policy, and on the procyclical effect of capital adequacy requirements.

JEL Classification: E5, E31; G12, G21, G33

Keywords: Asset Prices, Elastic Credit, Inside Money, Default, Non-Performing Loans, Banking, Capital Adequacy, Credit Crunch, Financial Instability, Banking Crisis, Debt Deflation.

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*Economics Department, Columbia University New York. Email: gv43@columbia.edu.

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1 Introduction

Motivation. The essence of central banking lies in the pursuit of macroeconomic and financial stability.[1] There are complete models of macroeconomic stability, and a reasonably broad consensus on how to achieve it. Not so for financial stability. There is no widely accepted model, much less a consensus on how to achieve it - even the definition is a matter of debate. This is disturbing, given the frequency with which financial instability has befallen the world in the last 25 years, often with devastating productive and redistributive consequences.[2]

This paper extends the reach of macroeconomics to financial instability in a very simple and explicit way. We depart from Kiyotaki and Moore's (1997) model of credit cycles. They consider leveraged firms, and how their exposure to asset prices generates macroeconomic dynamics. We believe that taking the route of leverage and asset prices is even more promising for understanding financial stability, the other dimension of central banking.[3]

To push the theory in this direction, we focus on a new element: losses to the financial system. To do so, we integrate a banking system. Our main innovation is to allow for wide-spread default among bank borrowers following a decline in asset prices. We then ask how loan losses affect the banking system, and how the state of the banking system in turn affects the economy. We find that the interaction of credit, asset prices, and loan losses provides a unified approach for explaining capital crunches, financial instability, and banking crises.

In spite of their empirical relevance, loan losses have not previously been endogenized. They measure the transfer of losses from defaulting borrowers to the banking system. Being themselves indebted, banks cannot absorb them indefinitely. Loan losses of a certain size constrain bank lending [capital crunch]; larger losses cause an unstable contraction of credit [financial instability], which propels the system toward insolvency [banking crisis]. At that point, the credit and payment mechanisms cease to function.

The emphasis we place on banking and balance sheets is uncommon in macroeconomics. This kind of analysis is important because macroeconomics has contributed rather little to the policy debates on financial instability that have engaged central banks and international financial institutions. This is because macroeconomic models typically (a) ignore banking, (b) avoid the issue of default, and (c) analyze mostly the neighborhood of the steady state.[4] By overcoming these limitations, our analysis shows that financial instability can be analyzed within a simple macroeconomic model.

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[1] Macroeconomic stability refers to the stability of the price level and of output. Financial stability refers to the smooth, uninterrupted operation of both credit and payment mechanisms. (This succinct definition is taken from Federal Reserve Bank of St. Louis 2002). Central banks supervise and typically operate the payment system, along with lending of last resort facilities. They also assume responsibility for the overall stability of the financial system, even when the regulation and supervision of financial institutions rests with other authorities. See Fry et al (1999), chapter 6, and Brealey et al. (2001), chapter 2.

[2] For instance, no macroeconomic model captures the non-performing loans problem that has plagued Japan for a decade, following the bursting of the asset price bubble.

[3] Leverage and falling asset prices are the main concepts around which Kindleberger (1996) organized his famous history of financial crises. These concepts have taken every opportunity in the recent past to reassert themselves.

[4] This technical limitation applies to dynamic general equilibrium models that rely on linearization.

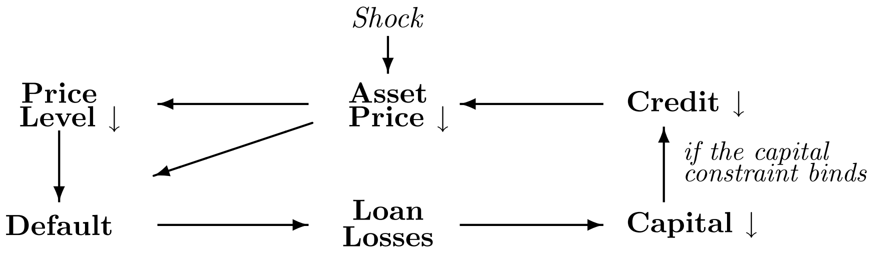
Set-up. The model is a flexible-price overlapping generations model with three main features. First, asset prices play a central role, as in Kiyotaki and Moore (1997). Second, a banking system arises to intermediate payments between firms and households, as in McAndrews and Roberds (1999). Finally, the banking system operates under a capital constraint, such as the minimum capital requirements established by the 1988 Basel Accord.

We set up the following experiment. Firms purchase productive assets on bank credit. Next period, they resell them to the new generation of firms, and sell their output at the current price level. While undisturbed, the economy perpetuates itself in steady state. We then let an adverse productivity shock set off dynamics. The forward-looking asset price falls to reflect the reduced return on assets, and old firms suffer an unexpected loss on assets sold. The resulting wealth effect also reduces consumption spending, and the price level falls (see diagram below). Deflation and asset price decline together threaten the solvency of old firms: they had incurred debt expecting to sell goods and assets at continued steady state prices. For large enough shocks, wide-spread default among firms becomes inevitable. We then ask:

(1) How do losses affect the banking system?
(2) How does the state of the banking system in turn affect the economy?
(3) What determines whether a capital crunch, financial instability, or a banking crisis occurs?

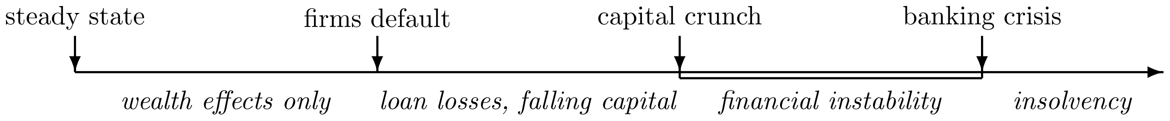
Results. The model suggests the following answers.
(1) As fundamentals worsen, prices fall, and balance sheets deteriorate. The greater the adverse shock, the lower the price level and asset prices relative to outstanding debt. The resulting losses cascade down the debt structure: they first reduce firms' profits; once firms default, further losses reduce the banking system's dividends and capital. Once those are zero too, the banking system is insolvent, and any further losses are borne by depositors. In this 'fundamental equilibrium', there is a unique mapping from worsening fundamentals to deteriorating balance sheets and economic outcomes.

(2) When the banking system complies with a capital constraint, financial instability and multiple equilibria arise. The capital constraint closes the loop (see diagram). It generates feedback from the banking system to the economy, because any fall in bank capital, due to loan losses, translates into a multiple contraction of credit. This depresses asset prices and accelerates loan losses, which in turn tightens the capital constraint.



A threshold now splits the space of fundamentals. An economy with weak fundamentals suffers financial instability: unstable credit contraction propels the system toward a banking crisis. An economy with strong fundamentals may attain the fundamental equilibrium, but self-fulfilling capital crunches and banking crises are also possible. Therefore, the mapping from fundamentals to outcomes is no longer unique when the banking system reacts to loan losses by reducing credit. Loan losses, not necessarily fundamentals, decide whether a capital crunch, financial instability, or a banking crisis occurs.

(3) Each phenomenon is triggered by a threshold asset price decline determined by the economy's structural features, including leverage. Leverage increases an economy's vulnerability, because a given asset price decline produces greater losses. While leverage is essential for financial instability, deflation and recessions are not. Macroeconomic and financial stability are distinct, but not independent. We show that they tend to reinforce each other, but either one may also occur alone. In sum, the diagram depicts the phenomena the model can explain as a function of losses:



Related literature. This appears to be the first model to characterize a complete spectrum of outcomes between the steady state and a systemic banking crisis. Separate theories exist for each range. The first range ('wealth effects only') is captured by the **financial accelerator**.[5] Much empirical evidence supports the view that balance sheet variables, mainly cash flow and net worth, affect investment (Hubbard 1998). The financial accelerator aggregates these balance sheet effects to produce business cycle dynamics. While sharing the emphasis on balance sheets in a macroeconomic context, our model focuses less on borrowers, and more on the banking system.[6] The financial accelerator confines itself to small balance sheet variations.[7] As such, the theory stops short of addressing the extremes that had motivated its development. Debt deflation, financial instability, and banking crises were explored in the empirical and narrative accounts of Bernanke (1983), Mishkin (1991, 1999), and Calomiris (1993, 1995). They found, inter alia, that falling asset values may impair borrowers' balance sheets to the point of interrupting the intermediation of credit, which in turn exacerbates macroeconomic conditions. This is the two-way causation we study here (questions (1) and (2) above). We allow borrowers' net worth to fall until default occurs. From this perspective, our paper attempts to extend the financial accelerator to the space beyond default.

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[5] The main contributions are Bernanke and Gertler (1989, 1990, 1999); Greenwald and Stiglitz (1993); Kiyotaki and Moore (1997); and Bernanke, Gertler and Gilchrist (1999).

[6] The concept of 'financial fragility' (Bernanke and Gertler 1990) is about borrowers' net worth and investment, hence output and, ultimately, macroeconomic stability. Our concept of financial instability is about the intermediation of credit and payments.

[7] The formal theory quantifies the marginal contribution of balance sheet variables to business cycle dynamics. Correspondingly, (a) linearization is employed, and (b) the issue of default is either ruled out, (Kiyotaki and Moore 1997), or made inconsequential for diversified lenders (Bernanke, Gertler and Gilchrist 1999).

The second range in the diagram ends in a **capital crunch**. The empirical evidence from New England and Japan outweighs the few models that address this problem. They provide better microfoundations for bank capital, but a poorer treatment of loan losses, than does our model. Some papers take falling bank capital as exogenous (Bernanke and Gertler 1987, Holmström and Tirole 1997, and Chen 2001), or as unrelated to loan losses (Blum and Hellwig 1995, Gorton and Winton (2000), Freixas and Bolton 2001). Others do consider loan losses, but do not relate them to any borrowers (Rajan 1994, van den Heuvel 2002), or to any endogenous macroeconomic variables (Gersbach 2002). By contrast, the macroeconomic endogeneity of loan losses, hence that of bank capital, is central to our approach. From that perspective, our paper attempts to endogenize loan losses, a key cause of capital crunches, within a macroeconomic framework.

The final range in the diagram ends in a **banking crisis**. Banking crises have almost exclusively been analyzed in terms of the microeconomics of bank runs. A vast literature builds on the idea that liquidity-providing demand deposits make banks prone to runs: the existence and fragility of banks are then simultaneously explained, as in Diamond and Dybvig (1983), Allen and Gale (1998), and Diamond and Rajan (2001).[8] To the extent that bank *assets* are modelled at all, their deterioration is taken as exogenous. Our approach relates bank assets to firms, and to the macroeconomic factors that govern their financial condition. We think that doing so has empirical advantages. First, the deterioration of bank assets through non-performing loans is characteristic of banking distress, as reflected in the list of 168 crises compiled by Caprio and Klingebiel (2003). Second, a banking system can be in distress even when bank runs are not a problem, as in the case of Japan (see section 5.1).[9] Even the classic banking panics are being revised in the light of new evidence on the fundamental deterioration of bank assets (section 5.2). Bank runs are perhaps better viewed as a symptom, rather than the cause, of financial instability. From that perspective, our paper attempts to provide an asset-based explanation of banking distress.

The model's main appeal is its simplicity. Yet it articulates all the links depicted on page 2 and generates a complete spectrum of outcomes. In spite of dynamic general equilibrium, explicit solutions and balance sheet effects are found without resorting to linearization.[10] This is made possible by the overlapping generations structure (which minimizes persistence following default), and by our inside money approach to banking. This approach is considerably simpler than the alternatives in monetary economics, because the credit apparatus is frictionless until low bank capital interferes with the elastic provision of credit. It has the further advantage of being consistent with basic payment system facts, and with the determination of the money supply by credit counterparts.

Applications. Two case studies and two central banking policy debates illustrate possible uses of the model. Japan's Lost Decade (1990s) can be understood in terms of our characterization of a

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[8] Useful surveys appear in Bhattacharya and Thakor (1993), Freixas and Rochet (1997), and deBandt and Hartmann (2000).

[9] The last systemic banking panics in the US and UK took place in 1933 and 1866, respectively. Deposit insurance and lending of last resort are almost universal today.

[10] This contrasts not only with the financial accelerator, discussed above, but also with general equilibrium models with incomplete markets (GEI). The GEI paradigm takes a more complete, but far more complex, approach to integrating default and financial instability. See Dubey et al. (2000), and Tsomocos (2002), respectively.

capital crunch. The model helps explain where the 'non-performing loans problem' came from, and how it undermined the effectiveness of monetary policy (see Ueda 2003). The US Great Depression (1929-33) is an example of financial instability ending in a banking crisis. The model suggests a fundamental explanation for observed bank runs, and captures the collapse of intermediation (Bernanke 1983).

Regarding monetary policy, we show that a central bank mindful of financial stability may react to asset prices, (only) when their decline exceeds a threshold determined by the economy's leverage. Only a timely interest rate cut is likely to be successful, if it coordinates the banking system on the fundamental equilibrium. Regarding regulatory policy, we show that capital adequacy requirements can have a strong procyclical effect on the economy. Nevertheless, removing capital adequacy regulation might well exacerbate procyclicality.

The model can be applied to these issues because it distinguishes between macroeconomic and financial stability. The latter primarily depends on asset prices and loan losses. Their effect on the banking system is highly non-linear around certain thresholds, which depend on the structural features of the economy. Our modelling of balance sheets and thresholds compares to the stress testing exercises conducted at central banks and international financial institutions to assess risks to financial stability.

The paper proceeds as follows. Section 2 lays out the basic model for the perfect foresight case. Section 3 introduces a shock and determines the fundamental equilibrium. Section 4 adds the capital constraint, explores capital crunches and financial instability, and performs comparative statics. Finally, section 5 presents the applications and concludes.

2 The Basic Model

2.1 Set-up

The model is an flexible-price, infinite-horizon non-stochastic general equilibrium model with real assets and consumption goods. There are overlapping generations of firms and households, each of unit measure, and a banking system intermediating between them (see figure 1, page 9). *Households* are the lenders in this economy; they solve a standard intertemporal consumption problem, and their Euler equation will govern the price level. *Firms* use real assets to produce and sell consumption goods; the productivity of their technology will govern the asset price. The *banking system* arises to help households and firms attain their optimal pattern of exchange by intermediating their payments. Firms and banks are modelled as separate from households, consuming their profits and dividends, respectively.[11] Aggregate demand will be the sum of spending by households, firms' profits, and bank dividends.

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[11] This simple ownership structure makes sure that (a) borrowing takes place, and that (b) loan losses and bank capital structure matter. This would not necessarily be so if (a) firms were owned by households (production and consumption would be internalized), or if (b) banks were owned by firms or by households.

