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Asset prices and banking distress: a macroeconomic approach

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Abstract*

This paper links banking with asset prices in a monetary macroeconomic model. The main innovation is to consider how falling asset prices affect the banking system through wide-spread borrower default, while deriving explicit solutions and balance sheet effects even far from the steady state.

We find that the effect of falling asset prices is indirect, non-linear, and involves feedback from the banking system in the form of a credit contraction. When borrowers repay, the effect 'passes through' the bank balance sheet; once borrowers default, asset prices drive bank capital, and constrained credit in turn drives asset prices. This interaction can explain capital crunches, financial instability, and banking crises, either as fundamental or as self-fulfilling outcomes.

This model, unlike others, distinguishes between financial and macroeconomic stability, and makes precise the notion of balance sheet vulnerability. It also carries regulatory implications and adds to the debate on asset prices and monetary policy. The case studies apply the model to Japan's Lost Decade, the Nordic Banking Crises, and the US Great Depression.

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

Keywords: Banking, Asset Prices, Inside Money, Default, Non-Performing Loans, Capital Requirements, Credit Crunch, Financial Instability, Banking Crisis, Vulnerability.

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Introduction

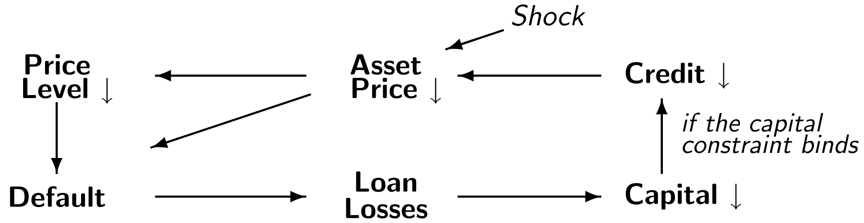
The essence of central banking lies in the pursuit of macroeconomic and financial stability. Macroeconomic stability refers to the stability of the price level and of output. Financial stability refers to the smooth, uninterrupted operation of both credit and payment mechanisms.[1] There are complete models of macroeconomic stability, and a reasonably broad consensus on how to achieve it. Not so for financial stability. There is no consensus how to achieve it, nor a widely accepted model.

This paper studies the relation between asset prices and the banking system. This relation is a suitable reduction, having been a central element, and a major policy concern, in many episodes of financial instability. To do so requires going beyond existing macroeconomic models in three ways. First, the model incorporates a banking system that intermediates the payments supporting the asset market. Second, we allow default and loan losses to affect the banking system. Finally, we avoid log-linearisation to incorporate financial extremes far from the steady state.

More precisely, we propose an overlapping-generations model designed for assets to play a central role, as in Kiyotaki and Moore (1997), and for banks to intermediate payments, as in Black (1970) or McAndrews and Roberds (1999). The model works as follows. Firms purchase productive assets on bank credit. Next period, they resell them to the new generation of firms, and sell their output to other firms and households. While undisturbed, the economy remains in steady state.

We then let an adverse productivity shock set off the 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 reduces consumption spending, and the price level falls. Falling prices in the presence of fixed nominal debt may cause wide-spread default among firms. If so, the banking system faces loan losses which, if large, reduce bank capital. A binding capital constraint generates feedback from the banking system: the contraction of credit in turn depresses asset prices, and drives up the bank loan rate.

Figure 1: Mechanism



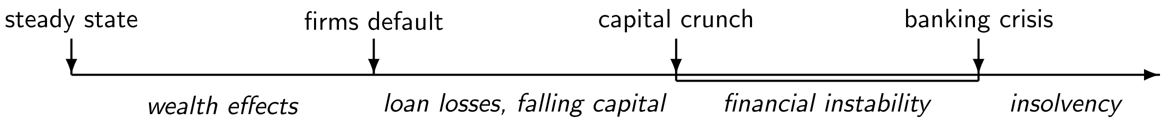
The model's main appeal is the simplicity with which it articulates these links. In spite of dynamic general equilibrium, explicit solutions and balance sheet effects are found without resorting to linearisation. This is made possible by the overlapping generations structure, and by our inside

[1] This succinct definition is from Federal Reserve Bank of St. Louis (2002). Central banks supervise, and typically operate, the payment system, including lending of last resort facilities. They often 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), and Healey (2001).

money approach to banking.[2]

We find that the effect of falling asset prices on the banking system is indirect, non-linear, and involves feedback. It is indirect, because banks need not hold the assets to be exposed to falling asset prices through the default of their borrowers. The effect is non-linear, because small losses largely 'pass through' the bank balance sheet, affecting passive money and credit aggregates. But larger losses may constrain bank lending [capital crunch], or cause an unstable contraction of credit [financial instability], which propels the system toward systemic insolvency [banking crisis]. At that point, the credit and payment mechanism ceases to function and the economy reverts to autarky. In this way the interaction of credit, asset prices, and loan losses provides a unified approach for explaining financial extremes.

Figure 2: Outcomes



This appears to be the first model to characterise the complete spectrum of outcomes between the steady state and a systemic banking crisis. The literature has devised separate, mostly microeconomic, models for each range.

The first range ('wealth effects') is captured by the *financial accelerator*.[3] Much empirical evidence supports the view that balance sheet variables such as cash flow and net worth affect investment (Hubbard 1998). The financial accelerator aggregates these balance sheet effects to produce business cycle dynamics. The role of asset prices is emphasised in Kiyotaki and Moore (1997), Bernanke and Gertler (1999), and Chen (2001). Our model differs in several respects. While sharing the emphasis on balance sheets in a macroeconomic context, our model is simpler about borrowers (credit demand), but incorporates a banking system (credit supply). Second, the financial accelerator is about borrowers' investment, output and, ultimately, macroeconomic stability.[4] By contrast, our model focuses on financial stability, and the way loan losses may interrupt the intermediation of credit and payments. Third, the financial accelerator confines itself to small deviations from steady state, and thereby excludes the financial extremes that had motivated its development. The narratives of Bernanke (1983), Mishkin (1991, 1999), and Calomiris (1993, 1995) emphasised that falling asset values can impair borrowers' balance sheets to the point of interrupting the intermediation of credit,

[2] This approach is considerably simpler than the alternatives in monetary economics, because the credit apparatus is frictionless until bank capitalisation 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.

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

[4] This becomes clear in how Bernanke and Gertler (1990) describe 'financial fragility'. Another indication is the treatment of default. 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).

which in turn exacerbates macroeconomic conditions. This feedback is incorporated in our model. Hence, compared with the financial accelerator, our model allows wide-spread default to affect the banking system hence credit supply.

The second range in figure 2 ends with a *capital crunch*. In spite of abundant empirical evidence from New England and Japan, few models 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 borrowers (Rajan 1994, van den Heuvel 2002), or to any endogenous macroeconomic variables (Gersbach 2002). In contrast to capital crunch models, our paper endogenises loan losses within a simple macroeconomic framework.

The final range in the diagram ends with a *banking crisis*. Compared with existing models, ours emphasises the deterioration of bank *assets* in a macroeconomic context. 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), or Diamond and Rajan (2001).[5] This literature takes bank *assets* and their deterioration as exogenous. In contrast to bank run models, our paper provides an asset-based explanation of banking distress. In taking a macroeconomic approach, we link bank assets to firms, and firms' financial position to macroeconomic conditions.

We think this perspective has several advantages. The deterioration of bank assets through non-performing loans is characteristic of banking distress, as becomes clear from the 168 banking crises compiled by Caprio and Klingebiel (2003). Importantly, a banking system can be in distress even when bank runs are not a problem.[6] This was the case during Japan's Lost Decade and the Nordic Banking Crises which are discussed as case studies. Even the classic banking panics of the Great Depression are being revised in the light of new evidence on the fundamental deterioration of bank assets. We argue that bank runs are perhaps better viewed as a symptom, rather than the cause, of financial instability. Our macroeconomic approach to financial stability is in line with the macroprudential perspective (Borio 2003).

The main limitations of our analysis are due to the absence of frictions, uncertainty, and asymmetric information. First, our results on instability and multiplicity depend on the presence of a capital constraint. While there are models that rationalise such a constraint, here it is imposed rather than derived. Second, the model captures financial extremes rather than the business cycle – financial factors affect output only once the banking system collapses. A more realistic, continuous output response would require price rigidities or agency costs. Finally, the paper does not model policy, but financial instability as an issue of policy concern.

With these limitations in mind, the analysis bears on important policy issues. This model, unlike

[5] Useful surveys appear in Bhattacharya and Thakor (1993), Freixas and Rochet (1997).

[6] 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.

others, distinguishes between macroeconomic and financial stability. Macroeconomic stability depends on the factors governing deflation and output; financial stability depends instead on asset prices and loan losses. This distinction raises the question whether monetary policy should react to asset prices in pursuing financial stability. The model also has regulatory implications. Restrictions on direct asset holding would not eliminate banks' effective exposure to asset prices. Also, banks' reaction to losses can induce an extreme form of procyclicality. Finally, the model substantiates the notion of 'balance sheet vulnerability' in terms of critical thresholds and structural features of the economy.

The paper is organised as follows. Section 1 presents the basic model in perfect foresight. Section 2 studies the effect of a shock on prices, borrowers, and on the banking system. Section 3 considers the feedback from the banking system to credit, asset prices and the loan rate. Section 4 discusses policy implications, and section 5 presents the case studies.

1 The Basic Model

The model is a flexible-price general equilibrium model with real assets and consumption goods. There are overlapping generations of firms and households, each of unit measure. *Households* are the lenders in this economy, solving a standard intertemporal consumption problem; their Euler equation, along with goods market clearing, will govern the price level. *Firms* use real assets to produce and sell consumption goods; the productivity of their technology, along with future price levels, will determine the value of assets. The *banking system* arises to help households and firms attain their optimal pattern of exchange by intermediating their payments. Regarding modelling choices, we note that firms and banks are treated as separate from households, consuming their profits and dividends, respectively.[7] Also, we treat firms as overlapping generations as doing so affords analytical tractability in the presence of default.

1.1 Firms

The typical firm of generation $t-1$ buys assets h_{t-1}, such as real estate, and uses them to produce $f(h_{t-1})$ consumption goods. Next period, the goods are sold at the price level p_t, and assets are resold, undepreciated, at the asset price q_t. Firms are run by owner-entrepreneurs, who maximise profits for purchasing output from other firms,

$$\max_{h_{t-1}} \quad u(c_t^f) \qquad s.t.$$

$$\begin{aligned} 0 &\leq p_t c_t^f \leq \Pi_t \\ q_{t-1} h_{t-1} &= b_{t-1} \\ \Pi_t + R_{t-1} b_{t-1} &= p_t f\left(h_{t-1}\right) + q_t h_{t-1}. \end{aligned} \tag{1}$$

[7] 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 internalised), or if (b) banks were owned by firms or by households.

Firms enjoy limited liability and earn positive profits.[8] The final two lines are the period budget constraints: firms borrow the full value of assets before production takes place, and repay their debt with interest ($R > 1$) after selling output and assets. We rule out a rental market – if assets were rented and paid for after use, there would be no need for borrowing and no debt in equilibrium (firms would finance their holding of assets entirely out of sales revenue).[9] The first-order condition equates the marginal revenue product to the *user cost* of holding assets,

$$p_t f'(h_{t-1}^d) = R_{t-1}q_{t-1} - q_t. \tag{2}$$

The user cost is a small fraction of the purchasing price q_{t-1} because assets, unlike goods, can be resold after use. This gives firms a strong incentive to become leveraged.

1.2 Households

Alongside firms, there are infinitely-lived households who derive utility from consuming goods. They are endowed at date 0 with a fixed supply H of productive assets. They could run their own production, with $g(h) \leq \varepsilon f(h)$, where $\varepsilon > 0$ is small, and $g'(0) < f'(H)$. Households therefore have little productive use for assets; they will sell them to the first generation of firms.[10] Households then solve a standard intertemporal consumption problem with initial wealth $q_0 H$,

$$\begin{aligned} \max_{\{c_t\}} \quad & \sum_{t=0}^{\infty} \beta^t u(c_t^h) \qquad s.t. \\ & s_0 + D_0 = q_0 H \\ & s_t + D_t = R_{t-1}D_{t-1} \quad \forall t \geq 1, \end{aligned} \tag{3}$$

where $s_t \equiv p_t c_t^h$ denotes their spending on consumption, and D_t their wealth carried over. The slope of optimal consumption is given by the Euler equation,

$$u'(c_t^h) = \beta R_t \frac{p_t}{p_{t+1}} u'(c_{t+1}^h). \tag{4}$$

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 $D = qH/R$. 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 specify a process for the nominal interest rate R_t.

[8] We allow for positive profits because zero profits would make firms too prone to default. Profits can be understood as an implicit wage for the entrepreneur's specific labour, subsumed in the production function.

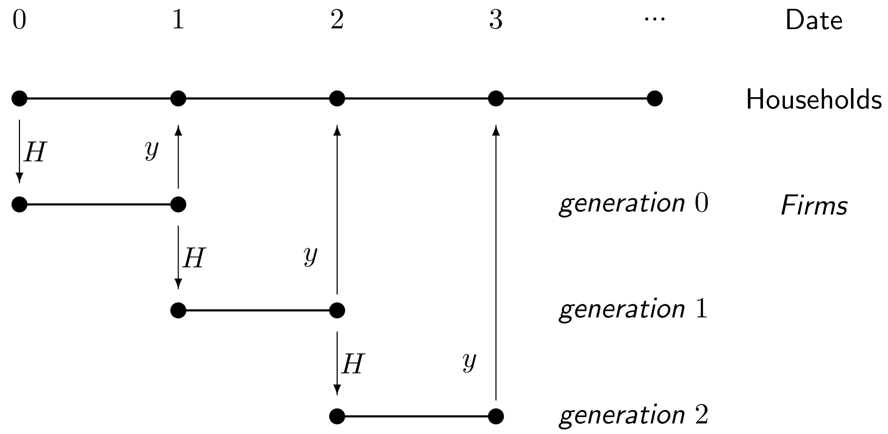
[9] The incomplete contracts approach can explain why ownership dominates renting when the entrepreneur's human capital is essential (Hart 1995, chapter 2).

[10] Since households do not rent assets out, they would only hold assets in equilibrium if these appreciated at almost 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, as situation we refer to as *autarky*.

1.3 The Banking System

Households are the lenders in this economy – they will never run down their wealth ($u'(0) = \infty$). Firms are borrowers each period, since production takes time. To achieve efficient intertemporal exchange, the assets must be passed down successive generations of firms, in exchange for (part of) the output produced with assets, as illustrated in figure 3.

Figure 3: Intertemporal Exchange



Barter is ruled out in our context. Hence agents need a means of payment; entrepreneurs want to purchase assets and goods of other firms, and households want to purchase goods from current and future firms. Accomplishing all the necessary payments with agents' IOUs would require the collection and clearing of an infinity of IOUs within and across generations. Moreover, to be accepted as a means of payment, agents' IOUs would have to be enforceable. In reality, these are challenges taken on by specialized institutions.

In this context we motivate banking as a payment mechanism. Circulating media (cash, bank notes, or private IOUs) are liable to the incentive for strategic default inherent in (1).[11] By contrast, the transfer of deposits requires a bank to intermediate each payment; the banking system can take advantage of its position to block payments from those firms that have not repaid their debt. This reasoning suggests that *payment intermediation* makes debt enforceable.[12] 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 (1).

[11] Observe that part of the sales revenue in (1) is intended for repaying debt (in equilibrium, the asset price cannot appreciate at the rate of interest). Entrepreneurs would in fact be better off absconding with their entire sales revenue, and purchasing $f(h_{t-1})$ goods from other entrepreneurs. To take advantage of strategic default they would trade each others' output against payment. Such bilateral trades cannot be prevented when agents make payments with circulating media. (Knowing that, households would not lend in equilibrium.)

[12] This argument stands in for a more complete model of banking as a payment system, left for future research. Consistent with this view, Mester et al (2003) provide evidence that banks use the payments information available through their checking accounts to better monitor borrowers.

The banking system intermediates payments as follows. Every period t, it creates deposits worth $q_t h_t$ by extending loans to new firms; this enables them to purchase assets by transferring the deposits to old firms. Old firms use these deposits to reduce their existing debt with the bank to $(R_{t-1}q_{t-1} - q_t)\, h_{t-1}$. This balance is repaid using sales revenue $p_t f\,(h_{t-1})$, leaving profits consistent with (1).[13] Going backward, the first payment $q_0 H$ is received by the initial sellers of assets (households), who hold their wealth on deposit to finance their spending s_t every period. The bank balance sheet, recorded at the close of markets each period, consists of loans, deposits, and capital,

A Bank Balance Sheet	L
$q_t H$	D_t
	K_t.

Competitive behaviour leads to a zero spread between lending and deposit rates, so bank capital evolves as $K_t = R_{t-1}K_{t-1} - Div_t$. Suppose the banking system follows the simple dividend policy of paying out its profits if positive,[14]

$$Div_t = (R_{t-1} - 1)K_{t-1}. \tag{5}$$

Hence bank capital remains constant at $K_t = K$ in the absence of loan losses. The remaining issue concerns the composition of bank liabilities at the 'beginning of the world'. We assume banks are endowed with goods; since firms start selling their first production at date 1, households spend s_0 of their deposits to purchase $\alpha\beta y$ of bank endowment.[15] The banking system thereby acquires a deposit claim on itself which constitutes bank capital. Hence, the banking system starts with $K = s_0$ worth of bank capital.

Remarks on Banking. Our approach to banking has some features worth commenting on. In other overlapping generations models, outside money (Samuelson 1958), bank notes (Champ et al 1996), or private IOUs (Sargent and Wallace 1982) serve as means of payment – here bank deposits do. All payments are conducted through the banking system (see figure 6 below). This is only natural, and consistent with basic payment system facts.[16] Second, by granting credit, the banking system creates inside money by counterpart. Treating the banking system as a passive balance sheet allows the quantity of money and credit to be demand-determined. This notion of 'elastic credit' relates to several, mostly older, strands of the monetary literature.[17] Here it provides analytical simplicity

[13] The banking system interposes itself in all transactions. This substantially simplifies clearing and settlement, because it is conducted in terms of a single liability rather than an infinity of private agents' IOUs.

[14] Such a policy would be necessary in steady state for bank capital to remain constant.

[15] This simply states that, to become bank owners, they must initially give up some consumption. Gorton and Winton (1995) provide a more refined period-zero analysis.

[16] 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 cash. Similarly, contemporary banking theory (following Diamond and Dybvig 1983, or Diamond 1984) does not view deposits as a means of payment (McAndrews and Roberds 1995, 1999, and Skeie 2004 are exceptions).

[17] Goodhart emphasises 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

in separating the effect on, and feedback from, the banking system (see page 17). Third, note that the size of the bank balance sheet at all times equals the value of the asset market $q_t H$.[18] Finally, the deposits created as a means of payment end up being held across periods – the banking system combines the functions of payment system and credit intermediary. Hence the stability of the banking system is equivalent to financial stability as defined on page 1.

1.4 Perfect Foresight Equilibrium

A *perfect foresight equilibrium* is a sequence of endogenous prices $\{p_t, q_t, R_t\}_{t=0}^{\infty}$, and choices $\{h_t, s_t, \Pi_{t+1}, Div_{t+1}\}_{t=0}^{\infty}$, such that firms maximise (1), households maximise (3), the banking system follows (5), and the asset and goods markets clear every period. Clearly, a steady state with stable prices requires that the nominal interest rate in (4) equal $R = \beta^{-1}$, the natural rate. For simplicity, we assume that the banking system lends and borrows at this rate also outside the steady state.[19]

Asset market equilibrium. All firms have identical technologies and face the same prices; hence all choose h_{t-1}^d given in (2), which therefore represents aggregate asset demand. Demand has this form every period from 0 onward. Assets are in fixed supply H and do not depreciate. Hence market clearing requires

$$h_t^d = (f')^{-1}\left(\left[Rq_t - q_{t+1}\right]/p_{t+1}\right) = H.$$

Inverting this expression allows to relate the user cost of holding assets to the future price level,

$$\left(Rq_t - q_{t+1}\right) H = \alpha p_{t+1} y, \tag{6}$$

where $y \equiv f(H)$ is aggregate output, and $\alpha \equiv f'(H)\frac{H}{y}$ is output elasticity.[20] In equilibrium, firms spend α of expected sales revenue on the user cost of holding assets, and pay out the remainder as profits,

$$\Pi_t = p_t c_t^f = (1-\alpha)\, p_t y. \tag{7}$$

make loans freely available to qualified borrowers (e.g. Goodhart 2003, p. 88). Elastic credit is a common theme in Banking School (19th century), central banking and credit cycles (Thornton 1802, Bagehot 1873, Hawtrey 1919), pure credit economy (Wicksell 1907), inside money (Gurley and Shaw 1960, chapter 7), free banking (Selgin 1988), 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 Roberts 1999), on private bank note issue (Champ et al. 1996), and on payment systems (McAndrews and Roberts 1995, Freeman 1996 and Green 1997).

[18] This correspondence is natural in an economy whose asset market relies on bank credit. It is foreseeable that any constraint on the size of the bank balance sheet, such as low bank capital, will reduce credit availability and thereby depress asset prices.

[19] Woodford (2003) discusses other ways of dividing the real rate into R_t and p_t/p_{t+1}. As interest rate rules are not the subject of this paper, we assume a fixed rate and dispense with nominal price level indeterminacy by imposing $p_0 = 1$. (Doing so is no more arbitrary than the common assumption of a fixed quantity of unbacked fiat money in other models, see footnote 22). The assumption is weakened in section 3.

[20] As H is constant, so is α. Clearly $\alpha \in [0, 1]$; we impose the weak condition $\alpha > (R-1)$ as a lower bound on the marginal productivity of assets.

We can develop (6) into an asset pricing equation,

$$q_t = \frac{\alpha p_{t+1} y}{RH} + \frac{q_{t+1}}{R} \quad \Rightarrow \quad q_t = \frac{\alpha y}{H} \sum_{i=1}^{\infty} \frac{p_{t+i}}{R^i}. \tag{8}$$

The value of assets is the present value of marginal revenue products associated with their use.

Goods market equilibrium. The goods market clears when aggregate supply equals aggregate demand, the sum of spending by households, firms' profits and bank dividends, $p_t y = s_t + \Pi_t + Div_t$. After using (5) and (7),

$$\begin{aligned} s_t &= \alpha p_t y - (R-1) K \qquad \forall t \geq 1 \\ s_0 &= \alpha \beta y \quad (p_0 = 1). \end{aligned} \tag{9}$$

Successive goods market clearing conditions are connected by the Euler equations (4), which simplify to

$$s_t = \left(\frac{p_{t+1}}{p_t} \right)^{\frac{1-\gamma}{\gamma}} s_{t+1}. \tag{10}$$

Hence a perfect foresight equilibrium is a sequence of endogenous prices that satisfy (6), (9), and (10), for all $t \geq 0$, given H, $K = s_0$, $R = \beta^{-1}$, and $p_0 = 1$.