(1) Firms

Firms are run by owner-entrepreneurs, and are arranged around the unit circle. The entrepreneur derives utility from final period consumption, using the firm's profits to purchase output from the neighboring firm,

$$u(c_t^f) = c_t^f \qquad \text{s.t. } p_t c_t^f = \Pi_t. \tag{1}$$

Hence the entrepreneur maximizes profits. The typical firm of generation $t-1$ transforms capital and labor into consumption goods, sold next period for p_t (the price level). Labor consists of the entrepreneur's endowment l, and capital consists of real assets, such as real estate (land and buildings).[12] The production function is standard neoclassical with a unit total factor productivity coefficient, $y_t = f(h_{t-1})$. As in Kiyotaki and Moore (1997), production uses real assets and takes time. In contrast to their model, however, we let firms choose their first-best plan (no borrowing constraint), and let financial arrangements arise to accommodate their credit and payment needs. The firm therefore maximizes the unconstrained problem

$$\max_{h_{t-1}} \ \Pi_t = p_t f(h_{t-1}) - a_{t-1} h_{t-1} \tag{2}$$

where a_{t-1} is the cost of holding assets, specified below. Equating this cost to the marginal revenue product implies the optimal asset holding h_{t-1}^d

$$p_t f'(h_{t-1}^d) = a_{t-1}.$$

With a unit measure of identical price-taking firms, h_{t-1}^d also denotes aggregate asset demand (only firms will hold assets). Assets are in fixed supply H and do not depreciate. Market clearing then determines the cost of holding assets,

$$a_{t-1} H = \alpha p_t y \tag{3}$$

where $y \equiv f(H)$ is aggregate output, and $\alpha \equiv f'(H)\frac{H}{y}$ is output elasticity.[13] In present value terms, firms plan to allocate the fraction α of (expected) future sales revenue $p_t y$ to holding productive assets; the remainder is paid out as profits and spent on consumption,

$$\Pi_t = (1-\alpha)\, p_t y. \tag{4}$$

Profits are the implicit wage for the entrepreneur's specific labor.[14] In aggregate, the fractions α and $(1-\alpha)$ of revenue, $p_t y$, are the shares of national income paid to the factors of production.

We now turn to the financial implications of firms' optimal allocation. Suppose for a moment that assets were rented, and paid for after use. Firms would then finance assets entirely out of their

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[12] The entrepreneur's labor is specific to the project, and no outside labor is employed. The constant l is subsumed in the production function.

[13] Both are constant because assets in fixed supply are the only variable factor of production.

[14] We allow for positive profits, because zero profits would make firms overly prone to default (see (23) below). Allowing positive profits amounts to $\alpha < 1$. With the additional (weak) condition $\alpha > R - 1$, we impose a lower bound on the marginal productivity of assets.

sales revenue in t. There would be no need for borrowing in $t-1$, no debt, no banks, and no vulnerability to asset prices – a poor environment for studying financial instability.

Assumption 1 (Borrowing). Firms must purchase the assets they use in production. The absence of a rental market creates a mismatch in cash flows.[15] It forces firms to borrow, before production takes place, the full market value of assets $b_{t-1} = q_{t-1}H$. Next period, they repay their debt after selling output y and assets H,

$$\begin{aligned} q_{t-1}H &= b_{t-1} \\ \Pi_t + R_{t-1}b_{t-1} &= q_tH + p_ty \end{aligned} \tag{5}$$

where $R_{t-1} > 1$ is the gross nominal interest rate between $t-1$ and t. Combining (4) with (5) gives

$$\left(R_{t-1}q_{t-1} - q_t\right)H = \alpha p_t y. \tag{6}$$

Comparison with (3) shows that assumption 1 makes the cost of holding assets $a_{t-1} = R_{t-1}q_{t-1} - q_t$. The right hand side is what Kiyotaki and Moore (1997) call *user cost.* It is a small fraction of the purchasing price q_{t-1} because assets, unlike goods, can be resold after use. (This gives firms the incentive to become leveraged). We can develop (6), forwarded once, into an asset pricing equation,

$$q_t = \frac{\alpha p_{t+1}y}{R_tH} + \frac{q_{t+1}}{R_t}. \tag{7}$$

Iterating forward, and ruling out bubbles yields

$$q_t = \frac{\alpha y}{H}\sum_{i=1}^{\infty}\frac{p_{t+i}}{R^{(t+i)}} \tag{8}$$

where $R^{(t+i)} \equiv \prod_{j=0}^{i-1} R_{t+j}$. As in q-theory, the value of assets is the discounted stream of future marginal revenue products associated with their use.

(2) Households

Alongside firms, there are overlapping generations of households, treated as an infinitely-lived dynasty (Barro 1974). Households derive utility from consuming goods. They are endowed at date 0 with all H assets. They could run their own production, but it is much less efficient than firms': $g(h) \leq \varepsilon f(h)$, where $\varepsilon > 0$ is arbitrarily small, and $g'(0) < f'(H)$. Households therefore have little productive use for assets; they will sell them to the first generation of firms.[16]

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[15] An incomplete contracts approach would indicate that ownership dominates renting when the entrepreneur's human capital is essential (Hart 1995, chapter 2). Kiyotaki and Moore (1997) also rule out renting, but for reasons specific to their set-up (fn. 8).

[16] Since households do not rent them out (assumption 1), they would only use assets in equilibrium if these appreciated at (close to) the rate of interest; but a user cost of zero is inconsistent with firms' finite demand necessary for equilibrium. Households run their own production only if intertemporal exchange breaks down (autarky).

Households then solve a standard intertemporal consumption problem, with initial wealth $q_0 H$ given by (8). Let s_t denote their spending on consumption ($s_t \equiv p_t c_t^h$), and D_t financial wealth carried over to the next period,

$$\begin{aligned} s_0 + D_0 &= q_0 H \\ s_t + D_t &= R_{t-1} D_{t-1} \qquad \forall t \geq 1. \end{aligned} \tag{9}$$

Households maximize utility subject to their intertemporal budget constraint,

$$\max_{\{c_t\}} \sum_{t=0}^{\infty} \beta^t u(c_t^h) \qquad \text{s.t.} \qquad \sum_{t=0}^{\infty} \frac{s_t}{R^{(t)}} \tag{10}$$

Households are the lenders in this economy; they do not run down their wealth ($u'(0) = \infty$). The slope of optimal consumption is given by their Euler equation,

$$u'(c_t^h) = \beta R_t \frac{p_t}{p_{t+1}} u'(c_{t+1}^h).$$

In steady state it must be the case that $R = \beta^{-1}$, the interest rate equals the inverse rate of time-preference. Optimal consumption spending then equals $s = (R-1)D$, the permanent income from wealth $D = q_0 H / R$. To specify how households deviate from this perpetuity rule outside steady state, we posit time-separable CRRA utility $u(c) = \frac{c^{1-\gamma}-1}{1-\gamma}$ and consider $R_t = \beta^{-1}$ (see assumption 3). The Euler equation then directly relates the evolution of spending to that of the price level,

$$s_t = \left(\frac{p_{t+1}}{p_t} \right)^{\frac{1-\gamma}{\gamma}} s_{t+1}. \tag{11}$$

(3) The Banking System

We now consider how a banking system arises to help households and firms attain their optimal plans by intermediating their payments. Note first that efficiency requires that the stock of assets H be passed down successive generations of firms for productive use, as shown in figure 1.

This raises a payments problem: households only give up H at date 0 in exchange for a claim on the output of *all* future generations of firms, since they wish to consume every period, see (10). While this could be achieved by renting H out every period, renting was ruled out by assumption 1. Firms need to borrow, ultimately from households, to purchase the assets. But the value of such borrowing exceeds the value of firms' output.[17] To repay households, firms depend on the proceeds from selling assets to the next generation of firms, which also needs to borrow from households. The circulation of firms' debt (IOUs) could in principle overcome the payments problem. That, however, requires the collection and clearing of an infinity of IOUs, within and across all generations

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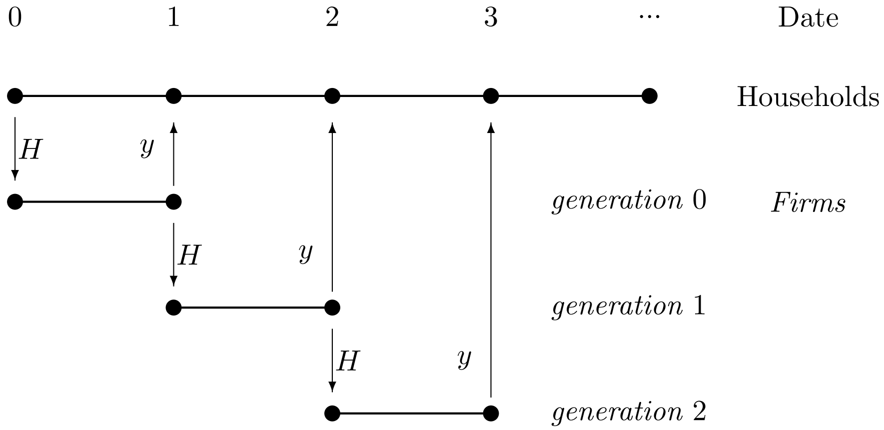
[17] The value of assets exceeds that of output because assets produce *every* period's output. See footnote 14 and equation (16) below.

of firms, which poses a formidable organizational challenge.

Figure 1: Intertemporal Exchange



Assumption 2 (Clearing). Households and firms find it too costly to clear against each other firms' IOUs.[18] As a result, the circulation of firms' IOUs cannot overcome the payments problem, even if IOUs are enforceable. In view of the inefficiency of autarky, one should expect some institution to arise. The following result determines the nature of this institution.

Proposition 1 ***Banking***
(Only) a deposit banking system overcomes the payments problem.

Proof: Assume initially that firms' IOUs are enforceable. Let the institution collect firms' IOUs and issue a non-circulating liability of equal value ('deposits'). All transactions can now be conducted in terms of this liability on the institution's balance sheet (see appendix C).[19] Every period t, the institution creates deposits worth q_tH for new firms, enabling them to purchase the assets by transferring the balance to old firms. Old firms use these deposits to reduce their existing debt with the institution to $R_{t-1}q_{t-1}H - q_tH$. This balance is repaid using sales revenue p_ty, which leaves profits Π_t consistent with (5).[20] Going backward, the first payment q_0H is received by the initial sellers of assets (households), who hold their wealth on deposit to finance their spending s_t every period. The institution overcomes the payments problem, since all transactions are feasible and consistent with (5) and (9) for all $t \geq 0$. The institution can be characterized as a deposit banking system, because (a) its assets consist of loans to firms (firms' IOUs), (b) its liabilities consist of

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[18] The literature on payment systems makes similar assumptions, based on spatial separation (Freeman 1996, Green 1997) or limited legal recourse (McAndrews and Roberts 1999).

[19] Assumption 2 does not apply with equal force to the banking system: interposing itself as a counterparty to all transactions substantially simplifies clearing, because it is now conducted in terms of a single liability, deposits.

[20] Sales revenue includes the profit spent by the neighboring firm. To visualize this, think of firm i borrowing Π_t to purchase the output from the neighboring firm $i+1$. This allows firm $i+1$ to cancel its debt, leaving Π_t to spend on firm $i+2$ output, and so on. The circle is closed, and the initial Π_t is repaid, when firm $i-1$ has purchased output from firm i.

deposits, used as the means of payment in the economy, and (c) its deposits are held (carried over to the next period) by households: the banking system combines the functions of payment system and credit intermediary.

Appendix B defines strategic default and shows that it cannot be prevented by arrangements with circulating liabilities (bank notes or fiat money). Deposit banking, by contrast, takes advantage of its command over the payment system to enforce firms' debt. Hence, only deposit banking overcomes the payments problem. •

In other overlapping generations models, outside money (Samuelson 1958), or private IOUs (Sargent and Wallace 1982), overcome the payments problem; here deposit banking does. Our notion of banking is closest to McAndrews and Roberds's (1999) analysis of overdrafts. In both models the banking system has an advantage in payment intermediation, which is conducted by transfer of bank deposits. By granting credit, the banking system creates inside money by counterpart. This, we believe, provides a better description of developed monetary systems than do the cash-or-barter models that dominate monetary macroeconomics.[21] Credit here is *perfectly* elastic, in the sense that firms can borrow any amount of deposits consistent with their life-time wealth. Banking removes the clearing friction for which it arose, and strategic default can be prevented: the model reverts to frictionless. Therefore, in contrast to Kiyotaki and Moore (1997), borrowing is not constrained by the future market value of assets: firms can also pledge their future sales revenue in (5). In other words, the cash-in-advance constraint implicit in assumption 1 is not distorting. We close this section with two assumptions.

Assumption 3 (Lending). Deposits and loans are standard debt, paying a nominal interest rate of $R = \beta^{-1}$. The use of standard debt (non-contingent until default) is pervasive in reality, and natural in our context of payment intermediation.[22] The fixed nominal interest rate $R = \beta^{-1}$ can be thought of as a policy rule; it is supported by the elasticity of credit (see footnotes 21, 26). Credit remains perfectly elastic as long as bank lending remains unconstrained by bank capital (section 4 addresses the constrained case).

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[21] McAndrews and Roberds (1999) identify payment intermediation as the original, and still vital, function of banks. Cash transactions today account for less than 1% of the value of payments in the US (Hancock and Humphrey 1998). Nevertheless, macroeconomic models almost exclusively work with fiat money. Contemporary banking theory (following Diamond and Dybvig 1983, and Diamond 1984) does not view deposits as a means of payment, and does not consider that deposits can be supplied elastically by the system as a whole (see footnote 41).

Goodhart emphasizes that bank credit, in reality, is made elastic by institutional construction, because central banks guarantee access to reserves at the chosen official short-term rate, which in turn allows commercial banks to make loans freely available to qualified borrowers (e.g. Goodhart 2003, p.1). Elastic credit is a common theme in several strands of the monetary literature, including the Banking School (1840s especially), pure credit economy (Wicksell 1907), credit cycles (Hawtrey 1919), inside money (Gurley and Shaw 1960, chapter 7), free banking (Selgin 1988), Gold Standard (Calomiris and Hubbard 1989), and post-Keynesian economics (Moore 1988). Hicks (1967, 1989 chapters 5-7), and Black (1970) describe a credit economy with banking similar to ours. Few formal models, however, identify elastic credit with banking; they include work on overdrafts (McAndrews and Roberds 1999), on private bank note issue (Champ et al. 1996), and on payment systems (McAndrews and Roberds 1995, Freeman 1996 and Green 1997).

[22] Following assumption 2, it is likely that the complexity of clearing is minimized when the means of payment is standard debt. See also Freeman (1996), Green (1997) and McAndrews and Roberds (1999). More generally, standard debt could also be justified in terms of optimal risk-sharing, because households here are risk averse, whereas entrepreneurs and banks are risk neutral. Finally, explanations based on asymmetric information are proposed in Gorton and Pennacchi (1990), and Townsend (1979) and Diamond (1984).

Assumption 4 (Bank Capital). The banking system has $K = s_0$ worth of bank capital. We can imagine a banking system endowed with $\alpha\beta y$ goods, sold in period 0 at $p_0 = 1$ to households.[23] This explanation of bank capital is little more than definitional; it simply states that to become bank owners they must initially give up some consumption (further discussion in section 5.4). The bank balance sheet, recorded at the close of markets each period, now consists of loans, deposits, and capital,

A Bank Balance Sheet	L
q_tH	D_t
	K_t

The balance sheet identity $K_t \equiv qH_t - D_t$ shows that the banking system earns a return of R on capital. Bank capital evolves as $K_t = RK_{t-1} - Div_t$. For simplicity, suppose the banking system follows the dividend policy of paying out its profits each period.[24] Absent loan losses,

$$Div_t = (R-1)K_{t-1}, \tag{12}$$

and bank capital remains constant at $K_t = K$. Bank owners spend their dividends, like firm owners spend their profits, on consumption.

Remarks. Note that the size of the bank balance sheet at all times equals the value of the asset market q_tH. This correspondence is natural in an economy whose asset market so heavily relies on bank credit. Any constraint on the size of the bank balance sheet, such as low bank capital, will reduce credit availability and thereby depress asset prices. Note also that the banking system combines both credit and payment mechanisms, hence its stability is equivalent to financial stability as defined on page 1. These considerations become essential in section 4.

2.2 Perfect Foresight Equilibrium

Asset market equilibrium is obtained from (6),

$$\begin{aligned} \alpha p_{t+1} y &= \left(Rq_t - q_{t+1}\right) H \qquad \forall t \geq 0 \qquad (13) \\ \Rightarrow q_t &= \frac{\alpha y}{H} \sum_{i=1}^{\infty} \frac{p_{t+i}}{R^i}. \end{aligned}$$

---

[23] Since firms only start selling their production at date 1, households will spend s_0 of their deposits to purchase the banking system's endowment. The banking system thereby acquires a deposit claim on itself, which constitutes bank capital. (Gorton and Winton (1995) provide a micro-founded analysis of optimal capital at the 'beginning of the world'). Assuming $p_0 = 1$ is no more arbitrary than assuming a fixed quantity of unbacked fiat money (see also footnote 26).

[24] In steady state, such a dividend policy is necessary for bank capital to remain constant.

Goods market equilibrium is obtained from equating the value of aggregate supply with aggregate demand, the sum of spending by households, firms' profits and bank dividends,[25]

$$p_t y = s_t + \Pi_t + Div_t \qquad \forall t \geq 1. \tag{14}$$

A **perfect foresight equilibrium** is a sequence of endogenous prices $\{p_t, q_t\}_{t=0}^{\infty}$, and choices $\{h_t, s_t, \Pi_{t+1}, Div_{t+1}\}_{t=0}^{\infty}$ such that, for given H, $R = \beta^{-1}$, and $p_0 = 1$,
– firms maximize (2), households maximize (10), and the banking system follows (12), and
– the asset market (13) and goods market (14) clear every period.

Proposition 2 ***Basic Economy***
(a) The perfect foresight equilibrium is unique and stationary.
(b) Firms and the banking system are leveraged.

Proof: We connect goods market conditions with the Euler equation to show that the price level, hence all other variables, are constant. Using (4), (12), and assumption 4, goods market equilibrium becomes

$$\begin{aligned} s_t &= \alpha p_t y - (R-1) K \qquad \forall t \geq 1 \\ s_0 &= \alpha \beta y. \end{aligned} \tag{15}$$

Substituting s_t and s_{t+1} into the Euler equations (11) gives an expression of the form $g(p_t) = g(p_{t+1})$ $\forall t \geq 1$. Since $g(\ )$ is monotonic, $p_t = p_{t+1}$ is the only solution: for $\gamma \geq 1$, $g'(p) > 0$ always; for $\gamma < 1$, $g'(p) > 0$ unless $\alpha p y - (R-1) K < 0$, which is ruled out by (15) because consumption cannot be negative. Thus the price level p is constant from $t = 1$ onward and, using (15) in (11), one obtains $p = p_0 = 1$.[26] Asset prices are constant from $t = 0$ onward, as (13) becomes

$$qH = \frac{\alpha}{R-1} py. \tag{16}$$

It follows that the choice variables $\{h_t, s_t, \Pi_{t+1}, Div_{t+1}\}_{t=0}^{\infty}$ also remain constant.[27]
Regarding part (b), define leverage as debt relative to net worth. From (5), firms' debt equals

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[25] Goods are not storable; real supply equals y irrespective of prices.

[26] The price level normalization in assumption 4 can be justified with a reserve requirement. A central bank can create and lend (non-circulating) reserves to the banking system, which holds them on deposit with the central bank. (This transaction is not distorting when reserves are borrowed and lent at R). An exogenously supplied quantity of reserves then limits deposits, hence bank assets. Since qH and p are related by (16), the reserve requirement can be chosen to imply $p = 1$.

[27] The steady state allocation of assets and goods is

Allocation	Firms	Households	Banking System
Assets	H	0	0
Goods	$(1-\alpha) y$	$\alpha\beta y$	$\alpha(1-\beta) y$

RqH, and sales revenue equals py, of which $(1-\alpha)\,py$ are profits,

$$\text{Firm Leverage} = \frac{\alpha}{1-\alpha}\frac{R}{R-1}. \tag{17}$$

The banking system's debt is $D = qH/R$, given household spending $s = (R-1)\,D$ in (9). The banking system's capital-asset ratio equals $K/A = 1-\beta$, and its inverse is

$$\text{Bank Leverage} = \frac{R}{R-1} \tag{18}$$

As both expressions exceed one, both firms and the banking system are leveraged. •

The economy starts in steady state and remains there, because the world looks identical looking forward from any t. Firms are leveraged because they purchase and resell assets whose value exceeds output and profits. Firms' leverage is increasing and convex in output elasticity: greater α increases debt (numerator) while reducing profits (denominator) through debt service. Kiyotaki and Moore (1997) also work with leveraged firms (p. 222). But their model ignores banking, which arises here to help the economy attain the optimal allocation. The banking system is also leveraged, because it intermediates a large value of credit and payments. High leverage is a defining characteristic of banking.

3 Fundamental Equilibrium with Default

Along a perfect foresight equilibrium, there can be no financial instability. All future equilibrium asset and goods prices are known. The banking system correctly factors agents' budget constraints into all lending decisions. As a result, there can be no loan losses, impaired bank capital, and falling supply of credit. We now drop the perfect foresight assumption to study the consequences of a shock relative to the perfect foresight benchmark. Kiyotaki and Moore (1997) do so to study macroeconomic dynamics, generated by asset prices interacting with borrowing constraints. We do so to explore financial instability, generated by asset prices interacting with loan losses.

Assumption 5 (Shock). An unexpected productivity shock permanently reduces total factor productivity from t onward by $\tau \in [0,1]$.[28] As production takes one period, the shock reduces aggregate output from period $t+1$ onward. The production technology becomes

$$y_{T+1} = (1-\tau)\,f(h_T) \qquad \text{for } T \geq t. \tag{19}$$

This shock entails a new set of prices $\{p_t, q_t\}$ through the following channels:

---

[28] The results are not specific to this type of shock: the same specification allows alternative interpretations, (e.g. τ could be a corporate tax increase), and some other specifications lead to similar results (e.g. an unexpected payment due from firms to households). Kiyotaki and Moore (1997), and Allen and Gale (2000) also make use of zero-probability shocks, because fully stochastic models make explicit solutions difficult to obtain.

(1) New firms (entering in t) pay less for assets, because assets are now less productive to them and to all future firms.
(2) Old firms (exiting in t) therefore sell assets at a loss, $q_t < q$. They also sell output at a loss, $p_t < 1$, if the fall in asset prices reduces aggregate spending through a wealth effect.[29] The unexpected losses reduce old firms' ability to repay debt RqH they had incurred in $t-1$, expecting to sell goods and assets at continued steady state prices.
(3) If old firms default, bank loans are not repaid in full, and the banking system must write off non-performing loans.

There are no further shocks after t, and the model reverts to perfect foresight. In this section we elaborate the channels (1)-(3), and aggregate agents' reactions to determine the new equilibrium $\{p_{t+i}(\tau), q_{t+i}(\tau)\}_{i=0}^{\infty}$. This experiment leads to falling prices relative to debt, and allows us to study the effect of wide-spread default on the banking system (question (1), introduction). We refer to the equilibrium as *fundamental*: it is the inescapable consequence of the shock $\tau > 0$. When the capital constraint is added as a fourth channel, $\{p_{t+i}, q_{t+i}\}_{i=0}^{\infty}$ can assume values independently of τ, and *self-fulfilling* capital crunches and banking crises become possible (section 4).

3.1 Reactions to the Productivity Shock

(1) New Firms and Asset Prices

The typical firm of generation t now chooses the quantity of assets used in production to maximize

$$\max_{h_t} \quad \Pi_t = p_{t+1}(1-\tau) f(h_t) - (Rq_t - q_{t+1}) h_t.$$

It remains optimal for each firm to spend the fraction α of sales revenue on holding H assets; the remainder constitutes profits. Therefore, aggregate profits and asset market equilibrium are

$$\begin{aligned} \Pi_{t+1} &= (1-\alpha)(1-\tau) p_{t+1} y \\ \alpha \underbrace{(1-\tau) p_{t+1} y} &= (Rq_t - q_{t+1}) H. \end{aligned} \tag{20}$$

These expressions differ from (4) and (13) only in as far as $\tau > 0$ reduces future output. As before, national income (braced) is distributed according to the factor shares (α remains unaffected by τ). Conditional on future goods prices, lower productivity reduces the return on assets, and leads to lower asset prices. Using (20) modifies the asset pricing equation (13) to

$$\begin{aligned} q_t &= (1-\tau) \frac{\alpha y}{H} \sum_{i=1}^{\infty} \frac{p_{t+i}}{R^i} \\ q_t H &= (1-\tau) \frac{\alpha p_{t+1} y}{R-1}, \end{aligned} \tag{21}$$

---

[29] Their production y remains unaffected by the shock, because it was carried out during $t-1$.

where the latter anticipates that the new steady state is reached in $t+1$, as shown below. The comparison with (16) shows that q_t falls to

$$q_t = q\,(1-\tau)\,p_{t+1} \qquad \Leftrightarrow \qquad \delta = 1-(1-\tau)\,p_{t+1} \tag{22}$$

where δ denotes the asset price decline in percent, $\delta \equiv (q-q_t)/q$.[30] The fundamental asset price decline would simply equal that of productivity, $\delta = \tau$, if the future price level p_{t+1} remained at 1. The asset price decline has two effects: credit demand falls because assets are cheaper, and old firms suffer a capital loss on the assets they sell.

(2) Old Firms and Debt Deflation

Old firms face the threat of debt deflation. In $t-1$ they had borrowed qH, assuming that in t they would sell goods and assets at continued steady state prices $\{1, q\}$. Following the shock τ, a new set of equilibrium prices $\{p_t, q_t\}$ applies. Their debt is predetermined, but their ability to repay is not: default becomes a possibility. Their budget constraints (5), ex post become

$$\begin{aligned} qH &= b \quad \text{(predetermined)} \\ \Pi_t + (RqH-\lambda) &= p_t y + q_t H. \end{aligned} \tag{23}$$

The right hand side is firms' *ability to repay*, shared between repayment and profits. The new term λ arises because firms enjoy limited liability $\Pi_t \geq 0$: their owners' consumption (1) cannot be negative. Should the ability to repay fall short of the their debt RqH, the measure λ of the debt becomes non-performing to hold profits at zero,

$$\lambda = \max\{0, RqH - (p_t y + q_t H)\} \tag{24}$$

$$\Pi_t = \max\{0, (p_t y + q_t H) - RqH\}. \tag{25}$$

Figure 2 illustrates. Firms' ability to repay is increasing in goods and asset prices (together, 'prices'). In steady state, $py + qH$ covers RqH, leaving Π in profits (the double vertical line). As prices fall, so do firms' profits Π_t. While they can, firms repay in full. When prices fall below the default point, firms default on λ and profits remain at zero.

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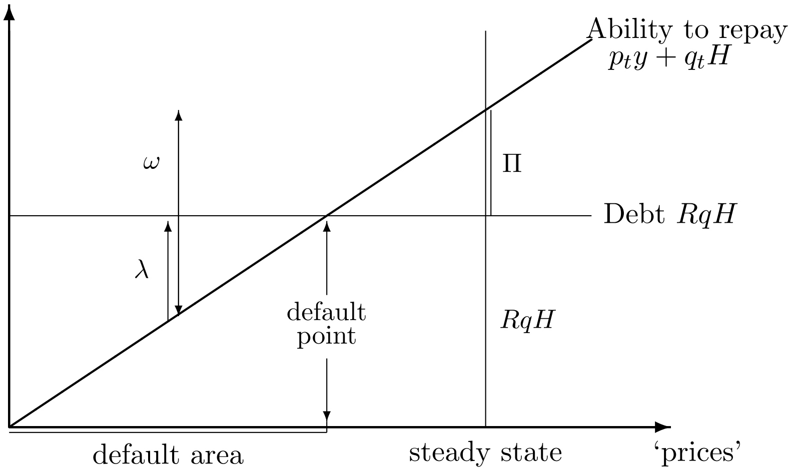
[30] Before t, the economy was still in steady state ($q_{t-1} = q$); δ measures the decline both relative to steady state, and relative to last period.

Figure 2: Repayment and Default



This convex payoff profile is typical for limited liability firms, and is often used for options pricing of corporate debt, following Merton (1974). Here, we focus on how firms' losses spill over to the banking system. Comparing (23) with its value in steady state, $y + qH$, shows that unexpected losses total

$$\omega \equiv \delta qH + (1 - p_t)\, y. \tag{26}$$

They consist of the decline in the value of asset holdings (if $\delta > 0$), plus lost sales revenue due to deflation (if $p_t < 1$). Steady state profits Π measure firms' ability to withstand unexpected losses. Small losses ($\omega \leq \Pi$) are borne by firms alone: $\Pi > \Pi_t \geq 0$ and $\lambda = 0$. Larger losses ($\omega > \Pi$) are *shared*: firms bear Π and default; the banking system bears $\lambda = \omega - \Pi$, which equals (24) above.

(3) The Banking System and Loan Losses

The main difference with other macroeconomic models is that we allow wide-spread default to affect the banking system.[31] When markets open in t, the banking system holds K in capital, and would normally earn $(R-1)\,K$ on loans, less deposits, carried over from $t-1$. As long as firms are able to repay in full ($\lambda = 0$), normal profits are paid out as dividends, $Div_t = (R-1)\,K$. Should macroeconomic conditions be such that non-performing loans λ arise, then bank profits fall by λ given in (24). Non-performing loans must be written off, reducing both assets and liabilities by λ (see appendix C).[32] How does this affect dividends and bank capital?

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[31] Kiyotaki and Moore (1997) restrict contracts to rule out default. Bernanke, Gertler and Gilchrist (1999) allow default, but make it inconsequential to diversified lenders: the spread paid by successful firms compensates for any loan losses from defaulting firms (and aggregate risk is offset by state-contingent loan rates). The financial accelerator models are about macroeconomic, not financial, stability.

[32] We assume that non-performing loans must be recognized as soon as they become certain, which is at date t. The write-off replaces the banking system's assets RqH by the actual repayment $(p_t y + q_t H)$, the *performing* portion of loans.

Assumption 6 (Equity). The banking system issues no new equity.[33] The assumption requires non-negative dividends, $Div_t \geq 0$. In keeping with the policy of paying out profits every period, small loan losses are offset by a reduced dividend $(R-1)\,K - \lambda$, leaving bank capital K intact. But large loan losses, $\lambda > (R-1)K$, reduce bank capital to $RK - \lambda < K$. Normal profits serve as a buffer: capital falls only to the extent that loan losses *exceed* normal profits, $K - K_t = \lambda - (R-1)\,K$. Since the banking system earns a return R on capital, future dividends fall to the extent capital does. To summarize,

Bank Capital and Dividends

$K_t =$	$Div_t =$	$Div_{t+1} =$	case
K	$(R-1)K - \lambda$	$(R-1)\,K$	if $\lambda \leq (R-1)\,K$
$RK - \lambda$	0	$(R-1)\,[RK - \lambda]$	if $\lambda \geq (R-1)\,K$

(27)

3.2 Fundamental Equilibrium

We now aggregate agents' reactions to determine the new equilibrium prices for goods and assets $\{p_{t+i}(\tau), q_{t+i}(\tau)\}_{i=0}^{\infty}$. Equilibrium is defined as on page 12.