Proposition 1 Basic Economy
(a) The perfect foresight equilibrium is unique and stationary.
(b) Firms and the banking system are leveraged.

Proof: Substituting s_t and s_{t+1} into (10) yields an expression of the form $g(p_t) = g(p_{t+1})$, which implies $p_{t+1} = p_t = p$, $\forall t \geq 0$.[21] Going backward, the price level remains constant at $p_0 = 1$. So does the asset price, since (8) becomes

$$qH = \frac{\alpha}{R-1} py. \tag{11}$$

Hence $\{h_t, s_t, \Pi_{t+1}, Div_{t+1}\}_{t=0}^{\infty}$ also remain constant.[22] Regarding part (b), we express leverage as debt over net worth. For firms, this is RqH over profits $(1-\alpha) py$. For the banking system, it is deposits $D = qH/R$ over capital $K = s = (R-1) D$. Hence,

$$\text{Firm Leverage} = \frac{\alpha}{1-\alpha} \frac{R}{R-1} > 1 \tag{12}$$

$$\text{Bank Leverage} = \frac{1}{R-1} > 1. \tag{13}$$

Both firms and the banking system are leveraged. ■

[21] The function g is increasing, for $g'(p_t)$ has the sign of $(s_t + \gamma(R-1)K)/p_t > 0$, since $s_t \geq 0$.

[22] The normalisation $p_0 = 1$ can then be justified by a reserve requirement: a central bank can create and lend non-circulating reserves to the banking system, to be held on deposit with the central bank. An exogenously supplied quantity of reserves then limits deposits, hence bank assets. Since qH and p are related by (11), the reserve requirement can be chosen to imply $p = 1$. Skeie (2004) instead determines $p = 1$ by means of a central bank exchanging goods. Alternatively, the fiscal theory of the price level could be invoked to pin down p_0, see Woodford (1995).

The economy remains in steady state because the world looks identical looking forward from any t. Firms are leveraged because they purchase and resell durable assets whose value exceeds output. While this is similar to Kiyotaki and Moore (1997), the present model also contains a banking system. Characteristically, the banking system is highly leveraged as it intermediates a large value of credit and payments.

2 Effect on the Banking System

Along a perfect foresight equilibrium there can be no financial distress. We now drop the perfect foresight assumption to study the consequences of a shock relative to this benchmark. Suppose an unexpected productivity shock permanently reduces total factor productivity from t onward by $\tau \in [0,1]$.[23] The production technology becomes $y_{+1} = (1-\tau)\, f(h)$. This experiment allows us to study the effect of falling asset prices on the banking system. In contrast to the fundamental equilibrium considered here, the multiple equilibria of the next section, where $\{p_{t+i}, q_{t+i}\}_{i=0}^{\infty}$ take values independent of τ, are entirely due to the feedback from the banking system to asset prices.

2.1 Reactions to a Shock

(1) New firms (entering in t) pay less for assets, because assets are now less productive. The first-order condition (2) now reads

$$p_{t+1}\,(1-\tau)\, f'(h_t^d) = Rq_t - q_{t+1}. \tag{14}$$

The same condition applies to subsequent generations, with subscripts forwarded accordingly.

(2) Old firms face a situation of debt-deflation.[24] In $t-1$ they had borrowed qH, assuming that in t they would sell goods and assets at continued steady state prices $\{1, q\}$. (Their production y remains unaffected by the shock, because it was carried out during $t-1$.) Their budget constraint (1) ex post becomes

$$\Pi_t + (RqH - \lambda) = p_t y + q_t H. \tag{15}$$

Debt is predetermined, but the ability to repay, on the right, is not. If it falls short of debt, the difference is transferred as a non-performing loan to the banking system,

$$\lambda = \max\{0, RqH - (p_t y + q_t H)\}. \tag{16}$$

This is how limited liability in (1) prevents $\Pi_t = p_t c_t^f$ from turning negative. An equivalent expres-

[23] There are no further shocks after t. Kiyotaki and Moore (1997), and Allen and Gale (2000) also assume zero-probability shocks. Note that the results are not specific to productivity shocks; a redistribution from firms to households, for instance, has similar effects. We assume a zero-probability shock because fully stochastic models make explicit solutions difficult to obtain. Zero-probability shocks are also used in Kiyotaki and Moore (1997), and Allen and Gale (2000) who discuss why a sufficiently small probability of a shock would not change results. Arguably, the history of financial crises is littered with events nobody appears to have expected, see Kindleberger (1996).

[24] See von Peter (2004) for a theory of debt-deflation in the spirit of Fisher (1933) and Minsky (1982).

sion for non-performing loans is $\lambda = \max\{0, \omega - \Pi\}$, which compares firms' ability to withstand unexpected losses, Π, with total losses

$$\omega \equiv \delta q H + (1 - p_t)\, y. \tag{17}$$

Total losses consist of the proportional decline in asset values ($\delta \equiv \frac{q - q_t}{q}$), plus the loss of sales revenue to deflation $(1 - p_t)$.[25]

(3) The banking system must write off non-performing loans if firms default, as soon as losses become certain in t. Entering t, the banking system would normally earn $(R-1)\,K$ on capital. In keeping with the policy of paying out profits, dividend payout is reduced by loan losses. However, we assume that the banking system issues no new equity (no negative dividends).[26] Hence when loan losses are large, dividends become zero and bank capital falls by $\lambda - (R-1)K$.

$K_t =$	$Div_t =$	case
K	$(R-1)K - \lambda$	if $\lambda \leq (R-1)\,K$
$RK - \lambda$	0	if $\lambda \geq (R-1)\,K.$

(18)

Thereafter, the simple dividend policy makes both future dividends and capital remain constant, $Div_{t+i} = (R-1)K_{t+i}$, and $K_{t+i} = K_t$.

2.2 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 following the shock is defined as on page 8.

Asset market equilibrium. Proceeding as before, (14) alters (6) and (7) to reflect that the shock reduces the output of new and future firms,

$$\begin{aligned} (Rq_t - q_{t+1})\, H &= \alpha\,(1-\tau)\, p_{t+1} y, \\ \Pi_{t+1} &= (1-\alpha)\,(1-\tau)\, p_{t+1} y. \end{aligned} \tag{19}$$

Subsequent asset markets are of the same form.

Goods market equilibrium. Clearing again requires that aggregate demand equal supply. The possibility of default makes aggregate spending inherit the case structure from (16) and (18),

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

[26] 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) or van den Heuvel (2002). Models incorporating costs of issuing bank capital include Gorton and Winton (1995), and Bolton and Freixas (2001).

$$p_t y = \begin{cases} s_t + [p_t y + q_t H - RqH + \lambda] + (R-1)K - \lambda & \text{if} \quad \lambda \leq (R-1)K \\ s_t & \text{if} \quad \lambda \geq (R-1)K. \end{cases} \tag{20}$$

The first equation applies when loan losses remain small. One observes a *wealth effect*: the lower p_t and q_t, the lower aggregate spending. Once firms' profits are zero, further losses affect aggregate demand through reduced bank dividends, until they too are zero. Once that happens, the second line applies: only households continue spending.[27]

Goods market clearing in $t+1$ equates the value of (reduced) output with the sum of household spending, new firms' profits (19), and bank dividends,

$$(1-\tau)\, p_{t+1} y = s_{t+1} + (1-\alpha)(1-\tau)\, p_{t+1} y + (R-1)\, K_t. \tag{21}$$

Subsequent goods markets are of the same form, but with $K_{t+i} = K_t$. Combining (20)-(21) with the Euler equations (10) completes goods market equilibrium. With high intertemporal elasticity of substitution ($\gamma < 1$), households spend more when goods are cheap. We focus on this case, for which the model admits a well-defined fixed-price limit as $\gamma \to 0$.[28] We now show that prices fall when fundamentals deteriorate (proposition 2); in the presence of fixed nominal debt this leads to deteriorating balance sheets (proposition 3).

Proposition 2 Falling Prices

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

(b) Relative to steady state, worse fundamentals (a greater shock τ) cause
- *greater asset price decline: $\delta'(\tau) > 0$,*
- *greater deflation: $p_t'(\tau) \leq 0$.*

Proof: Appendix 1 completes the argument that follows. ■

The short-lived dynamics are due to the overlapping-generations structure. Old firms exit, whether or not they default, and persistence is confined to bank capital. Thereafter, agents again correctly anticipate future prices when they incur debt, and the economy reverts to a perfect foresight equilibrium for which a unique steady state was shown to exist.

The asset price falls because the shock reduces the productivity with which assets are used. Solving (19) forward and inserting the new steady state price level $p_{t+1}(\tau)$, one finds

$$q_t = (1-\tau)\,\frac{\alpha y}{H}\sum_{i=1}^{\infty}\frac{p_{t+i}}{R^i} \qquad \Rightarrow \qquad q_t H = (1-\tau)\,\frac{\alpha p_{t+1} y}{R-1}.$$

[27] The case $\lambda > RK$ need not be addressed separately, because losses borne by depositors, $\lambda - RK$, affect aggregate demand through reduced s_{t+i} in the same way as $Div_{t+i} < 0$ would.

[28] The main effect of $\gamma > 1$ would be to reverse the pattern of price level movements, and deepen the asset price decline in proposition 2. See also footnote 37.

Comparing with (11) shows that the fundamental asset price decline equals

$$\delta(\tau) = \tau p_{t+1} + (1 - p_{t+1}) > 0 \qquad \forall\ \tau > 0. \tag{22}$$

This decline produces a wealth effect, because old firms' profits are a component of aggregate demand. The goods market (20) simplifies to

$$s_t = s + \delta(\tau) qH \qquad \Rightarrow \qquad p_t = \left[1 + \tfrac{R}{R-1}\delta\left(\tau\right)\right]^{\frac{\gamma}{\gamma-1}} < 1. \tag{23}$$

Equilibrium requires households' *extra* spending $(s_t - s)$ to offset the wealth effect $\delta(\tau)qH$, and the price level falls to attract such extra spending $(\gamma < 1)$. Since deflation lowers sales revenue and firms' spending in (20), the fall in aggregate demand is consistent with $p_t(\tau) < 1$. Deflation in this model is temporary, however, 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 $p = 1$ (see appendix 1). Since s_t exceeds permanent income s, s_{t+1} must fall below s to ensure that households do not overspend. The price level movements implement this pattern of equilibrium spending. Deflation is also limited because the wealth effect in (20) acts on profits and bank dividends only; it ceases to operate when these are zero. At that point aggregate demand and the price level reach a minimum,

$$\begin{aligned} \overline{p}_t &= (R/\alpha)^{-\gamma} < 1 \\ \overline{s}_t &= \overline{p}_t y = s(R/\alpha)^{1-\gamma}. \end{aligned} \tag{24}$$

Proposition 3 Deteriorating Balance Sheets

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

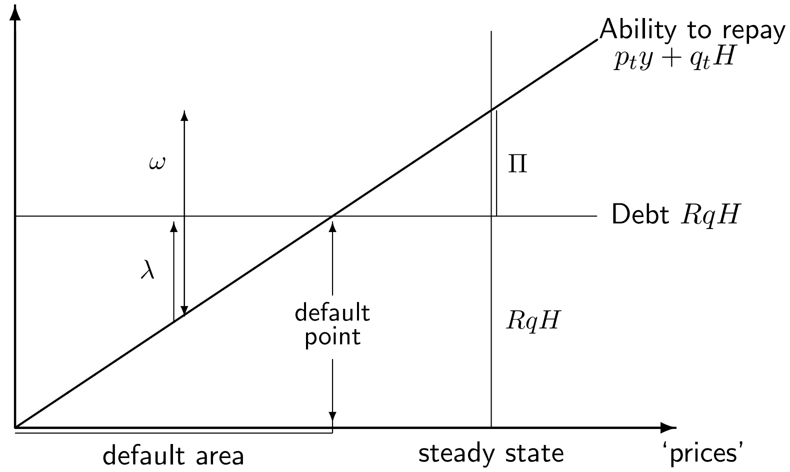
(b) Small losses are borne by firms; larger losses are shared. The space of fundamentals $[0,1]$ splits into four ranges, delimited by thresholds $\{\tau_i, \delta_i, \lambda_i\}$, according to how losses are borne.