Asset market equilibrium was given in (20).
Goods market clearing equates aggregate demand with supply, as in (14). The possibility of default makes aggregate demand inherit the case structure from (25) and (27),

$$p_t y = \begin{cases} s_t + [p_t y + q_t H - RqH + \lambda] + (R-1)\,K - \lambda & \text{if} \quad \lambda \leq (R-1)\,K \\ s_t & \text{if} \quad \lambda \geq (R-1)\,K \end{cases} \tag{28}$$

The first equation applies when loan losses remain small. Clearly visible is the *wealth effect* that weighs on aggregate demand: when q_t and p_t fall below their steady state values, lower asset market wealth and sales revenue lead to less spending. The expression is the same whether or not firms default (λ drops out); this is so because once firms' profits are zero, further losses continue affecting aggregate demand through reduced bank dividends, until they too are zero.[34] Once that happens, the second line applies: only household spending remains. Note that, by definition of λ, the two expressions for aggregate demand merge at $\lambda = (R-1)K$; there are no discontinuities.

Goods market clearing in $t+1$ equates the value of (reduced) output with the sum of household spending, new firms' profits (20), and bank dividends (27),

$$(1-\tau)\,p_{t+1} y = \begin{cases} s_{t+1} + (1-\alpha)\,(1-\tau)\,p_{t+1} y + (R-1)\,K & \text{if} \quad \lambda \leq (R-1)\,K \\ s_{t+1} + (1-\alpha)\,(1-\tau)\,p_{t+1} y + (R-1)\,[RK - \lambda] & \text{if} \quad \lambda \geq (R-1)\,K \end{cases} \tag{29}$$

---

[33] In other words, households wish to hold deposits, not bank equity. Evidence suggests that banks find it difficult to raise equity when sustaining losses. The assumption is less objectionable here than in the context of Rochet (1992) and van den Heuvel (2002). Gorton and Winton (1995, 2000) show that the costs of raising additional capital tends to be highest when the return on bank assets is low or volatile, and when private bank charter values are impaired. An alternative explanation, based on signalling, is suggested by Bolton and Freixas (2001).

[34] Recall the discussion following (26).

The only difference with (14) is reduced productivity ($\tau > 0$), and, possibly, reduced bank dividends if loan losses impaired bank capital.[35] Subsequent goods markets are of the same form.

The goods market conditions relate price levels $\{p_t, p_{t+1}, ...\}$ to household spending $\{s_t, s_{t+1}, ...\}$. The Euler equations (11) do likewise, because household spending responds to price incentives. Combining Euler equations and market clearing conditions completes goods market equilibrium. Appendix 1 shows that the Euler equations (11) can be written as

$$p_{t+i} = \left(\frac{s_{t+i}}{s}\right)^{\frac{\gamma}{\gamma-1}} \qquad \forall i \geq 0. \tag{30}$$

This expression usefully compares price levels to $p = 1$, depending on s_{t+i}, the equilibrium spending required by (28) and (29). With $\gamma < 1$ (high intertemporal elasticity of substitution), households spend more when goods are cheap. We focus on this case, for which the model admits a well-defined fixed-price limit as $\gamma \to 0$.[36]

Proposition 3 establishes that asset prices and the price level fall when fundamentals deteriorate. Falling prices in the presence of fixed nominal debt lead to deteriorating balance sheets, with the consequences elaborated in proposition 4.

Proposition 3 ***Falling Prices***

(a) The new steady state is reached in $t+1$, the period after the shock.

(b) Over the range $\lambda \leq (R-1)K$, increasing τ produces:
- *permanent asset price decline,*
- *temporary deflation.*

(c) Over the range $\lambda \geq (R-1)K$, increasing τ produces:
- *continued asset price decline,*
- *no further deflation.*

Proof: Appendix 2. •

The model is easy to work with for a dynamic general equilibrium model, because part (a) shows that we can restrict attention to periods t and $t+1$. The reason for the short-lived dynamics is the overlapping-generations structure. Old firms exit, whether or not they default: persistence is confined to bank capital. Once they have exited, all agents again correctly anticipate future prices when they first incur debt, and the economy reverts to a perfect foresight equilibrium for which a unique steady state was shown to exist.

The proposition shows that the fundamental equilibrium progressively moves away from the steady state as the shock increases, $\delta'(\tau) > 0$ and $p_t'(\tau) \leq 0$. The asset price falls because productivity does,

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[35] The case $\lambda > RK$ need not be addressed separately here: (29) retains the same form (as long as the banking system intermediates), because the losses borne by depositors, $\lambda - RK$, would affect aggregate demand through reduced s_{t+i} in the same way as $Div_{t+i} < 0$ would.

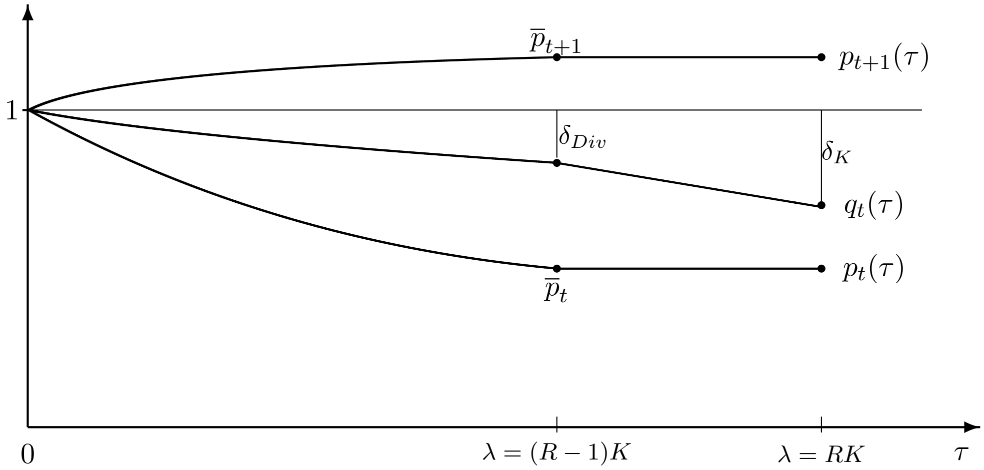
[36] The main effect of $\gamma > 1$ would be to reverse the pattern of price level movements in proposition 3. Subsequent results remain largely unchanged, because the asset price always falls, irrespective of γ.

as suggested by (22). Deflation then results from the wealth effect of $\delta > 0$ on profits (25), because profits are a component of aggregate demand. This becomes clear when the goods market (28) is simplified (see appendix 2) to

$$s_t = s + \delta(\tau)qH \quad \Rightarrow \quad p_t = \left[1 + \tfrac{R}{R-1}\delta(\tau)\right]^{\frac{\gamma}{\gamma-1}} < 1. \tag{31}$$

Equilibrium requires households' *extra* spending $(s_t - s)$ to offset the wealth effect $\delta(\tau)qH$. The price level falls to attract such extra spending ($\gamma < 1$). Since deflation lowers sales revenue and firms' spending in (28), the fall in aggregate demand is consistent with $p_t(\tau) < 1$.

Figure 3: Falling Prices



Deflation in our model is temporary, and its extent is limited. It is temporary because households' budget constraint implies that the price level $p_{t+1}(\tau)$ reverts to slightly above 1.[37] Deflation is limited because the wealth effect only affects profits and bank dividends; it ceases to operate when these are zero. When only household spending remains, aggregate demand and the price level p_t reach their minimum,

$$\begin{aligned} \overline{p}_t &= (R/\alpha)^{-\gamma} < 1 \\ \overline{s}_t &= \overline{p}_t y = s(R/\alpha)^{1-\gamma} \\ \overline{p}_{t+1} &= \left(1 - (R-1)\left[(R/\alpha)^{1-\gamma} - 1\right]\right)^{\frac{\gamma}{\gamma-1}} > 1. \end{aligned} \tag{32}$$

When fundamentals deteriorate further, neither aggregate demand nor the price level continue to fall, but the asset price does: from (22), $\delta(\tau) = 1 - (1-\tau)\,\overline{p}_{t+1}$. Falling goods and asset prices in the presence of fixed nominal debt lead to deteriorating balance sheets.

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[37] See appendix 2(b). Since s_t exceeds permanent income s, s_{t+1} must fall below s to ensure that households do not overspend permanently. The price level movements implement this pattern of equilibrium spending.

Proposition 4 ***Deteriorating Balance Sheets***

(a) Total losses $\omega(\tau)$ and loan losses $\lambda(\tau)$ are monotonically increasing in τ.

(b) The space of fundamentals $[0,1]$ can be divided into four ranges, according to how losses are borne (see figure 4).

(c) Falling credit demand is matched by
- *(i) monetary contraction if $\tau \leq \tau_{Div}$ (figure 5),*
- *(ii) monetary contraction and falling bank capital if $\tau > \tau_{Div}$.*

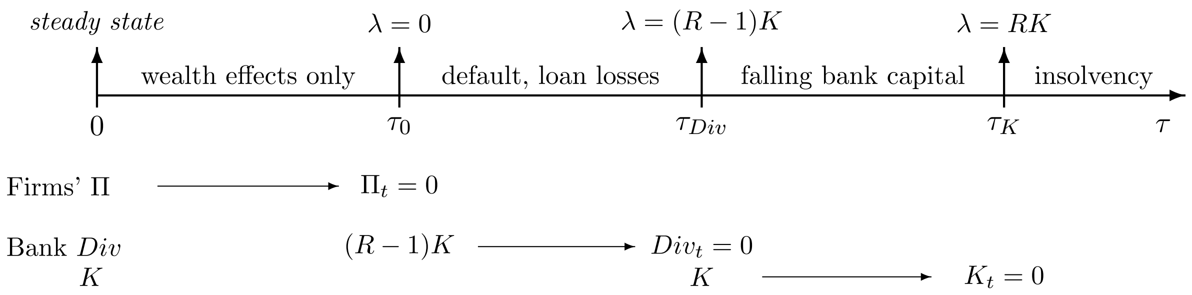
Proof: It suffices to show that losses are monotonically increasing, and that the worst possible fundamentals imply losses exceeding the firms' and banking system's combined ability to withstand them. The nature of standard debt then implies that losses are borne hierarchically. Recall from (26) that total losses are $\omega(\tau) = \delta(\tau) qH + [1 - p_t(\tau)] y$, of which the banking system bears $\lambda(\tau) = \max\{0, \omega(\tau) - \Pi\}$. Clearly, $\omega'(\tau) > 0$ since proposition 3 established that $\delta'(\tau) > 0$ and $p'(\tau) \leq 0$ for all $\tau \in [0,1]$. At the extremes we have $\omega(0) = 0$, and $\omega(1) > RK + \Pi$ (see appendix 3). By continuity, there exist thresholds, ordered $0 < \tau_0 < \tau_{Div} < \tau_K < 1$, such that

$$\begin{array}{lll} \tau_0: & \omega(\tau_0) - \Pi = 0 & \lambda \text{ turns positive} \\ \tau_{Div}: & \lambda(\tau_{Div}) = (R-1)K & \lambda \text{ eliminates bank dividends} \\ \tau_K: & \lambda(\tau_K) = RK & \lambda \text{ eliminates bank capital.} \end{array}$$

The thresholds τ_i are shown in appendix 3. The remaining results follow. •

Proposition 4 shows how losses cascade down the debt structure.[38] As fundamentals deteriorate, losses first affect firms, then also the banking system, then also depositors as shown in figure 4.

Figure 4: Deteriorating Balance Sheets



Four ranges can be distinguished:
(1) Over the first range, the wealth effect on aggregate demand is too small to cause any default.[39] Losses are borne by firms, and profits fall from Π to Π_t (horizontal arrow).

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[38] The metaphor evokes Minsky's work, in which debt structure plays a central role. See Minsky (1982) on debt deflation, and Minsky (1970, 1977, 1978) on the financial instability hypothesis.

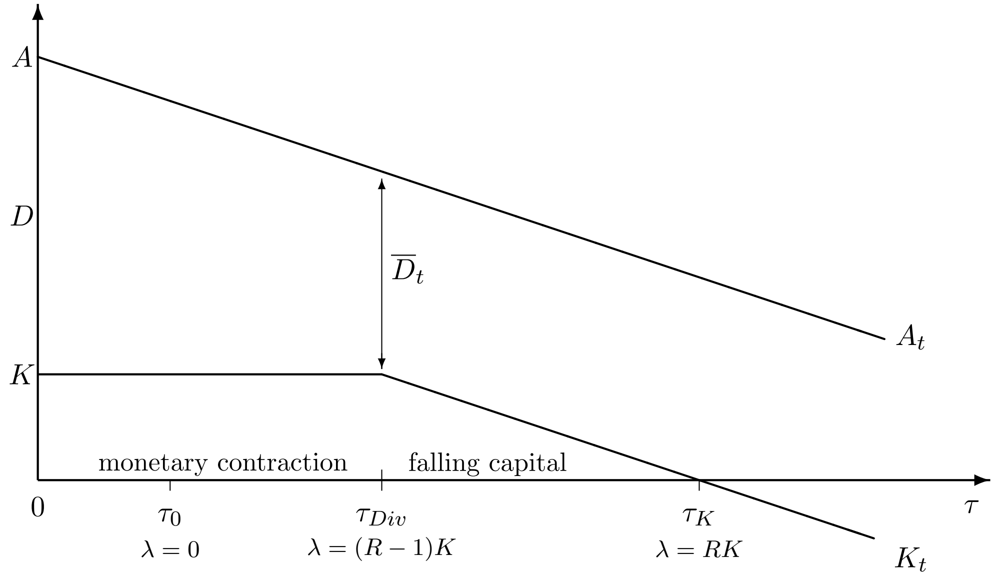
[39] Other macroeconomic models only examine this range.

(2) Once profits reach zero, firms default and pass on any further losses to the banking system in the form of non-performing loans, $\lambda > 0$. Over this second range, the banking system absorbs loan losses by reducing its dividend payout, leaving bank capital intact.
(3) When $\tau > \tau_{Div}$, loan losses exceed normal bank profits, $\lambda > (R-1)\,K$, and the difference is written off bank capital.
(4) Finally, fundamentals might deteriorate to the point of eliminating bank capital, $K_t \leq 0$. Over this last range, the banking system is insolvent, and losses are ultimately borne by depositors.

Note that the mapping from fundamentals to losses and outcomes is unique. We can therefore express the thresholds delimiting these ranges in terms of τ, δ, or λ, although it is the latter, the size of loan losses, that decides in which range the economy settles. Proposition 4 provides an answer to question (1) posed in the introduction, how losses affect the banking system. The result is pure, in the sense that our elastic credit specification allowed us to examine this direction of causality *without any* of the feedback that would arise if credit were not perfectly elastic.[40] Credit demand is always accommodated at R. Elastic credit then implies that the size of the banking system endogenously shrinks as fundamentals deteriorate: credit demand falls, because new firms borrow less money for purchasing less-valued assets, and credit supply matches this decline.