(c) On the bank balance sheet, reduced credit is matched by
- *monetary contraction for any $\tau > 0$, and*
- *falling capital for $\tau > \tau_{Div}$ only.*

Proof: That losses are increasing follows directly from proposition 2. The nature of standard debt, and limited ability to absorb losses, together imply that losses are borne hierarchically. Explicit thresholds $\{\tau_i, \delta_i\}$ are derived in appendix 2. ■

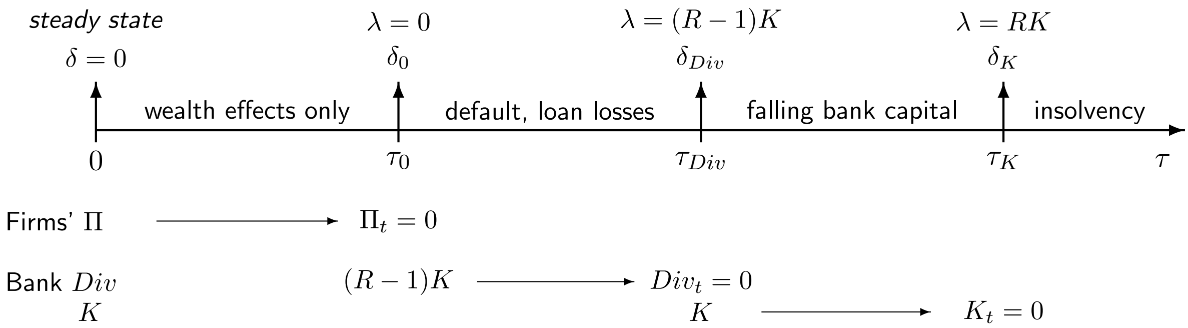
Figure 4 illustrates how falling prices translate into deteriorating balance sheets, as measured by λ and ω. Firms' ability to repay, given in (15), decreases when goods and asset prices fall. In steady state, $py + qH$ covers RqH, leaving Π in profits (the double vertical line). As prices fall, so do profits Π_t. Firms repay in full while they can. When prices fall below the default point, firms default on λ and profits remain at zero.

Figure 4: 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. Losses 'cascade' down the debt structure.[29] Each transition is marked by a threshold i; each threshold can be expressed equivalently as τ_i, δ_i, or λ_i, since the mapping from fundamentals to outcomes is unique.

Figure 5: Deteriorating Balance Sheets



- When $\tau < \tau_0$, the asset price decline is too small to cause default. Losses are borne by firms as profits fall from Π to Π_t. (Most macroeconomic models are only concerned with this range.)
- When $\tau > \tau_0$, firms default and pass on further losses as non-performing loans λ. Over this second range, the banking system absorbs loan losses by reducing its dividend payout.
- When $\tau > \tau_{Div}$, loan losses exceed normal bank profits, $\lambda > (R-1)K$, and the difference is written off bank capital.
- Finally, when $\tau > \tau_K$, loan losses eliminate bank capital, $K_t \leq 0$. The banking system is insolvent, and losses are ultimately borne by depositors.

The effect of falling asset prices on the banking system can now be examined by looking at all components of its balance sheet. Clearly, as fundamentals deteriorate, credit demand falls since

[29] This expression evokes Minsky's work, where debt structure plays a central role. See Minsky (1982b) on debt-deflation, and the essays in Minsky (1982a) on the financial instability hypothesis more generally.

new firms borrow less money for purchasing less-valued assets ($q_tH < qH$). Credit demand is accommodated at R and the size of the banking system endogenously shrinks. But if bank assets contract, so must liabilities. Figure 6 demonstrates the mechanics, given that the banking system intermediates all payments made in this inside money economy.

Figure 6: Balance Sheet Mechanics

t^-			t			t^+	
RqH	RD	$\rightarrow$	$RqH - \lambda$	$RD - s_t$	$\rightarrow$		$RD - s_t$
			q_tH	$q_tH + s_t + Div_t$		q_tH	
	RK			$RK - \lambda - Div_t$			$RK - \lambda - Div_t$

Entering period t, balance sheet t^- reflects loans and deposits with interest due. While markets are open during t, four transactions occur:

(1) new firms borrow q_tH 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 spends Div_t on output. Through (1)-(3), old firms accumulate deposits worth $q_tH + s_t + Div_t$, and

(4) loan losses, if positive, are written off by subtracting λ from both loans and bank capital. The accumulated deposits in (3) repay the performing portion of loans, cancelling $RqH - \lambda$ on both sides of t.[30] This yields balance sheet t^+, which is carried over to period $t + 1$.

Now proposition 2 gives the equilibrium prices at which these transactions occur. Both bank capital and deposits depend on the asset price decline. Hence balance sheet t^+ shows how reduced credit is matched by monetary contraction and falling bank capital.

Monetary contraction. For $\tau < \tau_{Div}$, loan losses are small and bank capital remains constant ($RK - \lambda - Div_t = K$). Hence deposits must fall to match the decline in credit. This is consistent with increased spending by households, $s_t > s$ found in (23),

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

The spending s_t that clears the goods market also reduces deposits in just the right measure. (This link reflects the consistency of market equilibrium with the bank balance sheet.) Since deposits serve as means of payment, a monetary contraction is taking place: the extra spending received by firms is applied toward repaying debt, 'extinguishing' more loans and deposits than was the case in steady state.[31]

30 The equality uses (18) and (20), and holds for any $\lambda \geq 0$.

31 The model is consistent with the 'credit counterparts' determination of the money supply: inside money expands by loan extension, and contracts by loan repayment. This principle informs the analysis of monetary aggregates, especially in the UK. 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).

Falling bank capital. For $\tau > \tau_{Div}$ (hence $\delta > \delta_{Div}$), loan losses exceed bank profits, so any further losses hit bank capital (while $\overline{D}_t = RD - \overline{s}_t$). As 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},

$$K - K_t = \lambda(\tau) - (R-1)K = [\delta(\tau) - \delta_{Div}]\, qH. \tag{25}$$

This one-to-one relation between asset prices and bank capital is remarkable, since the banking system holds no marketable assets – its exposure to asset prices is entirely *indirect*, through its borrowers' default.[32]

Expression (25) also shows that normal profits serve as a buffer: capital falls only to the extent that loan losses exceed normal profits. The banking system turns insolvent ($K_t = 0$) when the asset price falls by δ_K and loan losses reach $\lambda = RK$. Even larger fundamental shocks than τ_K are conceivable, whereupon depositors start taking losses of $\lambda - RK$. At the extreme $\tau \to 1$, assets lose their productive use, their price collapses to zero, so does credit demand, and deposits are engulfed by negative net worth ($\delta(1) = 1$, $q_t H = 0$; $K_t = -\overline{D}_t$). The banking system seizes the assets from defaulting firms, and households repossess H instead of their deposits. The collapse of the banking system destroys the payment mechanism that had enabled firms and households to produce and allocate resources efficiently; the economy degenerates to autarky, where households produce output $g(H) \leq \varepsilon y$.[33]

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 crisis. The effect of falling asset prices on the banking system can be summarised as *indirect and non-linear*. While deposits match the decline in credit, the effect "passes through" the balance sheet; but once the asset price decline exceeds the threshold δ_{Div}, bank capital falls in parallel with asset prices, even though the banking system holds none of the assets.

[32] Put differently, loss-given-default (LGD) depends on the performance of collateral (the asset price). In the presence of uncertainty one could say the banking system is exposed to market risk *via* credit risk.

[33] See page 5. Until the banking system collapses, the real effects in our model are distributional. Output effects would set in earlier if we had incorporated credit-constrained producers, as do Kiyotaki and Moore (1997), or costly state verification, as do Bernanke, Gertler and Gilchrist (1999).

3 Feedback from the Banking System

So far, lending behaviour did not change as bank capital fell: credit demand was always accommodated at R. This meant that asset prices and credit were driving money and bank capital; 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. Yet when bank capital fell one-for-one with credit in (25), the capital-asset ratio fell rapidly as the shock approached τ_K. Banks in reality are not indifferent to their capital-asset ratio, be it for reasons of regulation, market discipline, or risk management. We consider this possibility by introducing a capital constraint. This allows us to address separately how the state of the banking system feeds back onto asset prices.

3.1 Capital-Constrained Equilibrium

Suppose the banking system maintains a minimum capital-asset ratio of $(R-1)/R$, the steady state ratio.[34] This constraint introduces two new considerations. First, credit supply may become capital-constrained: bank credit must not exceed a multiple of capital,

$$q_t H \leq \frac{R}{R-1} K_t = \begin{cases} qH & \text{if} \quad \lambda \leq (R-1)\,K \\ qH - \frac{R}{R-1}\left[\lambda - (R-1)\,K\right] & \text{if} \quad (R-1)\,K \leq \lambda \leq RK \\ 0 & \text{if} \quad \lambda \geq RK. \end{cases} \tag{26}$$

where we have used (25) along with the restriction that bank assets cannot be negative. Second, if credit is capital-constrained, so are asset prices. Hence the asset pricing equation (8) now determines the bank loan rate R_t,

$$q_t H = \frac{\alpha(1-\tau)p_{t+1}y}{R_t} + \frac{q_{t+1}H}{R_t}. \tag{27}$$

We call this *credit-constrained asset pricing*: viewing (27) as an asset pricing equation, the loan rate $R_t > R$ discounts the market's forward-looking asset valuation down to the constrained asset price. Equivalently, viewing (27) as credit demand, the loan rate rises to bring credit demand down to capital-constrained credit supply (26).[35]

A *capital-constrained equilibrium* is a set of endogenous variables $\{p_{t+i}, q_{t+i}, R_{t+i}\}_{i=0}^{\infty}$ that satisfies the capital constraint (26), and the equilibrium conditions of the goods market (20)-(21) and the asset market (27), hence the credit market. The main feature of such an equilibrium is that the asset price q_t (hence δ) is now determined by the capital constraint. This constraint depends on loan losses, which in turn depend on the asset price decline and on structural parameters.

[34] The debt-capital ratio in (13) corresponds to an asset-capital ratio of $R/\left(R-1\right)$.

[35] Firms spend a certain amount on the total cost of borrowing in (19); raising the price of credit effectively reduces the size of the loans they can afford.

3.2 Financial Extremes

We now show how feedback from banking to asset prices may lead to financial instability and multiple equilibria.