If bank assets contract, so must liabilities, and it is insightful to go through the mechanics (proposition 4(c)). Figure 5 shows the balance sheet identity $A_t = D_t + K_t$ as a vertical sum, plotted against the size of the shock τ. The fall in bank assets is first matched by falling deposits, and then by falling bank capital.

Figure 5: The Banking System's Balance Sheet



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[40] The new phenomena in section 4 can then be attributed to the effect of the banking system on the economy (question (2), introduction).

(i) Monetary contraction. For $\tau \in [0, \tau_{Div}]$, loan losses are small, hence bank capital remains constant. Therefore deposits fall to match the decline in credit. This is consistent with the increased spending by households $s_t > s$ found in (31)

$$D_t = RD - s_t = D - \delta qH.$$

The extra spending received by firms is applied toward repaying debt; both loans and deposits are thereby 'extinguished' (appendix C shows the balance sheet entries). Since deposits are the means of payment in this model, a monetary contraction is taking place. The model is consistent with the 'credit counterparts' determination of the money supply: inside money expands by loan extension, and contracts by loan repayment.[41] Note that the spending s_t that clears the goods market also reduces deposits in just the right measure; this link demonstrates the consistency of market equilibrium with the bank balance sheet identity. When household spending has reached $\overline{s}_t$, deposits remain at $\overline{D}_t = RD - \overline{s}_t$. We can then find the asset price decline δ_{Div} that generates loan losses eliminating bank profits,[42]

$$\delta_{Div} = \frac{R-1}{R}\left[(R/\alpha)^{1-\gamma} - 1\right].$$

(ii) Falling bank capital. With bank profits eliminated, it is bank capital that absorbs any further loan losses resulting from $\tau > \tau_{Div}$. Since the price level stops its decline at $p_t(\tau_{Div}) = \overline{p}_t$, loan losses beyond $(R-1)K$ are entirely due to asset price declines beyond δ_{Div},

$$\lambda(\tau) - (R-1)K = [\delta(\tau) - \delta_{Div}]\,qH. \tag{33}$$

The left hand side is the decline in bank capital $K - K_t$ from (27), hence

$$K_t = K - [\delta(\tau) - \delta_{Div}]\,qH.$$

This close relation between bank capital and asset prices is remarkable: the banking system holds no marketable assets – its exposure to market prices is entirely *indirect*, through its borrowers' credit risk. The banking system turns insolvent ($K_t = 0$) when the asset price decline reaches

$$\delta_K = \delta_{Div} + K/A = \frac{R-1}{R}(R/\alpha)^{1-\gamma},$$

At that point, assets just equal the remaining deposits, $A_t(\tau_K) = \overline{D}_t$. Even larger fundamental shocks than τ_K are conceivable, whereupon depositors start taking losses, $\lambda - RK$. At the extreme $\tau \to 1$, assets lose their productive use. Their price collapses to zero ($\delta(1) = 1$), so does credit demand ($A_t = 0$), and deposits are engulfed by the negative net worth of the banking system

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[41] This principle informs the analysis of monetary aggregates. From this perspective one might question Friedman's claim that people cannot in aggregate succeed in reducing nominal balances, because "One man's expenditures are another's receipts." (Friedman 1970, p. 195).

[42] Use (32) and (18) to solve the balance sheet identity $A - \delta qH = \overline{D}_t + K$. The solution δ_{Div} can then be used in (22) to back out the corresponding shock τ_{Div}, see appendix 3(b).

($K_t = -\,\overline{D}_t$). The banking system seizes the real assets H from defaulting firms, and households repossess H in stead of their deposits. The closing of the banking system precipitates severe real effects. It destroys the mechanism that had enabled firms and households to produce and allocate resources efficiently, and the economy degenerates to autarky (see page 7).[43]

We have now covered the fundamental equilibrium for all possible shocks $\tau \in [0,1]$, spanning the entire space between steady state and systemic banking crises.

4 Financial Extremes

The last section described how the state of the economy affects the banking system. The elastic provision of credit ensured that there was no feedback whereby the banking system would in turn affect the economy. Lending behavior did not change as bank capital fell: credit demand was always accommodated at R. Yet when bank capital fell at the speed of credit, the capital-asset ratio must have been falling rapidly (see figure 5). Banks, in reality, are not indifferent to their capital-asset ratio, be it for reasons of regulation or risk management. We account for this possibility by introducing a capital constraint. This allows us to address question (2) in the introduction separately, how the state of the banking system in turn affects the economy. The new results in this section can be attributed to this feedback.

4.1 Capital-Constrained Equilibrium

Assumption 7 (Capital Constraint). The banking system maintains a minimum capital-asset ratio of $(R-1)/R$.[44] This is the same ratio the banking system had maintained in the perfect foresight equilibrium (page 13). The capital constraint states that bank lending (credit supply) must not exceed a multiple of bank capital, $A_t \leq \frac{R}{R-1}K_t \equiv \overline{A}\,(\delta)$. Two new considerations arise: (1) credit supply may now be capital-constrained, and if so, (2) the loan rate adjusts to equate credit demand with capital-constrained credit supply (assumption 3 is lifted).

(1) Credit supply. Credit supply can be related to loan losses and their macroeconomic determinants. Recall that $K_t = K - [\lambda - (R-1)K]$ and use (33) to obtain

$$\overline{A}\,(\delta) \equiv \frac{R}{R-1}K_t = \begin{cases} A & \text{if} \quad \lambda \leq (R-1)\,K \\ A - \frac{R}{R-1}\left[\lambda(\delta) - (R-1)\,K\right] & \text{if} \quad (R-1)\,K \leq \lambda \leq RK \\ 0 & \text{if} \quad \lambda \geq RK. \end{cases} \tag{34}$$

$\overline{A}\,(\delta)$ inherits the case structure from K_t, along with the restriction that bank assets cannot be

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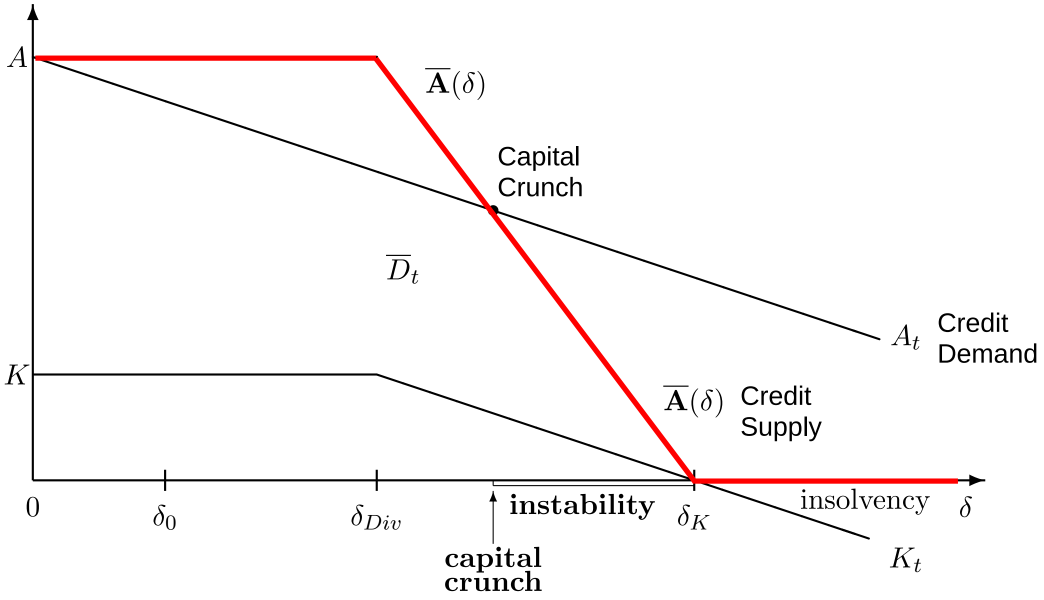
[43] Until the banking system collapses, the real effects in our model are merely distributional: when firms default, their owners consume nothing. Output effects would set in earlier if we had incorporated credit-constrained producers, as do Kiyotaki and Moore (1997).

[44] The 1988 Basel Accord in our context requires the ratio 0.08 on all assets (corporate loans are subject to the 100% risk weight). A capital constraint may also arise in the absence of regulation, see section 5.4.

negative. Figure 6 plots $\overline{A}(\delta)$ as a function of the asset price decline δ,

Figure 6: The Capital Constraint $\overline{\mathbf{A}}(\delta)$



The capital constraint (thick line) never binds as long as capital remains intact at K, because admissible lending A exceeds credit demand $A_t = q_t H = A - \delta q H$. Once loan losses reduce bank capital, $\overline{A}(\delta)$ declines very steeply, as the second segment of (34) shows. Constancy of the capital-asset ratio requires each loan loss to be met with a $R/(R-1)$-fold contraction of credit, where the multiple is the leverage of the banking system (18). Once loan losses eliminate capital, the constraint stipulates zero bank assets.

(2) Credit demand. As before, credit demand is driven by the market's asset valuation as before, since assets are purchased on credit. With a variable loan rate R_t as in (7), credit demand equals

$$q_t H = \frac{\alpha(1-\tau)p_{t+1}y}{R_t} + \frac{q_{t+1}H}{R_t}. \tag{35}$$

A **capital-constrained equilibrium** is a set of endogenous variables $\{p_t, q_t, R_t\}$ that satisfies the capital constraint (34), and the equilibrium conditions of the goods market (28) and of the asset market (35), hence the credit market. The main feature of a capital-constrained equilibrium is that the asset price q_t (and δ) is now determined by the capital constraint (34). With asset prices determined by bank capitalization, (35) determines the loan rate R_t instead. This can be understood in two equivalent ways. Viewing (35) as credit demand, the loan rate rises to $R_t > R$ to bring credit demand down to capital-constrained credit supply $\overline{A}(\delta)$.[45] Viewing (35) as an asset

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[45] The borrowing rate $R_t > R$ chokes off excess credit demand. Firms spend a certain amount on the total cost of borrowing in (20); raising the price of credit effectively reduces the size of the loans they can afford.

pricing equation, the loan rate R_t discounts the market's forward-looking asset valuation down to the credit-constrained asset price. We call this *credit-constrained asset pricing.*

To understand the remaining results the following scheme is useful to keep in mind. The capital constraint depends on the size of loan losses (given bank leverage). Loan losses, in turn, are driven by two factors: (1) the asset price decline, which can be fundamental or self-fulfilling, and (2) the structural parameters, which determine the size of loan losses generated by any given decline. Correspondingly, the remaining results concern fundamental and self-fulfilling outcomes (propositions 5-6), and comparative statics on structural parameters (propositions 7-8).

4.2 Capital Crunches and Banking Crises

We first show that sufficiently poor fundamentals ($\tau > \tau^*$) necessarily result in a systemic banking crisis, whereas good fundamentals ($\tau < \tau^*$) admit multiple equilibria: self-fulfilling capital crunches and banking crises coexist with the fundamental equilibrium of propositions 3 and 4.

Proposition 5 ***Capital Crunches and Banking Crises***

(a) The size of loan losses λ determines whether a capital crunch, financial instability, or a banking crisis occurs.

(b) For $\tau \leq \tau^*$ the fundamental equilibrium is unconstrained (as before),
for $\tau = \tau^*$, the fundamental equilibrium is a capital crunch,
for $\tau > \tau^*$, the fundamental equilibrium is a banking crisis.

(c) For $\tau \leq \tau^*$, self-fulfilling capital crunches and banking crises may occur, with
- *a jump decline in goods and asset prices,*
- *an interest rate spread $R_t(\tau) - R$, due to credit-constrained asset pricing.*

Proof: The capital crunch and the banking crisis are fixed points of (34), where the asset price decline (hence credit demand) coincides with the contraction required by the capital constraint (hence credit supply). This can only happen when losses exceed bank profits, $\lambda > (R-1)\,K$. Hence, the goods market conditions imply the solution (32), irrespective of τ.[46] Given $\{\overline{p}_t, \overline{s}_t\}$ and $\left\{\overline{p}_{t+1}, \overline{s}_{t+1}\right\}$, we find $\{q_t, R_t\}$ consistent with (34) and (35). Expressing $q_t H = \overline{A}\,(\delta)$ in deviations from $qH = A$,

$$\delta qH = \begin{cases} \frac{R}{R-1}\left[\lambda(\delta) - (R-1)\,K\right] & \text{if} \quad (R-1)\,K \leq \lambda \leq RK \\ qH & \text{if} \quad \lambda \geq RK. \end{cases} \tag{36}$$

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[46] When $R_t > R$, the banking system earns a *spread* on all lending. As profits are paid out as dividends, Div_{t+1} increases by $(R_t - R)\,q_t H$. This leaves the goods market unaffected, because new firms' spending is reduced by the same amount: the spread is a transfer.

The size of λ determines whether a banking crisis (line 2) or a capital crunch (line 1) occurs.[47] The respective asset price declines are $\delta = 1$, and

$$\delta^* = (R-1)\left[(R/\alpha)^{1-\gamma} - 1\right]. \tag{37}$$

These declines are fundamental if $\tau = 1$ and $\tau = \tau^*$, respectively. The latter is found by solving $\delta^* = 1 - (1-\tau^*)\,\overline{p}_{t+1}$, see appendix 3(b). The banking system's dividend policy implies that the same capital constraint holds in subsequent periods. Hence, the asset price remains constant after t, and credit demand (35) becomes $q_t H = \alpha(1-\tau)\,\overline{p}_{t+1} y / (R_t - 1)$. When expressed in deviations, and upon replacing $\overline{p}_{t+1}$, we can express the loan rate as

$$\frac{R_t - 1}{R-1} = (1-\tau)\,\frac{(1-\delta^*)^{\frac{\gamma}{\gamma-1}}}{1-\delta}.$$

In a fundamental equilibrium, we let particular fundamentals $\{\tau^*, 1\}$ bring about the declines $\{\delta^*, 1\}$ (while $R_t = R$). In a self-fulfilling equilibrium, we let a particular loan rate $R_t(\tau)$ bring about $\{\delta^*, 1\}$ (while $\tau < \tau^*$). Accordingly, the following equilibria are possible,

Characterization	**Capital Crunch**	**Banking Crisis**	**Both**
if fundamental	$1-\tau^* = (1-\delta^*)^{1/(1-\gamma)}$	$\tau > \tau^*$	$R_t = R$
if self-fulfilling	$\frac{R_t(\tau)-1}{R-1} = \frac{1-\tau}{1-\tau^*}$	$R_t \to \infty$	$\tau \leq \tau^*$
in both cases	$\delta = \delta^*$	$\delta = 1$	$\overline{p}_t, \overline{s}_t$

(38)

The capital constraint (34) binds only for $\delta \geq \delta^*$ (see figure 6). Therefore, any $\tau < \tau^*$ also admits the fundamental equilibrium with $\delta(\tau) < \delta^*$, found in proposition 3. Any $\tau > \tau^*$ implies $\delta(\tau) > \delta^*$, which can satisfy (34) only if $\delta = 1$. •

We interpret these results as follows. As in the fundamental equilibrium (page 21), the size of loan losses determines the outcome. But loan losses may occur due to poor fundamentals *or* due to self-fulfilling asset price declines: the mapping from fundamentals to loan losses is no longer unique, because the system can always jump to a binding capital constraint (which closes the loop in the diagram on page 2). Accordingly, the space of fundamentals is split around the threshold τ^* that makes the capital constraint *just* bind.

Good fundamentals ($\tau < \tau^*$). The capital constraint does not bind, provided assets are valued according to fundamentals, $\delta(\tau) < \delta^*$; if so, the fundamental equilibrium materializes. But in spite of good fundamentals, self-fulfilling credit crunches and banking crises may occur: the capital constraint binds whenever $\delta \geq \delta^*$, whether or not this decline is due to fundamentals. The capital crunch ($\delta = \delta^*$), and the banking crisis ($\delta = 1$), are the two self-fulfilling equilibria where the asset price decline generates exactly the measure of loan losses $\lambda(\delta)$ that forces bank lending to contract by δ percent.[48] This may happen even when $\tau = 0$. Intuitively, if the market expects

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[47] Proposition 6 shows that financial instability occurs between these two equilibria.

[48] All balance sheet items contract in the same proportion, $(A - A_t)/A = \left(D - \overline{D}_t\right)/D = (K - K_t)/K = \delta^*$ or 1.

that credit is not forthcoming, the asset price falls until loan losses indeed interrupt credit supply. Likewise, if the expectation prevails that loan losses are imminent, then the banking system reduces lending, enforced by $R_t(\tau) > R$, and the resulting asset price decline and defaults cause exactly the anticipated loan losses. Capital crunches and banking crises can be understood as equilibrium phenomena, as the two fixed points where credit contraction and asset price decline are mutually consistent.[49] The spread in (38) provides a measure of the degree to which a capital crunch equilibrium is self-fulfilling. This is why the spread is *decreasing* in τ: better fundamentals are associated with a larger spread on safe loans, because credit demand must be reduced *more* to match capital-constrained credit supply.[50]

Poor fundamentals ($\tau > \tau^*$). The only possible equilibrium in that range is a banking crisis, because $\delta(\tau)$ necessarily exceeds the threshold δ^*. Therefore, the capital constraint necessarily binds, and it propels the system toward a banking crisis. We interpret this process as financial instability.

4.3 Financial Instability

The model is unstable in the space between the capital crunch and the banking crisis. The disequilibrium adjustment yields a natural characterization of financial instability as an unstable credit contraction, accompanied by falling asset prices and mounting loan losses.

Proposition 6 ***Financial Instability***

(a) the capital crunch equilibrium is unstable, the banking crisis equilibrium is stable.
(b) for $\delta > \delta^*$ financial instability occurs.

Proof: follows directly from proposition 5 and (36). •
Consider the point that defines the capital crunch equilibrium,

$$\delta q H = \frac{R}{(R-1)}\left[\underbrace{\delta q H + (1-\overline{p}_t)\,y - \Pi}_{\lambda(\delta)} - (R-1)\,K\right].$$

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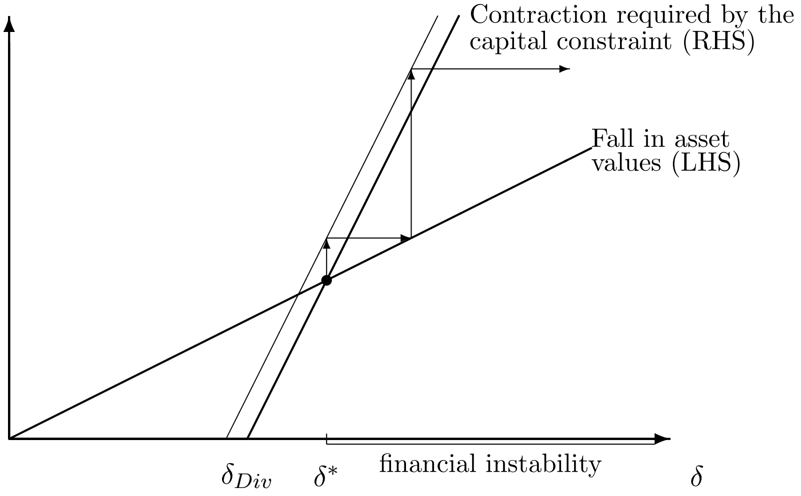
[49] In a multi-bank extension, this corresponds to multiple symmetric Nash-equilibria in an interest-setting game (Bertrand competition). The capital constraint causes complementarity: other banks' reduced lending causes low asset prices and losses, so that the remaining bank's lending is thereby constrained. (Rajan (1994) studies another form of lending complementarity, based on reputation. In Diamond and Dybvig (1983), the complementarity is due to the sequential service constraint.) Note that asymmetric equilibria can be ruled out because household spending – hence the deposits of each bank – respond identically to the economy-wide price level p_t. This is useful, because asymmetric equilibria would force us to apply bank reserves (footnote 26) to the clearing and settlement of asymmetric interbank balances.

[50] Think of $1-\tau$ as the strength of the economy (hence credit demand), and $1-\tau^*$ as the state of the banking system (with capital-constrained credit supply). The ratio $(1-\tau)/(1-\tau^*)$ then measures the relative inadequacy of credit supply; the spread is smallest when $\tau \to \tau^*$, because credit demand is as depressed as credit supply, and it is greatest when a self-fulfilling capital crunch occurs despite strong fundamentals $\tau \to 0$.

Figure 7 visualizes this equation. The asset price decline δ appears on the right (RHS), because the asset price decline contributes to loan losses λ. It also appears on the left (LHS), because reducing lending (which increases δ) is the way to comply with the capital constraint. The capital crunch equilibrium δ^* is found at their intersection.

Due to high bank leverage, the RHS is much steeper in δ than the LHS: the capital crunch equilibrium is unstable under perturbation. Consider a slight deterioration of loan losses. Given δ^*, compliance with a tighter capital constraint requires bank lending to contract (arrow up). Reduced credit worsens the asset price decline (arrow right). But $\delta > \delta^*$ generates new loan losses, which requires further credit contraction (arrow up). This sets off a new round of loan losses (arrow right) with further contractionary effects. Loan losses accrue at a faster rate than the contraction of bank credit can keep up with (the trajectory diverges). Financial instability therefore occurs whenever $\delta(\tau) > \delta^*$, which is unavoidable if $\tau > \tau^*$.

Figure 7: Financial Instability



Under the continued compliance with the capital constraint, financial instability comes to a halt only when credit and asset prices have collapsed: once capital becomes negative, the system jumps to $\left\{A_t = 0, \delta = 1, K_t = -\overline{D}_t\right\}$. We have encountered this outcome before (page 22), but only for the worst possible fundamentals ($\tau = 1$). The capital constraint brings this outcome forward, as any shock $\tau \in (\tau^*, 1)$ now triggers financial instability ending in a banking crisis. The outcome is a *financial* crisis in the sense that it is precipitated by a financial constraint, rather than by poor fundamentals. But the real effects are as severe. In sum, the capital crunch equilibrium repels, the banking crisis equilibrium attracts, and financial instability is the process of adjustment between the two.

4.4 Vulnerability

The effect of asset prices on the banking system is highly non-linear: as long as borrowers repay, there is no effect. Once they default, a stable relation emerges whereby asset prices affect bank capital through the value of collateral (page 22). Once the capital constraint binds, that relation becomes unstable, and capital, credit and asset prices implode. Each transition is marked by threshold values τ_i and δ_i that depend on structural features of the economy, $\{\alpha, \beta, \gamma\}$.[51]

This leads to a natural definition of vulnerability as the sensitivity of the economy to falling asset prices. The smaller the thresholds $\delta_i(\alpha, \beta, \gamma)$, the more vulnerable the economy to any given decline δ. The model is well-suited to explore these comparative statics, because $\{\alpha, \beta, \gamma\}$ and $\{\tau, \delta\}$ can be varied independently of each other. It is useful to take a structural approach to devising thresholds as they are commonly used in stress testing exercises that assess risks to financial stability.

Proposition 7 ***Vulnerability***

An economy is more vulnerable to asset price declines with
- *greater leverage (α)*
- *higher rate of time preference (β)*
- *greater deflationary tendency (γ).*

Proof: Appendix 3(c) shows that the greater α, β, and γ, the smaller the thresholds τ_i. •

The intuition is straightforward: greater values of $\{\alpha, \beta, \gamma\}$ translate any given asset price decline into greater loan losses, the size of which drives our previous results. In particular, higher leverage (α) and a lower interest rate (higher β) both increase asset valuation qH in (16). Similarly, higher γ leads to greater deflation, given the size of the wealth effect δqH, see (31) and (32). Taken together, these effects increase the size of losses (26) for any given δ, while the ability to withstand them, Π, falls. Therefore, loan losses $\lambda(\alpha, \beta, \gamma | \delta, \tau)$ increase and precipitate more adverse outcomes. Equivalently, the same outcomes are now reached at smaller thresholds δ_i and τ_i.

One interpretation of this result is that more developed financial systems are more prone to financial instability: they feature greater leverage and lower interest rates.[52] Firm leverage is essential for financial instability because leverage constitutes exposure to asset price declines.[53] Bank leverage is

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[51] Recall that α measures firm leverage, since higher output elasticity encourages firms to purchase more assets and incur more debt qH (see page 13). Parameter β represents the rate of time preference, the inverse of the nominal interest rate R. Finally, γ measures the 'deflationary tendency' of the economy: a lower intertemporal elasticity of substitution $1/\gamma$ makes households less willing to increase their spending s_t to plug the hole in aggregate demand and attenuate deflation. (At the limit $\gamma \to 0$, spending is so responsive that the price level remains fixed, $p_t(\tau) = 1$. The slightest deviation would evoke infinite (or zero) spending by households, which conflicts with market clearing).

[52] Borio and Lowe (2002) argue that an environment of low inflation and high growth may encourage the build-up of financial imbalances. Their emphasis on the 'unwinding of financial imbalances' following asset prices declines (p. 19) is similar to the mechanism of our model. Indicative of this possibility is the frequency of financial instability in the aftermath of liberalizations (Kaminsky and Reinhart 1999).

[53] With no leverage, $\alpha = 0$, default is impossible. With unit leverage, $\alpha = (R-1)/R$ in (17), firms' expected profits

also essential, because a lower capital-asset ratio provides a smaller buffer for absorbing losses. By contrast, a positive deflationary tendency γ is *not* essential for financial instability. It exacerbates vulnerability ($\gamma \to 1 \Rightarrow \delta^* \to 0$), but its absence does not guarantee financial stability.

Proposition 8 ***Macroeconomic versus Financial Stability***

(a) Macroeconomic and financial stability are distinct, but not independent.
(b) A policy preventing deflation does not necessarily deliver financial stability.

The model distinguishes between the two concepts as defined on page 1. Macroeconomic stability depends on the parameters governing deflation and output, γ and τ. Financial stability, by contrast, depends on the size of loan losses and asset price declines, λ and δ. To relate the two concepts, we arrange previous results in four cases. While macroeconomic and financial instability (MiS and FiS) tend to occur together, either may occur alone:

MiS⇒FiS. In a fundamental equilibrium, causation runs from the economy to the banking system. Asset prices fall only if future output and price levels do. Only a sufficiently large macroeconomic shock brings about financial instability ($\tau > \tau^*$).

FiS⇒MiS. In a self-fulfilling equilibrium, the causation is reversed: deflation (and output collapse) can occur as a by-product of self-fulfilling capital crunches (and banking crises).

MiS alone. A large productivity shock τ may depress output without causing any loan losses, if leverage (α) and deflationary tendency (γ) are sufficiently low.

FiS alone. A self-fulfilling banking crisis may occur without producing any deflation, and a self-fulfilling capital crunch may produce neither deflation nor an output gap, if $\gamma \to 0$ and $\tau \to 0$ respectively.

One is led to the conclusion that a policy preventing deflation does not necessarily deliver financial stability.[54] Such a policy may be conducive to financial stability, as claimed by Bordo and Wheelock (1998), and Bernanke and Gertler (1999), but it is not sufficient to guarantee it.

5 Applications

5.1 Case Study I: Japan's Lost Decade

Japan's Lost Decade (1990s) is marked by the bursting of an asset price bubble, and a decade of banking distress with sluggish growth.[55] Models ignoring asset prices and non-performing loans

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match their debt ($RqH = \Pi$); absent deflation, not even $\delta = 1$ causes default.

[54] This policy amounts to reducing R sufficiently in the original Euler equation (page 8), to implement equilibrium spending $\{s_t, s_{t+1}\}$ with no need for price level movements. The lower bound $R \geq 1$ means that this policy can remove deflation for γ sufficiently small.

[55] See Cargill et al (1997) for the background, especially chapters 5-6.

cannot reasonably explain this experience. Our characterization of capital crunches (section 4.2), however, captures several essential aspects of this episode.

First, the **decline in asset prices** has been spectacular (large δ). Stock prices fell 70% since 1989, and urban commercial land prices fell 85% since 1992 (Ueda, 2003, p. 3). Second, the sharp decline in asset prices caused a large measure of **loan losses** to Japanese banks (large λ). The often cited 'non-performing loans problem' almost completely characterizes the state of the Japanese financial system. Estimates of aggregate non-performing loans for the late 1990s settle around 7-8% of GDP (Hoshi and Kashyap, 1999). Loan losses exceeded operating profits every year since 1994.[56] In the model this corresponds to $\lambda > (R-1)K$ where proposition 3(c) applies. Importantly, the evidence that real estate-related industries caused the heaviest loan losses (Hoshi, 2001) is consistent with our direction of causality from falling asset prices to the default of leveraged firms.[57] Propositions 3 and 4 are therefore relevant to the Japanese case,

> "It has been the deflation of asset prices, not that of general prices, that has generated serious negative effects on the balance sheets of borrowers and, over time, on those of lenders." p. 2
> The deterioration of balance sheets can be mostly explained by declines in asset prices and by non-performing loans (in the case of banks). Moreover, most of the declines in bank lending since the mid-1990s can be attributed to these two factors, together with the liquidity problems of banks during 1997-98. Ueda (2003) p. 4

Third, the non-performing loan problem induced a **capital crunch**. The liquidation of Jusen companies during early 1996 had already imposed losses on the founder institutions (mostly large banks); the phasing in of prompt corrective action accelerated write-offs, and focused supervisory attention on capital ratios.[58] Since 1990, issuing new equity had been virtually impossible: given low profitability and limited access to capital markets, banks responded by trying to squeeze their asset size (Nakaso 2001) – as the model suggests. Total bank lending growth fell throughout the decade to become negative in the late 1990s.[59] The clearest evidence of a capital crunch points to private banks during fiscal year 1997, see Woo (1999), and Watanabe (2002).[60] This timing is consistent with the hypothesis that non-performing loans were responsible for the capital crunch.

Capital crunches can be fundamental or self-fulfilling (proposition 5). If fundamentals are weak, so is credit demand, and the **spread** is small, $\tau \to \tau^*$ in (38). Hoggarth and Thomas (1999) note that spreads indeed remained small. Our model then appears to imply that Japan's banking distress is

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[56] See Figure 9 in Nakaso (2001). The loan losses reported by banks during 1992-99, amount to 13.2 times the average annual operating profit; it would have taken 13 years for Japanese banks to dispose of loan losses relying on profits alone (p. 30). Between April 1992 and March 2000, 17% of GDP has been spent on dealing with the non-performing loans problem (p. 2); the figure is now approaching 20% (Ueda, 2003, p. 4).