Proposition 4 Capital Crunches, Financial Instability, and Banking Crises

(a) *For good fundamentals ($\tau \leq \tau^*$),*
- *the fundamental equilibrium is as before, but*
- *self-fulfilling capital crunches and banking crises are also possible.*

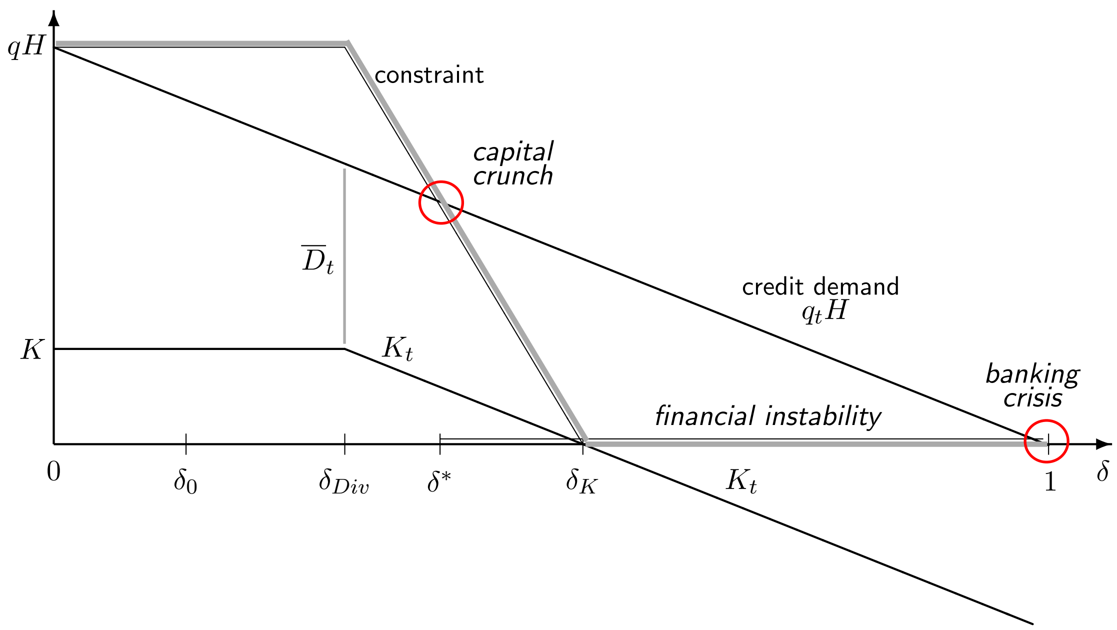
(b) *For poor fundamentals ($\tau > \tau^*$),*
- *the only equilibrium is a systemic banking crisis, and*
- *financial instability drives the system toward systemic banking crisis.*

(c) *Financial instability results from the two-way interaction between banking and asset prices when their decline exceeds a threshold δ^*.*

Proof: Appendix 3. ■

These results are best explained graphically. Figure 7 plots credit demand and bank capital against the asset price decline δ.

Figure 7: Financial Extremes



The thick lines represent the capital constraint (26). It never binds while bank capital remains intact, because credit demand $q_t H$ falls short of admissible lending qH. However, once capital falls, admissible lending declines very steeply: to keep bank leverage constant, each loan loss must be met with a $R/(R-1)$ -fold contraction of credit. Appendix 3 shows that the constraint binds once the asset price decline reaches the threshold

$$\delta^* = R\delta_{Div} = (R-1)\left[(R/\alpha)^{1-\gamma} - 1\right]. \tag{28}$$

At this point a *capital crunch* sets in. The space of fundamentals is now split around the threshold τ^* that makes δ^* a fundamental decline.

Good fundamentals $(\tau \leq \tau^*)$. $(\tau \leq \tau^*)$. The fundamental valuation of assets in (22) would imply that the capital constraint does not bind $(\delta(\tau) < \delta^*)$; hence the fundamental equilibrium of section 2 remains an equilibrium. But credit crunches and banking crises are also possible: the capital constraint binds *whenever* $\delta \geq \delta^*$, whether or not this decline is driven by fundamentals. Figure 7 shows the fixed points of (26) where credit contraction and asset price decline are mutually consistent.[36] The capital crunch $(\delta = \delta^*)$ and the banking crisis $(\delta = 1)$ are the two equilibria where the asset price decline generates exactly the measure of loan losses $\lambda(\delta)$ that forces bank lending to contract by δ percent. This may happen even as $\tau \to 0$, because the system can always jump to a constrained asset price – the mapping from fundamentals to outcomes is no longer unique.

This instance of multiplicity can be thought of in terms of self-fulfilling equilibria. If the market expects that credit is not forthcoming, the asset price falls until loan losses indeed constrain credit supply. Similarly, if loan losses are expected, then the banking system reduces lending, and the resulting asset price decline and defaults cause exactly the anticipated loan losses. Associated with self-fulfilling equilibria is a jump decline in goods and asset prices, and an interest rate spread due to credit-constrained asset pricing (see appendix 3). The stronger fundamentals, the greater the spread required to bring strong credit demand down to constrained credit supply.

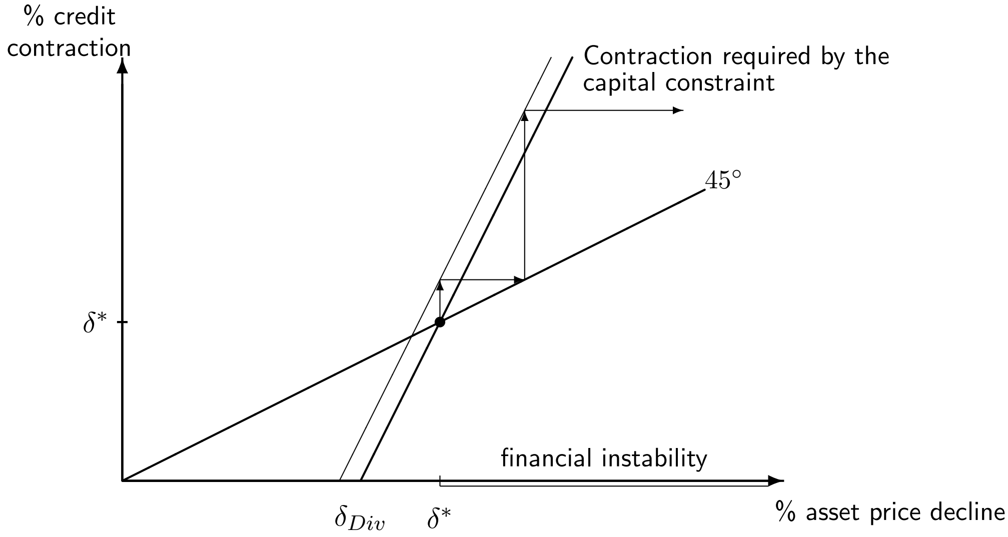
Poor fundamentals $(\tau > \tau^*)$. When the shock is large, $\delta(\tau)$ necessarily exceeds δ^* and the capital constraint binds. Financial instability then propels the system toward a systemic banking crisis as the only possible outcome, as illustrated in figure 8. Consider the point that defines the capital crunch,

$$\delta^* = \frac{R}{(R-1)} \left[\underbrace{\delta^* qH + (1 - \overline{p}_t)\, y - \Pi}_{\lambda(\delta^*)} - (R-1)\, K \right] /(qH). \tag{29}$$

The $45°$-line states that a credit contraction reduces the asset price by the same percentage. But the slope on the right is much steeper in δ, because every loan loss must be met by a multiple contraction of credit. The capital crunch equilibrium is unstable: given δ^*, a slight deterioration of loan losses requires a credit contraction to comply with the capital constraint (arrow up); reduced credit deepens 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 with further contractionary effects. Loan losses accrue at a faster rate than the capital-compliant contraction of bank credit can keep up with.

[36] In a multi-bank extension, this corresponds to multiple symmetric Nash-equilibria in an interest-setting game, where 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 consider bank reserves in the clearing and settlement of interbank balances.

Figure 8: Financial Instability



This interaction between asset prices and banking distress yields a natural characterisation of financial instability as an unstable credit contraction, accompanied by falling asset prices and mounting loan losses. Financial instability occurs in the space between the unstable capital crunch and the stable banking crisis equilibria. It materialises whenever $\delta(\tau) > \delta^*$, which is unavoidable if fundamentals are sufficiently poor ($\tau > \tau^*$). It comes to a halt only when credit and asset prices have collapsed in a systemic banking crisis. Although we have encountered this outcome before (page 16), it now occurs for a whole range of shocks $(\tau^*, 1]$. But the real effects are as severe, as the credit and payment mechanism ceases to function. This outcome of financial instability is consistent with the definition provided on page 1.

3.3 Vulnerability

We define vulnerability as the sensitivity of the banking system to falling asset prices. The smaller the thresholds $\{\tau_i, \delta_i\}$, the more vulnerable the banking system to any given decline δ. We now relate vulnerability to the structural parameters of the economy, $\{\alpha, \beta, \gamma\}$. The model is well-suited to explore these comparative statics, as $\{\alpha, \beta, \gamma\}$ can be varied independently of $\{\tau, \delta\}$.

Regarding the structural parameters, recall from (12) that firm leverage is measured by α, because higher productivity encourages firms to purchase more assets and incur more debt qH. The interest rate equals $R = \beta^{-1}$, the inverse rate of time preference of households. 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, which attenuates deflation in (23)-(24).[37]

[37] At the limit $\gamma \to 0$, spending is so responsive that the price level remains fixed, $p_t(\tau) = 1$. Any deviation would evoke infinite (or zero) spending by households, which conflicts with market clearing. Hence $\gamma \to 0$ implies fixed goods prices.

Proposition 5 Balance Sheet Vulnerability

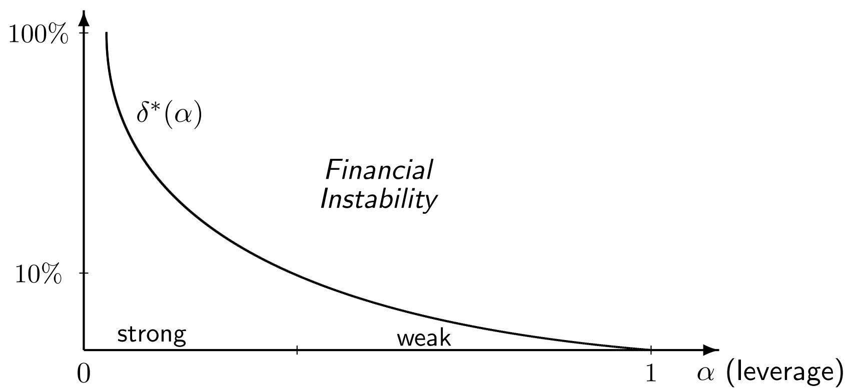
The banking system is more vulnerable to asset price declines in the presence of
- *greater leverage (α),*
- *higher rate of time preference (β),*
- *greater deflationary tendency (γ).*

Proof: Appendix 2 shows that greater values of $\{\alpha, \beta, \gamma\}$ lead to smaller thresholds $\{\tau_i, \delta_i\}$. ■

The result is intuitive. It is the size of loan losses that determines whether a capital crunch, financial instability, or a banking crisis occurs (proposition 4). Greater values of $\{\alpha, \beta, \gamma\}$ translate any given asset price decline into greater loan losses, the size of which determines the outcome. Higher leverage (α) and a cheaper financing (higher β) both increase asset valuation qH in (11) on which the decline δ acts. Similarly, higher γ leads to greater deflation, given the size of the wealth effect δqH in (23) and (24). (Meanwhile, the ability to withstand losses, Π and K, falls as we raise α or β.) Hence, $\lambda(\delta)$ shifts up and precipitates more adverse outcomes; that is, the same outcomes occur at smaller $\{\tau_i, \delta_i\}$.

One interpretation of this result is that highly developed financial systems, and low-interest rate regimes, may be particularly prone to financial instability: both factors encourage greater leverage.[38] These are among the factors Borio and Lowe (2002) identified as conducive to financial imbalances. To illustrate the importance of leverage, figure 9 plots $\delta^*(\alpha)$ as derived in (28). In view of proposition 4, this curve is called the *financial stability frontier*.

Figure 9: The Financial Stability Frontier



The greater leverage, the smaller the asset price decline that causes financial instability. Firm leverage is essential for financial instability as it constitutes exposure to asset prices.[39] By contrast, deflationary tendency is not essential in our context. It exacerbates vulnerability ($\gamma \to 1 \Rightarrow \delta^* \to 0$), but its absence does not guarantee financial stability.

[38] Indicative of this possibility is the frequency of financial instability in the aftermath of liberalisations (Kaminsky and Reinhart 1999).

[39] Default is impossible with no leverage. With unit leverage, $\alpha = (R-1)/R$ in (12), firms' expected profits match their debt ($RqH = \Pi$); absent deflation, not even $\delta = 1$ causes default.

4 Policy Implications

We conclude the paper with applications to illustrate possible uses of the model. The model provides a fresh perspective on central banking policy debates in the areas of monetary and regulatory policy. The three case studies we include, Japan's Lost Decade, the Nordic Banking Crises and the US Great Depression, suggest that the variables we have modelled are relevant in reality.

4.1 Macroeconomic versus Financial Stability

The model distinguishes between macroeconomic and financial stability. Macroeconomic stability depends on the parameters governing deflation and output (γ and τ). Financial stability, by contrast, depends on asset prices and loan losses (δ and λ). Macroeconomic and financial instability (MiS and FiS) are distinct concepts. Either one may cause the other, and while they tend to occur together, they need not. This can be illustrated by arranging previous results in four cases.

- **MiS⇒FiS.** In a fundamental equilibrium, causation runs from the economy to the banking system.[40] Only a sufficiently large macroeconomic shock brings about financial instability.
- **FiS⇒MiS.** In a self-fulfilling equilibrium, the causation is reversed: deflation (and output collapse) can occur as a by-product of a self-fulfilling capital crunch (and banking crisis).
- **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 output gap, if $\gamma \to 0$ and $\tau \to 0$ respectively.

One is led to the conclusion that a policy preventing deflation would not necessarily deliver financial stability. Such a policy may be conducive to financial stability, as claimed by Schwartz (1995) or Bordo and Wheelock (1998), but it is not sufficient to guarantee it. This may help explain why central banks treat macroeconomic and financial stability as distinct, albeit related, concerns.

Our approach suggests that financial stability matters in a way that is not fully captured by macroeconomic stability. The model features two instances where financial instability reduces representative agent welfare. First, the distributional effects diminish welfare, for instance when defaulting entrepreneurs consume nothing. Second, financial instability leads to autarky with minimal output and consumption. This stylised output response reflects a dysfunctional credit and payment mechanism, rather than the regular macroeconomic channels associated with macroeconomic stabilisation. In both instances a traditional loss function would reflect financial instability. Beyond these conventional metrics, however, policy makers may view the smooth functioning of the credit and payment mechanism as a goal in itself.

[40] The *unconstrained* asset price falls only if future output or price levels do, as in (8). The asset price is affected independently by bank credit only in a constrained equilibrium, as in (26).

4.2 Monetary Policy and Asset Prices

A widely held view maintains that interest rates should not react to asset prices beyond their predictive content for future inflation (Bernanke and Gertler 1999). A large and abrupt asset price decline is the main exception considered in policy discussions. But the literature provides little guidance on how to identify such an exception. Mishkin and White (2003) clarify the debate, proposing financial stability as the decision 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."
>
> Frederic Mishkin and Eugene White (2003) p. 73-74

We have not modelled monetary policy, but the situation to which monetary policy may have to react. In doing so, the model helps understand their argument, since it explicitly solves for the asset price decline beyond which financial instability sets in. The critical threshold δ^* was shown to depend on leverage (figure 9). Consider two economies that differ only in this measure of balance sheet strength. In the economy with weak balance sheets ($\alpha > 1/2$), an asset price decline above 5.5% triggers financial instability. In the economy with strong balance sheets ($\alpha < 1/4$), it takes a decline of 16% to do so. The critical asset price decline is a different number in different economies, depending on the state of balance sheets.[41]

Conversely, a sudden asset price decline of 10% causes financial instability and a banking crisis in the former case, yet hardly affects the banking system in the latter. Given these diverging outcomes, it is plausible that monetary policy should react only in the former case. This example illustrates Mishkin and White's general point that monetary policy should react to the threat of financial instability, not to the level of asset prices per se. When the argument is cast in the form of interest rate rules, this policy would be captured by a flexible threshold term, not by the systematic reaction to asset prices examined by Bernanke and Gertler (1999) and Cecchetti et al (2000).

Can monetary policy avert financial instability? The answer requires extensions best left to future research, but the model admits some conjectures.[42] First, a successful policy must be timely, carried out in t. Once losses have materialised, the damage cannot be undone by subsequent monetary easing. Second, an interest rate cut ($R_t < R$) supports asset prices only if banks remain unconstrained. This policy works in the presence of multiple equilibria if it coordinates the banking system on the better,

[41] Our example uses $R = 1.05$ and $\gamma = 0$ in (28). Neither deflation nor recession is necessary for the argument. (A positive deflationary tendency ($\gamma > 0$) would shift down the locus in figure 9.) 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).

[42] Note that we focus on interest rate policy, as there is no role for liquidity injections in our context. The model by construction rules out illiquidity, since money and credit are perfectly elastic, and there is neither internal nor external drain: agents do not withdraw money; and treating the banking system as a whole obviates the need to introduce reserves for interbank clearing and settlement.

fundamental equilibrium (proposition 4). Therefore, a timely interest rate cut might avert financial instability provided fundamentals remain reasonably strong ($\tau < \tau^*$). A related policy question concerns the case for preemptive tightening (Borio and Lowe 2002). While the model does not incorporate booms and financial imbalances, what matters is the asset price decline relative to the existing debt structure, regardless of whether the economy is in steady state or at a cyclical peak. We note that an increase in R, if phased in carefully, would reduce leverage and vulnerability, shifting up the financial stability frontier $\delta^*(\alpha)$.

The view that there may be a case for monetary policy runs counter to the traditional notion that financial stability pertains only to the domain of prudential regulation.

4.3 Regulatory Implications

The model touches on several regulatory issues. First, asset prices were shown to affect the banking system through borrower default. Hence restrictions on direct asset holding might mitigate, but cannot eliminate, banks' effective exposure to asset prices. This is particularly relevant for real estate, the asset modelled in this paper, for its wide-spread use as collateral. Real estate developments indeed play an increasing role in financial stability assessments.[43] Second, normal profits buffer the impact of loan losses on bank capital; greater profits are conducive to financial stability (they move up δ_{Div}, hence also $\delta^* = R\delta_{Div}$). The argument that greater profitability reduces the incidence of bank failure is also familiar from the literature on charter value and risk taking (Keeley 1990).

Third, the model produces financial instability as an extreme form of procyclicality.[44] Evidence suggests that the procyclicality of the financial system may cause financial instability (Borio et al 2001). 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 in credit and asset prices. In the context of the late 1980s and early 1990s, Goodhart (1995) singles out the role of capital adequacy,

> "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 Basel capital adequacy ratios, bit more tightly, and will, to some largely unquantifiable extent, have aggravated the constriction of bank credit."
>
> Charles Goodhart (1995) p. 293

This quote essentially restates the mechanism we have modelled (figure 1). The effect of the capital constraint is to interact asset prices and banking distress, which in this model produces a form of procyclicality once the feedback drives financial instability (figure 8). The capital constraint in our model resembles a simple form of capital adequacy requirement also considered in other models.[45]

[43] See International Monetary Fund and World Bank (2003), Basel Committee on Banking Supervision (2004), and various central banks' Financial Stability Reviews.

[44] 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.

[45] Blum and Hellwig (1995) provide a macroeconomic model to show that a binding capital requirement increases

Yet financial instability cannot be attributed to capital regulation even within the confines of our model, for several reasons. First, weaker capital regulation would not change the results: with lower capital requirements, the contraction would set in earlier and with greater force.[46] At the same time our approach disregards the benefits of capital adequacy regulation, since we have abstracted from issues of risk and incentives (Rochet 1992 provides a model). Moreover, similar results would obtain if banks observed a capital ratio for reasons other than regulation – indeed, it is plausible that regulation merely raises the capital ratio that banks would otherwise adopt.[47]

More generally, bank capital is not indispensable to the mechanism we proposed. The essential link goes from losses to credit contraction, whether or not this link involves bank capital (see figure 1). That said, the results need not be confined to banks – mortgage companies, mutual funds, even individual investors might similarly reduce credit in response to losses.[48]

5 Case Studies

5.1 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.[49] Models ignoring asset prices and non-performing loans cannot reasonably explain this experience. The mechanism we have modelled (figure 1) captures several aspects of this episode. First, the **decline in asset prices** has been spectacular (large δ): stocks lost almost 70% since their peak in 1989, residential property lost 30%, and commercial property lost some 60% between 1992 and 2002 (see figure 10). The urban commercial land price index of 6 large cities declined even by 85% (Ueda 2003, p. 3).

> "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."
>
> Kazuo Ueda (2003) p. 4

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the sensitivity of output and the price level to aggregate demand disturbances. Their model is static and excludes asset prices and financial instability. Estrella (2004) develops a dynamic model of procyclicality.

[46] A binding capital constraint can be destabilizing whenever the coefficient in (29) exceeds one. This is necessarily the case for deposit banking. In terms of stability, a smaller capital ratio chosen by banks is worse than a higher ratio chosen by the regulator.

[47] Other reasons for capital constraints include monitoring incentives (Holmström and Tirole 1997, Chen 2001), market discipline (Calomiris and Wilson 1998), or buffer against failure (Gorton and Winton 1995, 2000, Diamond and Rajan 2000, Bolt and Tieman 2004). 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 the system was nationalised. Indeed, capital ratios used to be much higher: the century-long decline in bank capital ratios is documented in Berger et al (1995), figure 1.

[48] For instance, Shleifer and Vishny (1997) propose a model of performance-based arbitrage which, inter alia, implies that investment reacts to previous losses more than one-for-one.

[49] See Cargill et al (1997), Hoshi and Kashyap (1999), and Koo (2003).

The sharp decline in asset prices caused a large measure of **loan losses** to Japanese banks (large λ). Figure 10 plots asset prices against the number of bankruptcies and realised loan losses. The substantial and persistent decline in asset prices coincides with a rise in bankruptcies and loan losses.[50]

[See Figure 10: Japan]

The often cited 'non-performing loans problem' almost completely characterises 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, Inaba et al 2003). Loan losses exceeded operating profits every year since 1994.[51] In the model this corresponds to $\lambda > (R-1)K$, where proposition 4 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.[52]

The non-performing loan problem induced a **capital crunch**. The liquidation of Jusen companies during early 1996 had already caused losses to the founder institutions (mostly large banks); the phasing in of prompt corrective action accelerated write-offs, and focused supervisory attention on capital ratios.[53] Since 1990, issuing new equity had been virtually impossible: given low profitability and limited access to capital markets, private 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.[54]

As falling asset prices impair the balance sheets of *both* firms and banks, the question arises whether the decline in private lending was driven by low demand for loans, as in the financial accelerator, or by constrained supply, as in this model. Both channels have played a role. Koo (2003) emphasised the fall in demand by firms attempting to repair their balance sheets, and coined the term "balance sheet recession" to describe the macroeconomic consequence. The firm-level panel evidence of Inaba et al (2003) indeed reveals a significant negative effect of the debt-asset ratio on firm investment. But also the capital ratio of firms' main banks was shown to be significant, especially to non-bond issuing firms. The evidence of a capital crunch is further strengthened by bank-level evidence showing that both bank capitalisation and firms' debt-asset ratio "have made large negative contributions to bank lending" (p. 9). The clearest evidence of a capital crunch points to the large private banks during

[50] To visualise the percentage decline, the series are expressed relative to their peaks between 1985-92. Loan losses are "total losses on disposal of non-performing loans" (FSA), a figure smaller than estimates of non-performing loans. The bankruptcies in the 1990s, although fewer than their 1984 peak, involved far greater liabilities. Bankruptcy data were kindly provided by Teikoku Databank America, Inc.