[57] Hoshi (2001) shows that the cross-sectional variation of non-performing loans ratios of Japanese banks is best explained by the variation in the growth of loans to the real estate industry. The proportion of lending to this industry amounts to 12% (figure 6); that to real-estate related industries amounts to 25% (Okina et al, 2001, figure 16).

[58] PCA allows regulators to intervene in banks that do not comply with risk-based capital adequacy regulation (Basel Accord) in force since 1993.

[59] See Nakaso (2001), figure 12, Watanabe (2002), figure 4.

[60] Foreign lending by large City Banks saw the steepest decline, a fact exploited by Peek and Rosengren (2000) to identify an independent loan supply shock in US real estate markets.

fundamental, rather than self-fulfilling. In a controversial paper, Hayashi and Prescott (2002) put forth the view that falling productivity largely explains Japan's lost decade. Their hypothesis fits squarely with our model, because it would take a permanent fall in productivity of about 70% in (22) to produce the observed asset price decline, since deflation remained moderate. That would imply a severe recession in (19), contradicted by Japan's actual output realization. This large a productivity decline is implausible unless the bubble of the late 1980s was predicated on a vast overestimation of *future* productivity.

Proposition 6 (a) predicts that a capital crunch is an unstable equilibrium. Anecdotal evidence indeed suggests that the Japanese financial system witnessed signs of instability precisely in late 1997 during the capital crunch. As described in Nakaso (2001), the non-performing loans problem threatened the viability of several major banks (p. 7). When financial institutions started defaulting, a short period of financial instability ensued, which was contained by the Bank of Japan's intervention (p. 9).

In sum, the banking system did not collapse, but it suffered a capital crunch due to loan losses following substantial asset price declines, as illustrated on page 2. It is then not surprising that expansionary fiscal and monetary have failed to support asset prices and stimulate the economy: both depend on bank credit, which is constrained by low bank capital. Note that Japan's banking problem is about the deterioration of bank *assets* – no bank runs on any significant scale took place. Our model therefore provides a better fit than those reviewed on page 3. The relevance of our model faces a tougher test in the Great Depression.

5.2 Case Study II: The US Great Depression

The US Great Depression (1929-1933) witnessed the collapse of the financial system and a depression unprecedented in scale. The experience reveals a gap in our analysis: bank runs. Nonetheless, the model suggests a coherent story of default and banking distress that is largely new within macroeconomics.

The famous stock market crash of 1929 initiated a prolonged **decline of prices**. The stock market fell by 24% on October 28-29, 1929, and continued to fall until reaching a trough in early 1933, some 75% below its peak in September 1929 (Mishkin and White, 2003). Similarly, the decline of bond prices is cited by Friedman and Schwartz (1963) as a major source of losses to banks (p. 355-56). Most famously, **price level deflation** of 27% in consumer prices (39% in wholesale prices) contributed to financial distress by raising the real burden of debt, as pointed out by Fisher (1933).[61] The deflationary tendency was much more pronounced than during Japan's Lost Decade (with cumulative deflation of 3%, Ueda 2003). Falling prices and economic activity led to a generalized debt crisis. The evidence cited in Bernanke (1983) suggests high rates of default in all sectors.[62] Default on this scale produced significant **loan losses** to the banking system. As a

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[61] Deflation is cumulative between June 1928 and early 1933, see Bernanke and Mihov (2000) p. 112.

[62] The ratio of debt service to national income went from 9% (1929) to almost 20% (1932-33). Survey evidence

result, a **capital crunch** set in,[63]

> "In response to loan losses in the early 1930s, and high costs of raising new capital, banks faced significant pressure from depositors to reduce deposit risk. Banks cut dividends but avoided new offerings of stock and thus allowed capital to remain low. The primary means to reduce depositor risk, and thus prevent deposit withdrawals, was the contraction of the supply of loans."
> . Calomiris and Wilson (1998) p. 1-2

This response resembles that predicted by our model (proposition 5). However, the economy failed to maintain the delicate capital crunch equilibrium. **Bank runs** tipped the balance toward financial instability. Bank runs were an important channel that our model omits. But the variables we modelled (deflation, asset price declines and loan losses) help explain what *triggered* the bank runs. The traditional view considers them depositor panics.[64] Yet the poor state of the economy suggests that the bank runs may have been a symptom, rather than the cause, of the ongoing deterioration of balance sheets. Even Friedman and Schwartz (1963) recognize the "drastically weakened capital position of the commercial banks" (p. 330), and concede that the deterioration of credit quality may have triggered the bank runs (p. 356). Stronger evidence is provided by Calomiris and Mason (2002) in the most comprehensive study on **bank failures** to date. They show that fundamentals, including losses from loans and bond holdings, explain most of the incidence of bank failures. Their data (bank-level, local, and regional) reveal patterns invisible in the aggregates on which Friedman and Schwartz based their view. The only aggregate indicator that correlates with bank failures is 'liabilities of failed businesses'.[65] Interestingly, this variable corresponds to λ in our model.

Financial instability ended in the collapse of the banking system in March 1933. While this outcome coincides with proposition 6, the direction of causality does not. Friedman and Schwartz emphasize the "multiple contraction of deposits, hence of assets" (p. 355). Our model favors the reverse causation: loan losses bring about the multiple contraction assets, hence of deposits (and capital).[66] Even if secondary, this direction of causality is consistent with Bernanke's (1983) findings that 'non-monetary effects', caused by the impaired intermediation, contributed to the severity of the Great Depression. In particular, his regressions indicate that two distress variables, liabilities of failed businesses and deposits of failed banks, together predict bank loans, which in turn help predict industrial production.[67] Also the evidence on credit rationing and the rising cost of credit

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indicates that rates of default on mortgages of 38%, farm mortgage delinquency rates of 45%, and wide-spread failures among small business were not uncommon during the early 1930s, see Bernanke (1983), p. 260-61. His main point is that the debt crisis impaired the channels of credit intermediation.

[63] The decline in lending and anecdotal evidence are reported in Bernanke (1983), table 1 and p. 264-67.

[64] See Friedman and Schwartz (1963), and much of the theoretical literature following Diamond and Dybvig (1983).

[65] Calomiris and Mason (2002), p. 8. This complements earlier efforts by Gorton (1988) examining the seven banking panics of the National Banking Era (1863-1914): "Remarkably, the data support the notion of a critical or threshold value of the liabilities of failed businesses variable, and a threshold value of the perceived risk measure, at the [banking] panic dates. The seemingly anomalous event of a panic appears to be no more anomalous than recessions." (p. 241). See also Calomiris and Hubbard (1989), Calomiris and Gorton (1991).

[66] See figure 5 and footnote 41.

[67] Indicative of the same direction of causality is the finding that wholesale price deflation Granger-caused both M1 and industrial production, see Bernanke and Mihov (2000) p. 122.

intermediation (proxied by Baa-AAA spread) suggest a problem of intermediation and credit supply.

Overall, the model does not match the Great Depression as well as Japan's Lost Decade. But it does have the virtue of incorporating default and banking distress hitherto ignored in macroeconomics (see page 3). In both cases, the interaction of credit, asset prices and loan losses has played a central role. This approach, we believe, can be applied more broadly to boom-bust cycles and other episodes of financial distress.[68]

5.3 Policy Debate I: Monetary Policy and Asset Prices

A widely held view maintains that monetary policy should not react to asset prices beyond their predictive content for future inflation – *except perhaps* in the event of a large decline.[69] Yet the literature provides little guidance on how to identify such exceptions. Mishkin and White (2003) clarify the debate, proposing financial stability as the relevant criterion,

> "[...] financial instability is the key problem facing the policymaker and not stock market crashes, even if they reflect the bursting of an asset price bubble. If the balance sheets of financial and nonfinancial institutions are initially strong, then a stock market crash (bursting of the bubble) is unlikely to lead to financial instability. [...] However, central banks may see the need to directly respond to a stock market crash when the crash puts stress on the financial system in order to prevent financial instability. [...] A focus on financial instability also implies that central banks will respond to disruptions in the financial markets even if the stock market is not a major concern."
> . Mishkin and White (2003) p. 73-74

Their argument can only be evaluated within a macroeconomic model addressing financial instability. Our results support Mishkin and White's argument, provided that timely monetary policy is effective. Recall that α represents leverage, hence balance sheet vulnerability (proposition 7). Figure 8 plots $\delta^*(\alpha)$ as derived in (37): the greater leverage, the smaller the asset price decline that causes a capital crunch. Following proposition 6, this curve can be interpreted as a financial stability frontier.

Now consider two economies that differ only in this measure of balance sheet strength.[70] If balance sheets are initially weak ($\alpha = 1/2$, say), then an asset price decline above 5.5% triggers financial instability. With stronger balance sheets ($\alpha = 1/4$), it takes a decline of 16% to do so, three times the size. Put differently, a sudden asset price decline of 10% causes financial instability and a banking crisis in one case, yet barely affects bank capital in the other. The radically different

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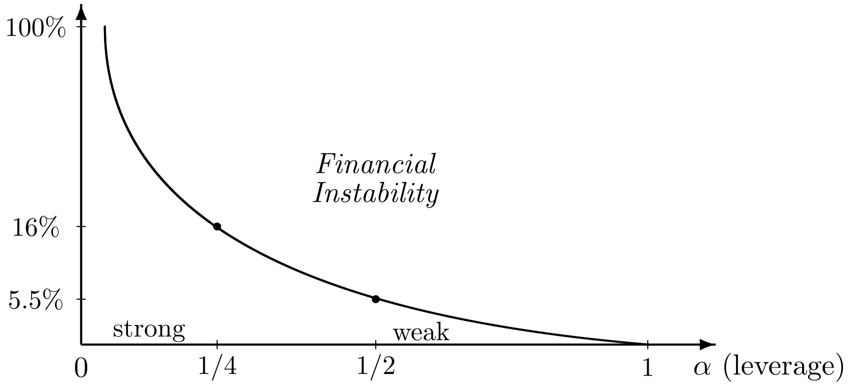
[68] On the role of deflation in financial crises, Bordo and Wheelock (1998); on the role of asset prices, Kindleberger (1996), Hunter et al (2003); on real estate in particular, Herring and Wachter (1999), Mera and Bertrand (2000). On asset prices and credit in predicting banking crises, Kaminsky and Reinhart (1999), and Borio and Lowe (2002). On loan losses in banking crises, Caprio and Klingebiel (2003), and Caprio et al (1998). On the role of capital crunches over the business cycle, Wojnilower (1980), Eckstein and Sinai (1986).

[69] See the four views in Bank of International Settlements (1998), and Bernanke and Gertler (1999).

[70] The example uses $R = 1.05$ and $\gamma = 0$. A positive deflationary tendency ($\gamma > 0$) implies greater losses for any δ, shifting the locus down. Bernanke and Gertler (1999) put forth a similar example (p. 21), but their simulations are confined to the neighborhood of the steady state (p. 31).

outcomes suggests that the response of monetary policy should be conditioned on α, the initial state of balance sheets.

Figure 8: Financial Stability Frontier



Can monetary policy avert financial instability? A complete answer requires two extensions best left to a separate paper, but some observations can be made. First note that any successful policy must be timely, carried out in t. Once losses have materialized, the damage cannot be undone by subsequent monetary easing.[71] Three policies can then be distinguished. First, liquidity injections at R are ineffective in our context, because the banking system needs no additional reserves (see footnote 26).[72] Second, an interest rate reduction ($R_t < R$) helps asset prices only if banks are unconstrained, see (21). When multiple equilibria are possible, this policy works if it coordinates the banking system on the better, fundamental equilibrium. Therefore, only a timely interest rate cut is likely to avert financial instability, and only if fundamentals are sufficiently good ($\tau < \tau^*$).[73] Finally, one may also consider preemptive tightening to prevent a build-up of financial imbalances in the first place (Borio and Lowe 2002). An increase in R, if phased in carefully, would indeed reduce leverage and vulnerability, shifting up the financial stability frontier $\delta^*(\alpha)$.

5.4 Policy Debate II: Procyclical Effect of Capital Adequacy Requirements

Empirical evidence suggests that the procyclicality of the financial system may cause financial instability (Borio et al 2001, p. 11).[74] Bank capital, provisioning, profits and risk assessments all move over the cycle in a way that encourages procyclical lending, which may feed boom-bust cycles

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[71] A financial crisis is not 'symmetrically reversible', to borrow the expression of Calomiris (1995) p. 253.

[72] However, making bank loans eligible for rediscount would allow the banking system to improve capital adequacy by selling loans to the central bank (bank reserves require no capital). The central bank would effectively take on part of the intermediation normally left to the banking system.

[73] This could explain why a small temporary rate cuts in a crucial moment, such as October 1987 or November 1998, can have a decisive effect on financial markets.

[74] Procyclicality refers to the tendency of the financial system to reinforce, and sometimes shape, the business cycle, where it is understood that the forces in question emanate from the financial system rather than from the economy.

in credit and asset prices. Goodhart (1995) singles out the role of capital adequacy requirements in the context of the late 1980s and early 1990s,

> "The asset price cycle was both driven by, and drove, an accompanying cycle in bank credit expansion, and to a somewhat lesser extent in broad money. The collapse of these asset markets after 1990 was associated with a widespread rise in bad debts, in the need for bank provisions and in a fall in bank profits. In many countries banks either failed, or exhibited considerable distress. Prudential regulations, e.g. the Basle capital adequacy ratios, bit more tightly, and will, to some largely unquantifiable extent, have aggravated the constriction of bank credit." Goodhart (1995) p. 293

This quote essentially restates the mechanism we have modelled (page 2). Our capital constraint (34) is identical to a capital adequacy requirement, and it generates an extreme form of procyclicality in our model.[75] Without the constraint, the banking system was shown to supply credit elastically without producing the slightest degree of procyclicality, even as loan losses undermined bank solvency (section 3). The addition of the constraint in section 4 induced self-fulfilling capital crunches and banking crises, and brought forward financial instability, with the associated collapse in output and asset prices (propositions 5 and 6). The capital constraint was shown to have a destabilizing effect once losses exceed a threshold.

Would it not be desirable, from a macroeconomic perspective, to remove capital adequacy requirements or pursue a policy of forbearance? To draw this conclusion from our analysis would be misleading. First, the analysis ignored the risk and incentive effects that motivate capital adequacy regulation (see Rochet 1992 for a model). If taxpayers are to be protected from risk-taking by undercapitalized banks, then bank assets of under-capitalized banks must shed risk or shrink, with the attendant procyclical effect. Second, a capital constraint may arise for reasons unrelated to regulation.[76] It is plausible that regulation merely raises the capital ratio that banks would otherwise adopt. If so, then removing capital adequacy regulation would in fact *exacerbate* procyclicality: with lower capital and dividends, the contraction would set in earlier and with greater force, as measured by the coefficient in (34). A smaller capital ratio chosen by banks may be worse than a higher ratio chosen by the regulator. Third, the phenomenon of procyclicality is more general than the particular capital constraint with which we chose to illustrate it. Financial instability remains possible whenever aggregate bank lending falls faster than loan losses accrue.[77] This is a weak condition, one that may very well be the result of individual banks' prudent lending policies. Moreover, such behavior need not be confined to banks.[78]

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[75] Blum and Hellwig (1995) provide an alternative analysis in a static macroeconomic model. They show that a binding capital adequacy requirement increases the sensitivity of output and the price level to aggregate demand disturbances. Their model does not deal with asset prices and financial instability.

[76] Explanations include monitoring incentives (Holmström and Tirole 1997), buffer against failure (Gorton and Winton 1995, 2000, Diamond and Rajan 2000), and market discipline (Calomiris and Wilson 1998). Historical evidence suggests a tendency toward self-regulation. Gorton (1985) shows that private clearinghouses in the US endogenously arose to coordinate and regulate banks (including capital requirements), long before such activities were nationalized following the founding of the Federal Reserve System (1913). Indeed, capital ratios used to be higher: the century-long decline in bank capital ratios is documented in Berger et al (1995), figure 1.

[77] This can be shown by combining (33) and (34).

[78] For instance, Shleifer and Vishny's (1997) model of performance-based arbitrage implies a similar condition, whereby current investment reacts to previous losses more than one-for-one (see their propositions 3 and 4).

It is sometimes suggested that loan loss provisions and regulatory capital ratios should increase during economic booms (Borio et al 2001, p. 49). Here, one would let the capital ratio depend inversely, and dividends positively, on τ. This would mitigate, but not remove, procyclicality. To overturn our result on instability, the constraint would have to be weakened to the point of making it non-binding everywhere. An alternative is to temporarily lift capital requirements following a large aggregate shock (Goodhart 1995, p. 290). This could implement the fundamental equilibrium, provided banks do not reduce lending for other reasons.

5.5 Conclusion

We proposed a model to extend the reach of macroeconomics to financial instability in a simple and explicit manner. The mechanism centered on loan losses, their origin (asset price declines and deflation), and their effect on the banking system (falling bank capital and credit). This way of interacting a deteriorating economy with a deteriorating banking system yields a unified approach to a broad spectrum of outcomes, including capital crunches, financial instability, and banking crises. The ability to distinguish between macroeconomic and financial stability, and the emphasis on banking and balance sheets, make this approach useful for interpreting episodes, for evaluating policy debates, and for devising stress testing thresholds for assessing risks to financial stability.

For our approach to become more than a first step, several extensions should be undertaken. First, a treatment of risk would be desirable, because the main justification for bank capital is its role as a buffer. Our results may change little if an unexpectedly large shock has a similar effect as the unexpected shock we considered. But the inclusion of risk would allow one to examine other interesting questions such as whether the New Basel Capital Accord (with more risk-sensitive weights in the capital constraint) would enhance or reduce procyclicality.

Second, including asymmetric information would be sensible, for its role in shaping financial arrangements, and because asymmetric information problems are widely believed to exacerbate financial instability. Our specification of perfect information and elastic credit ensured that default occurred only when unavoidable, and that no inefficiencies took place. The effect of informational frictions can be measured by the extent to which they shift down thresholds (increase vulnerability). Third, extending the system to several banks would allow a systematic treatment of interbank payments and liquidity needs. This would provide a foundation for analyzing lending of last resort and interest rate policy during financial distress.

Finally we touch on some empirical implications. One could measure the extent of feedback and procyclicality due to the banking system by estimating the reduction in bank lending in response to loan losses in (36): if the coefficient exceeds one, financial instability is possible once banks become capital-constrained. Another testable implication is the spread on safe borrowers predicted by (38). More generally, we have shown that loan losses can be a decisive macroeconomic quantity. Using loan losses in econometric models may lead to more accurate estimates in two areas of central banking: the assessment of risks to financial stability, and the effectiveness of monetary policy.

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Appendix A

1. Euler Equation of the form $p_{t+i} = \left(\frac{s_{t+i}}{s}\right)^{\frac{\gamma}{\gamma-1}}$.

Invert the Euler equation (11) to obtain $p_t = (s_{t+1}/s_t)^{\frac{\gamma}{1-\gamma}} p_{t+1}$. This is the *original* form. The *proposed* form $p_t = (s_t/s)^{\frac{\gamma}{\gamma-1}}$ coincides with the original form if $(s_t/s)^{\frac{\gamma}{\gamma-1}} = (s_{t+1}/s_t)^{\frac{\gamma}{1-\gamma}} p_{t+1}$, which requires $p_{t+1} = (s_{t+1}/s)^{\frac{\gamma}{\gamma-1}}$. This in turn coincides with the original form for p_{t+1} if $p_{t+2} = (s_{t+2}/s)^{\frac{\gamma}{\gamma-1}}$. Going forward, the two forms are equivalent if some future p_{t+T} assumes the proposed form. The proposed form can then be justified by a long-run neutrality criterion: the new steady state price level equals the old only if household spending does, $p' = 1 \Leftrightarrow s' = s$.[79] This criterion is satisfied by the proposed form, $p' = (s'/s)^{\frac{\gamma}{\gamma-1}}$. •

2. Falling Prices, Proposition 3.

We make use of the parameter relations $s = (R-1)\,D$ and $qH = RD$, and the identities $q_t \equiv q\,(1-\delta)$ and $A \equiv D + K = qH$.

Part (a) The goods market clearing conditions from $t+1$ onward are always of the form (29). Connecting consecutive s_{t+i} using the Euler equation (11) implies a constant price level, hence a new steady state, from $t+1$ onward: the proof of proposition 2 applies regardless of the case in (29).

Part (b) To obtain (31), use the first line of (28), cancel $p_t y$, and split RqH into $qH + (R-1)qH$. This brings out δqH and $(R-1)(qH-K) = (R-1)D = s$, and yields $s_t = s + \delta qH$. We solve the model by finding the solution function $p_{t+1}(\tau)$, and recover $\delta(\tau)$ and $p_t(\tau)$. To find p_{t+1}, use s_{t+1} in (30). Having a new steady state in $t+1$ implies an inverse relation between s_t and s_{t+1}: with $s_{t+i} = s_{t+1}$, households' intertemporal budget constraint $\sum_{i=0}^{\infty} s_{t+i}/R^i = RD$ becomes $s_t + s_{t+1}/\,(R-1) = RD$, that is,

$$[s_{t+1} - s] = -\,(R-1)\,[s_t - s] \tag{39}$$

Hence we can use (31) in (39) to find $[s_{t+1} - s] = -Rs\delta$, and use it in (30) to obtain an expression $p_{t+1}(\delta)$. Using (22) to replace $\delta(\tau)$ gives

$$p_{t+1} = \left(1 - R\,[1 - (1-\tau)\,p_{t+1}]\right)^{\frac{\gamma}{\gamma-1}} \tag{40}$$

This equation implicitly defines the solution function $p_{t+1}(\tau)$.[80] Note first that $p_{t+1}(0) = 1$ for any γ, hence $\delta(0) = 0$, and $p_t(0) = 1$, and all remaining variables also retain their steady state values. A unique solution $p_{t+1}\,(\tau)$ is guaranteed by $\gamma < 1$, because the right side is decreasing in p_{t+1} and cuts the 45°-line once. The slope of the implicit function (40) is

$$p'_{t+1}\,(\tau) = \frac{p_{t+1}(\tau)}{(1-\tau) + \frac{1-\gamma}{\gamma}\frac{p_{t+1}(\tau)}{R}} > 0$$

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[79] This is a reasonable characterization of long-run neutrality, because other agents' spending will revert to steady state values due to the overlapping generations structure of the model (if $\lambda \leq (R-1)K$). It is also consistent with price determination by a reserve requirement (footnote 26). We use long-run neutrality as a normalization, because the forward-looking nature of households' intertemporal consumption brings about one degree of indeterminacy following the unexpected shock. Instead of long-run neutrality, we could have assumed that the Euler equation holds across $t-1$ and t in spite of the shock – doing so leads to the same proposed form.

[80] Explicit solutions can be found for specific values of γ. $\gamma = 1/2$ or 2 admit quadratic solutions.

Clearly $\gamma < 1$ is sufficient (not necessary) to guarantee $p'_{t+1}(\tau) > 0$ for any $\tau \in [0,1]$. The chain rule performed on (22) then implies $\delta'(\tau) > 0$, because the positive price level effect is weaker than the negative productivity effect (the elasticity condition $(1-\tau)\, p'_{t+1}(\tau)/p_{t+1}(\tau) < 1$ holds). From (31) then follows that $p'_t(\tau) < 0$. That deflation is temporary can also be understood as follows: since $s_t > 0$ implies $s_{t+1} < 0$ in (39), $p_t(\tau) < 1$ also implies $p_{t+1}(\tau) > 1$ in (30).

Part (c) Placing s_t from the second line of (28) into the Euler equation (30) gives $p_t = (p_t y/s)^{\frac{\gamma}{\gamma-1}}$. Replacing $s = \alpha y/R$ (see footnote 27) yields the lower bound of the price level $\overline{p}_t$, and $\overline{s}_t = \overline{p}_t y$ in (32). Using $\overline{s}_t$ in (39), we find $\overline{s}_{t+1} = s - s(R-1)[(R/\alpha)^{1-\gamma} - 1]$, and use it in (30) to obtain $\overline{p}_{t+1}$ in (32). •

3. Deteriorating Balance Sheets and Critical Shocks, Propositions 4 and 7.

Part (a) To show $\omega(1) > RK + \Pi$, note that $\delta(1) = 1$ and $p_t(1) = \overline{p}_t \leq 1$ for any γ. Therefore, (26) implies $\omega(1) > qH$. To show $qH > RK + \Pi$, use firm leverage (17) to replace $\Pi = \frac{1-\alpha}{\alpha}(R-1)qH$, and use bank leverage (18) to replace $qH = A = RK/(R-1)$. Cancelling RK, the inequality becomes $(R-1)^{-1} > 1 + (1-\alpha)/\alpha$, which holds since $\alpha > (R-1)$. Therefore, $\omega(1) > RK + \Pi$ for all α and γ considered.

Part (b) With $\omega(0) = 0$ and $\omega(1) > RK + \Pi$, the continuity of $\omega(\tau)$ and $\omega'(\tau)$ guarantees the existence and ordering of the thresholds $0 < \tau_0 < \tau_{Div} < \tau_K < 1$. We can find τ_K and τ_{Div} explicitly by using in (22) the solutions δ_{Div} and δ_K found on page 22, $1 - \tau_i = (1-\delta_i)/\overline{p}_{t+1}$. Before substituting δ_i and $\overline{p}_{t+1}$, it simplifies notation to express them in terms of the constant $\delta^* = (R-1)\left[(R/\alpha)^{1-\gamma} - 1\right]$, so that $\delta_{Div} = \delta^*/R$, $\delta_K = \delta^*/R + (R-1)/R$, and $\overline{p}_{t+1} = (1-\delta^*)^{\gamma/(\gamma-1)}$, from (32). Thus, the thresholds τ_i are given by

$$\begin{aligned} 1 - \tau_{Div} &= (1 - \delta^*/R) / (1-\delta^*)^{\gamma/(\gamma-1)} \\ 1 - \tau^* &= (1-\delta^*)^{1/(1-\gamma)} \\ 1 - \tau_K &= (1-\delta^*)^{1/(1-\gamma)}/R \end{aligned} \tag{41}$$

Only for τ_0 there is no explicit solution. δ_0 is implicitly defined by $\omega(\delta_0) = \Pi$. Since $\delta_0 < \delta_{Div}$, it follows that $\tau_0 \in (0, \tau_{Div})$.

Part (c) To show that the thresholds in (41) are decreasing in α and γ, note first that δ^* is. In each case of (41), τ_i and δ^* are related positively. Since τ_i depend on α only through δ^*, it follows that $\tau'_i(\alpha) < 0$. That also implies $\tau'_i(\gamma) < 0$, because γ also raises the exponent of $(1-\delta^*)^{1/(1-\gamma)}$. The remaining threshold is implicitly defined by $\omega(\delta(\tau_0), p_t(\tau_0)) = \Pi$. $\tau'_0(\alpha) < 0$ is shown as follows. $\delta(\tau)$ and $p_t(\tau)$ are independent of α; therefore, higher leverage α increases ω in (26) only through qH, due to (16). Moreover, $\Pi = (1-\alpha)\, y$ falls. When α is greater $\omega(\alpha, \tau) = \Pi$ is reached at smaller τ, so $\tau'_0(\alpha) < 0$. The same argument applies to γ, since $p'_t(\gamma) < 0$. The proof for $\beta = R^{-1}$ is very similar. Therefore, $\tau'_i(\alpha) < 0$, $\tau'_i(\beta) < 0$, and $\tau'_i(\gamma) < 0$: the greater α, β and γ, the smaller all thresholds τ_i. •

Appendix B: Strategic Default

Debt is enforceable if strategic default can be prevented. Assets cannot be hidden or stolen; the question of strategic default revolves around whether the firm's sales revenue py can be pledged for the repayment of debt, as in (5), or whether borrowing is confined to the discounted value of assets, as in Kiyotaki and Moore (1997). The latter would result from either of two possible moral hazard problems. The inalienability of human capital (Hart and Moore 1994) is not a problem here, because entrepreneurs' threat to withdraw their specific labor would not be credible: zero production implies zero overall consumption. The other possibility is that entrepreneurs secretly consume their production.[81] We shall see that only deposit banking can prevent this form of moral hazard.

First note that comparing (1) with (4) indeed suggests that entrepreneurs have an incentive to consume all output, and that doing so implies partial default.[82] For them to take advantage of strategic default, however, they must trade each others' output around the unit circle (see page 6). They cannot do so using only IOUs, as they cannot by themselves clear the infinite chain of IOUs required for the necessary trades (assumption 2). They cannot do so through a deposit banking system either, because all transactions are taking place *on* the banking system's balance sheet, and transfers from defaulting firms can be blocked. By contrast, if the economy used outside money as means of payment, or if the banking system issued circulating bank notes instead of deposits, defaulting firms could pay each other using the circulating liability without any need for payment intermediation by the banking system. These arrangements cannot prevent strategic default, and lending would not arise in the first place. Therefore, only deposit banking overcomes the payments problem. •

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[81] Much of the literature removes this incentive by assuming either costly bankruptcy whereby defaulting firms can only abscond with a fraction of their output (e.g. McAndrews and Roberts 1999), or by introducing auditing or monitoring with non-pecuniary penalties to emulate unlimited liability (Townsend 1979, and Diamond 1984).

[82] The asset price in (5) cannot appreciate at the rate of interest, see footnote 16.

Appendix C: Balance Sheet Mechanics

Every period old firms leave, and young firms enter, the bank's balance sheet. This process can be represented on the bank balance sheet in three steps.

t^-		t		t^+	
RqH	RD	$RqH - \lambda$	$RD - s_t$		$RD - s_t$
		$q_t H$	$q_t H + s_t + Div_t$	$q_t H$	
	RK		$RK - \lambda - Div_t$		$RK - \lambda - Div_t$

Step t^-. Entering period t, the bank's balance sheets reflects loans and deposits with interest due.

Step t. While markets are open during t, four transactions occur:
(1) new firms borrow $q_t H$, and spend the deposits so obtained on old firms' assets.
(2) savers spend s_t of their deposits on old firms' output.
(3) the banking system likewise spends Div_t on output.
Old firms thereby accumulate deposits worth $q_t H + s_t + Div_t$ (the middle row). This equals $RqH - \lambda$, which shows that if revenue falls short of RqH, old firms default. [The equality uses (23), (27) and (28) and holds for all $\lambda \geq 0$.]
(4) Loan losses are written off by subtracting λ from both loans and bank capital.

Step t^+. The accumulated deposits repay the performing portion of loans: this cancels $RqH - \lambda$ on both sides of t. This yields balance sheet t^+, which is carried over to period $t + 1$.