[51] 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).

[52] 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).

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

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

fiscal year 1997 (Woo 1999, Watanabe 2002).[55] 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 4). If fundamentals are weak ($\tau \to \tau^*$), so is credit demand, and the **spread** is predicted to be small (see page 41). Hoggarth and Thomas (1999) note that spreads indeed remained small. Our model then appears to imply that Japan's banking distress is 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 – it would take a permanent fall in productivity of about 70% in (22) to produce the observed asset price decline, deflation having remained moderate. That would imply such a severe recession as to contradict the actual output realisation. The productivity explanation appears implausible unless the bubble of the late 1980s was predicated on a vast overestimation of future productivity.

The model also predicts that a capital crunch is an **unstable equilibrium**. Anecdotal evidence indeed suggests that the Japanese financial system witnessed signs of instability precisely at the time of the capital crunch in late 1997. 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 but was contained by the Bank of Japan's intervention (p. 9).

In sum, the banking system did not collapse, but private banks suffered a short-lived capital crunch due to loan losses following substantial asset price declines. This pattern resembles figure 1 and the results of our model. It is then not surprising that expansionary policy has long failed to support asset prices and stimulate the economy, as the expansion was effectively constrained by the state of the banking system.

5.2 The Nordic Banking Crises

The Nordic Banking Crises (1988-1993) suffered by Finland, Norway, and Sweden followed a similar pattern. Rather than recount each episode, this brief review highlights the common pattern.[56] Systematic deregulation during the 1980s fuelled a **credit boom**. The rapid increase in bank lending was initially treated by regulators as a natural adjustment to a new regime (Berg 1998 p. 197).[57] The concurrent rise in asset prices was almost exactly reversed in the subsequent **asset price decline**.

> "Prices of residential and commercial real estate had increased as a result of the growth in bank lending, and vice versa [...] Real estate prices fell dramatically from their peak levels and trapped

[55] 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.

[56] Denmark's banking problems were of a similar nature, but less severe. The section draws on Vihriälä (1997) for Finland; Bäckström (1997) and Englund (1999) for Sweden; Gerdrup (2003) and Moe et al (2004) for Norway. The countries are analyzed jointly in Berg (1998), Drees and Pazarbaşioğlu (1998), Pesola (2001), and Hansen (2003). The data sources are Bank of Finland, Norges Bank and Statistics Norway; Sveriges Riksbank and Statistics Sweden.

[57] Drees and Pazarbaşioğlu (1998) catalogued the deregulation measures. They included the abolition of ceilings on deposit or lending rates, foreign-denominated borrowing, and reserve requirements or placement ratios.

many borrowers in positions where their loans were substantially higher than the market value of their collateral. When this coincided with higher real rates of interest and economic recession, increased loan losses to banks were an obvious consequence." p. 201

"Within a few years after loan growth had peaked, banks began to see heavy losses. Industry-wide loss provisions amounted to around 3% of total banking assets in 1991 in Norway, in 1992 in Finland, and in 1993-94 in Sweden. This should be compared to levels of equity capital that averaged only about 6% of total assets in these three countries."

Sigbjørn Berg (1998) p. 200

[See Figure 10: Finland, Norway, Sweden]

The timing of first banking problems reflected country-specific factors.[58] But falling prices across all asset classes led to wide-spread and correlated default. Figure 10 shows that the number of bankruptcies during 1990-95 was 3-4 times greater than a decade earlier. **Loan losses**, as a consequence, soared to unprecedented levels.

	Finland	Norway	Sweden
Equity Price (% decline)	67	48	40
Residential Real Estate (% decline)	40	27	21
Commercial Real Estate (% decline)	49	43	71
Loan losses in peak year (% of GDP)	4.4	2.8	3.8
Non-performing loans (% of GDP)	9	9	11
Cumulative bank credit contraction (%)	35.5	4.9	26.4

Sources: BIS asset price data; Sandal (2004) p. 84.[59]

Some 60-80% of loan losses in the three countries can be attributed to firms; default rates were particularly high in the **real estate** sector.[60] The Finnish savings banks, with a traditional concentration in real estate, had expanded faster than commercial banks during the boom and, as the downturn hit the real estate sector, they faced greater losses and contracted credit more than commercial banks (Vihriälä 1997 p. 40, 59, 90). The role of real estate was also apparent in Sweden; although real estate amounted to only 15% of lending, it accounted for 40-50% of loan losses (Englund 1999 p. 90). The Swedish banking crisis was compounded by the sharp rise in interest rates in defence of the krona's ERM parity (yet the twin crisis could not be averted).[61]

[58] For instance, Norway suffered from the sharp decline in oil prices (1986), Sweden from the tightening of monetary policy (1990-92), and Finland from the collapse of the Soviet Union (early 1990s).

[59] The asset price declines are calculated from peak to trough. The credit contraction refers to 1991-95 (Finland), 1990-91 (Norway), and 1990-95 (Sweden).

[60] See Drees and Pazarbaşioğlu 1998, table 11.

[61] About 40% of bank borrowing was from abroad. Once the twin crisis occurred, the krona's devaluation added to banks' losses (Englund 1999). Although banks' direct foreign-exchange exposure was balanced, that of their borrowers was not. This again reflects *indirect* exposure as examined in the model; it also suggests that the exchange rate plays a role similar to other asset prices – both devaluation and asset price decline compromise the ability to repay fixed nominal debt.

> "Looking back, one can see that in the course of the crisis the seven largest banks, with 90% of the market, all suffered heavy losses. In these years their aggregate loan losses amounted to the equivalent of 12% of Sweden's annual GDP. The stock of non-performing loans was much larger than the banking sector's total equity capital, and five of the seven largest banks were obliged to obtain capital contributions form either the state or their owners. It was truly a matter of a systemic crisis."
> "Rescuing the banking sector was necessary to avoid a collapse of the real economy. [...] The direct outlays in connection with the capital injection into the banking system added up to just over 4% of GDP."
>
> Urban Bäckström (1997) p. 133-35

Finland and Norway also had to **recapitalise** their banking systems. Vihriälä (1997) reports that bad assets of Finnish deposit banks amounted to 8% of total assets in 1990-95, clearly exceeding capital; he argues that "with losses of this magnitude most if not all banks would have failed without massive government intervention [of 10% of annual GDP]" (p. 39). The Norwegian banking system also continued operating with substantial capital injections (Sandal 2004).

The capital injections arguably had a stabilizing effect (Berg 1998). In terms of our stylised model, recall that loan losses beyond a threshold produce financial instability, propelling the system toward a banking crisis with zero credit and autarky (proposition 4). The Nordic banks did not react in this stylised fashion, even though the losses to the system as a whole may well have exceeded this threshold. There were nonetheless signs of a **capital crunch** in two of the three countries. In Sweden, where credit contracted by more than 20%, the lending spread rose to 5% and loan-to-value ratios fell from 90% to 60%, far below the pre-boom level of 75% (Englund 1999 p. 85, 91, 95). In Finland, the depletion of bank capital and the concurrent tightening of capital regulation also suggest a capital crunch in 1991-92; regressions found especially the link from non-performing loans to reduced lending to be strong (Vihriälä 1997 p. 55, 161).[62]

Econometric studies also reveal patterns consistent with the mechanism proposed in our model. Pesola (2001) found that most of the variation in the number of bankruptcies and loan losses in the Nordic countries can be explained by the interaction between financial fragility (debt/GDP) and adverse 'surprises'. Of the latter, increases in the bank loan rate, and the difference between forecast and realised output were both significant regressors. (The inclusion of asset price changes would likely have further improved the fit.) In a related study of the Nordic crises, Hansen (2003) showed that bankruptcies were less related to the business cycle than to the 'financial cycle'. Bank credit and house prices were found to Granger-cause bankruptcies (see figure 10). In particular, the joint departure of credit and house prices from their (co-integrating) long-run relation helped predict bankruptcies. This suggests that financial imbalances, in the sense of Borio and Lowe (2002), were an important feature of the Nordic banking crises.

These results are consistent with the **distinction** the model draws between macroeconomic and financial instability (section 4.1). For instance, Bäckström (1997) and Gerdrup (2003) observed

[62] Recall the discussion on page 25. Vihriälä (1997) finds in his regressions that the aggregate relation between bank capital and lending is weaker than that between loan losses and lending. The reason is that stronger banks sometimes expanded lending in a gamble for resurrection, whereas undercapitalised banks were forced to contract (p. 157-61).

that the 1990s saw more banking distress, yet less macroeconomic instability, than the 1920s and 1930s.[63] They attribute this difference to the greater effect of leverage and asset prices during the 1990s, although crisis management and monetary policy also have improved. Proposition 5 makes clear why one should expect this distinction to hinge on financial fragility, or balance sheet vulnerability.

Overall, the Japanese and Nordic banking crises were driven by the deterioration of bank *assets* – no bank runs on any significant scale took place. Our model therefore provides a better description than do microeconomic bank run models. The latter were designed with the Great Depression in mind, the episode that may well present the toughest test of the relevance of our model.

5.3 The US Great Depression

The US Great Depression (1929-1933) witnessed the collapse of the financial system and a depression unprecedented in scale. The episode exposes an important omission of the model, namely bank runs. Nonetheless, in providing a coherent story of default and banking distress, the model helps understand bank runs as a symptom, rather than the cause, of the deterioration of macroeconomic conditions.

The famous stock market crash of 1929 initiated a prolonged **decline of prices**. The stock market (Dow Jones Index) fell by 24% on October 28-29, 1929, and continued its decline until early 1933, closing more than 80% below its 1929 peak. Real estate prices may have declined by about 50%.[64] Also 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 reached a cumulative 27% (consumer prices), or 38% (wholesale prices).[65] The deflationary tendency was much more pronounced than during Japan's Lost Decade, where cumulative deflation reached merely 3% (Ueda 2003).

The consequences to the banking system of the collapse in prices had already been noted with alarm by Keynes (1931). Falling prices produced debt-deflation (Fisher 1933) where borrowers, attempting to reduce their indebtedness by distress selling assets, contributed to the contraction of money and credit producing further deflation. Bernanke (1983) emphasised the generalised nature of the **debt crisis**, and argued that it impaired the channels of credit intermediation. His evidence reflects high rates of default in all sectors.[66] Default on this scale produced significant **loan losses**. In line with λ of our model, the best available measure of loan losses is 'liabilities of failed businesses'.[67]

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[63] In the 1920s, Swedish GDP fell by 18%, and deflation reached 30%; in 1990s GDP fell by 6% with no deflation. Yet banking distress was more severe in the 1990s (Bäckström 1997 p. 137). In Norway, although the 1920s saw both macroeconomic and financial instability, the banking distress of the early 1930s appears small compared to the macroeconomic decline of 8% in 1931 alone (Gerdrup 2003 p. 30).

[64] Among the few consistent series are the urban Chicago real estate and land prices of Hoyt (1933).

[65] These measures cover 1929-1933 peak to trough, using the CPI and WPI of the Bureau of Labor Statistics. The agricultural price index also declined throughout this period (Calomiris and Mason 2003, figure 1), suggesting a continuation of the 1920s banking distress in the agricultural regions.

[66] The ratio of debt service to national income went from 9% (1929) to almost 20% (1932-33). Survey evidence 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 (Bernanke 1983 p. 260-61).

[67] We were unable to obtain consistent non-performing loans data. Some quantitative indication is given by the Report of the Comptroller of the Currency, p. 71. It reports a four-fold increase, from 1929 to 1932, in "losses charged

Bernanke (1983) finds a "powerful negative effect" of this indicator on the growth of bank loans and industrial production (p. 270).[68] Calomiris and Mason (2003) confirm its significance in their disaggregated study of bank failures. This evidence is consistent with high rates of default leading up to the bank runs.

The evidence on credit rationing and the rising cost of credit intermediation is consistent with either weak credit demand or constrained supply.[69] The contraction of credit can be characterised as a **capital crunch**,

> "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."
>
> Charles Calomiris and Berry Wilson (1998) p. 1-2

This response resembles that predicted by our model. However, the economy failed to maintain the unstable capital crunch equilibrium. Bank runs tipped the balance toward **financial instability**, ending in the collapse of the banking system in March 1933. The unstable credit contraction, accompanied by falling asset prices and mounting loan losses, resembles the notion of financial instability illustrated in figure 8.

Bank runs are nonetheless an important channel that our model omits. The traditional view considers them depositor panics (Friedman and Schwartz 1963). In modelling banking distress without bank runs, we depart from the existing theory building on Diamond and Dybvig (1983). Our focus on banks' asset-side helps explain what *triggered* the runs: we view them as a symptom, rather than the cause, of the ongoing deterioration of balance sheets. Even Friedman and Schwartz (1963) acknowledged the "drastically weakened capital position of the commercial banks", and concede that the deterioration of credit quality may have triggered the bank runs (p. 330 and 356). Detailed evidence is provided by Calomiris and Mason (2003) 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 the traditional view. Interestingly, the aggregate indicator that best correlates with bank failures is the liabilities of failed businesses, represented by λ in our analysis.

Overall, our model is less suited for the Great Depression than for Japan's Lost Decade and the Nordic Banking Crises. But it highlights the role of asset prices and loan losses which have received

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off on loans and discounts of national banks" (approximately 2.6% of total loans). I thank Joseph Mason for suggesting this source.

[68] Gorton (1988) has also used this indicator to predict the seven banking panics of the National Banking Era (1863-1914). He writes (p. 241) "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 panic dates. The seemingly anomalous event of a [banking] panic appears to be no more anomalous than recessions."

[69] Both explanations emphasise banks' asset-side rather than their liability-side as do traditional accounts. This perspective is also supported by the finding that wholesale price deflation Granger-caused both M1 and industrial production, see Bernanke and Mihov (2000) p. 122. The decline in lending and anecdotal evidence are reported in Bernanke (1983), table 1 and p. 264-67.

little attention in both macroeconomics and the microeconomics of banking. The approach, we believe, can be applied more broadly to boom-bust cycles and other episodes of financial distress.[70]

We close by touching on other empirical implications. The model suggests that credit may be more closely related to asset prices than to output. The latter relation enjoys mixed empirical success, whereas the former is gaining increasing attention, e.g. in Davis and Zhu (2004). They also find evidence that causality, normally running from asset prices to bank credit, may reverse once banking distress and declining asset prices coexist, in line with our analysis. The model also suggests that credit and bank capital should be treated as endogenous in regressions, as both depend on macroeconomic conditions. Hence the single-equation regressions of capital crunches, such as Bernanke and Lown (1991), may well suffer from simultaneity bias. One could measure the degree of procyclicality by estimating the reduction in bank lending in response to loan losses in (29); if this coefficient exceeds one, financial instability is possible once banks become capital-constrained. Another testable implication is the prediction of a spread on bank loans, as detected by Hubbard et al (2002). Regarding monetary policy, episodes of financial distress such as October 1987 and Fall 1998 might see the policy rate fall below an estimated Taylor rule based on macroeconomic variables alone. More generally, we have shown that loan losses can become a decisive macroeconomic variable; incorporating them in econometric models might lead to more accurate assessments of the risks to financial stability and of the effectiveness of monetary policy.

Conclusion

This paper links banking and asset prices in a simple monetary macroeconomic model. The effect of falling asset prices on the banking system is indirect, non-linear, and involves feedback. As long as borrowers repay, the effect 'passes through' the bank balance sheet. However, when borrowers default, a one-to-one relation between asset prices and bank capital emerges. Once the capital constraint binds, that relation becomes unstable, and credit and asset prices implode as financial instability leads to a systemic banking crisis.

The case studies show that the model describes episodes of banking distress associated with asset price busts, such as Japan's Lost Decade, the Nordic Banking crises and, to a lesser extent, the Great Depression. The model's ability to distinguish between financial and macroeconomic stability sheds new light on the role of asset prices in monetary policy. Moreover, it makes precise the notion of balance sheet vulnerability and has several regulatory implications. The characterisation of financial extremes in a monetary macroeconomic model is, we hope, of broader interest.

Yet the model's stylised nature involves limitations that future work should address. Adding asymmetric information or uncertainty would be necessary to justify the capital constraint or a generalised reaction to losses. Expanding the banking system to several banks would bring up issues of liquidity

[70] On the role of capital crunches over the business cycle, see Wojnilower (1980), and Eckstein and Sinai (1986). On asset prices and credit in predicting banking crises, see Kaminsky and Reinhart (1999), and Borio and Lowe (2002). Asset prices are also emphasised by Kindleberger (1996), and by Hunter et al (2003); on real estate in particular, see Herring and Wachter (1999), and Mera and Bertrand (2000) on the Asian crisis. On non-performing loans in banking crises, see Caprio and Klingebiel (2003).

and lending of last resort. Adding price stickiness would allow considering optimal monetary policy. And considering credit-constrained agents or costly state-verification would make firms' output response more realistic. Adding these elements would, we believe, strengthen rather than reverse the main qualitative results of this paper. But doing so would be worthwhile for obtaining quantitative implications of financial instability, and for exploring monetary and regulatory policy responses.

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Appendix

1. Falling Prices

New steady state. The goods market clearing conditions from $t+1$ onward are always of the form (21), involving the pairs $\{s_{t+i}, p_{t+i}\}$ with $K_{t+i} = K_t$. Connecting successive s_{t+i} using the Euler equation (10) implies a constant price level, hence a new steady state, from $t+1$ onward. (The proof of proposition 1 applies.)

Note that the new steady state in $t+1$ implies an inverse relation between s_t and s_{t+1}: the intertemporal budget constraint derived from (3) is $\sum_{i=0}^{\infty} s_{t+i}/R^i = RD$, and with $s_{t+i} = s_{t+1}$ it becomes $s_t + s_{t+1}/(R-1) = RD$, or, in deviations

$$[s_{t+1} - s] = -(R-1)[s_t - s]. \tag{30}$$

We propose to rewrite the Euler equations as

$$p_{t+i} = \left(\frac{s_{t+i}}{s}\right)^{\frac{\gamma}{\gamma-1}} \qquad \forall i \geq 0. \tag{31}$$

This proposed form is equivalent to (10) if the Euler equation holds between $t-1$ and t. The equivalence also holds if, instead, any future price level p_{t+T} takes the proposed form. This normalisation can be justified by requiring that a zero shock leaves the fundamental price level unchanged at $p=1$. Since other agents' spending reverts to old steady state values, p_{t+1} the new steady state price level equals the old only if household spending does, $p' = 1 \Leftrightarrow s' = s$. The proposed form $p' = (s'/s)^{\frac{\gamma}{\gamma-1}}$ satisfies this requirement.

Solution. To solve the model we find the solution function $p_{t+1}(\tau)$, and recover $\delta(\tau)$ and $p_t(\tau)$. From (21) we get $s_{t+1} = \alpha(1-\tau)p_{t+1}y - (R-1)K$, and insert it into (31). After using $K = \alpha y/R = s$, as implied by (11)-(13), to replace αy and K, we obtain

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

This equation defines the solution function $p_{t+1}(\tau)$ implicitly.[71] Note that $p_{t+1}(0) = 1$ for any γ, hence $\delta(0) = 0$, and $p_t(0) = 1$, and the remaining variables also remain in steady state. A unique solution $p_{t+1}(\tau)$ is guaranteed by $\gamma < 1$. The slope of $p_{t+1}(\tau)$ is given by the implicit function theorem,

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

Clearly $\gamma < 1$ is sufficient (not necessary) to guarantee $p'_{t+1}(\tau) > 0$ on $\tau \in [0,1]$.

Performing the chain rule on (22) then implies $\delta'(\tau) > 0$, because the negative productivity effect outweighs the weak positive price level effect. Now we use $\delta(\tau)$ to obtain $s_t(\tau)$ and $p_t(\tau)$. To go from the first line of (20) to (23), we cancel $p_t y$ and split RqH into $qH + (R-1)qH$. This brings out δqH and $(R-1)(qH-K) = (R-1)D = s$, yielding $s_t = s + \delta qH$. Clearly $s_t > s$, since $\delta'(\tau) > 0$. From (31) then follows that $p'_t(\tau) < 0$. Deflation is temporary: since $s_t > 0$ requires $s_{t+1} < 0$ in (30), $p_t(\tau) < 1$ requires $p_{t+1}(\tau) > 1$ in (31).

Finally, the lower bound of the price level, $\overline{p}_t$ in (24), is found by substituting $p_t y = s_t$ from (20) into (31) to obtain $p_t = (p_t y/s)^{\gamma/(\gamma-1)}$. Solving for p_t and replacing $s = \alpha y/R$ yields $\overline{p}_t$, and $\overline{s}_t = \overline{p}_t y$ follows. We then find $\overline{p}_{t+1}$ by writing (30) as $\overline{s}_{t+1} = Rs - (R-1)\overline{s}_t$, and using it in (31) to obtain

$$\overline{p}_{t+1} = \left(1 - (R-1)\left[(R/\alpha)^{1-\gamma} - 1\right]\right)^{\frac{\gamma}{\gamma-1}},$$

after replacing $\overline{s}_t = s(R/\alpha)^{1-\gamma}$. ■

[71] Explicit solutions can be found for specific values, e.g. $\gamma = 1/2$ or 2 admit quadratic solutions.

2. Thresholds

Existence. The thresholds are critical values of λ, which are driven by δ, which is in turn driven by τ. The thresholds are therefore found as follows,

$$\begin{array}{lllll} \lambda \text{ turns positive when:} & \omega = \Pi & \rightarrow & \delta_0 & \rightarrow \tau_0 \\ \lambda \text{ eliminates bank dividends:} & \lambda = (R-1)\,K & \rightarrow & \delta_{Div} & \rightarrow \tau_{Div} \\ \lambda \text{ eliminates bank capital:} & \lambda = RK & \rightarrow & \delta_K & \rightarrow \tau_K. \end{array} \quad (32)$$

Examining the extremes shows that interior thresholds exist. At one extreme $\omega(0) = 0$, so no one bears a loss when $\tau = 0$ (hence $\tau_i, \delta_i > 0$). At the other extreme $\omega(1) > RK + \Pi$, so $\tau = 1$ implies losses exceeding the firms' and banking system's combined ability to withstand them (hence $\tau_i, \delta_i < 1$).[72] By continuity, there exist thresholds, ordered $0 < \tau_0 < \tau_{Div} < \tau_K < 1$, which delimit the four regions of figure 5.

Thresholds δ_i. To translate λ_i into δ_i, we solve (32) for δ, using (17) and (24), and obtain

$$\begin{aligned} \delta_{Div} &= \frac{R-1}{R}\left[(R/\alpha)^{1-\gamma} - 1\right] \\ \delta^* &= (R-1)\left[(R/\alpha)^{1-\gamma} - 1\right] \\ \delta_K &= \frac{R-1}{R}\,(R/\alpha)^{1-\gamma}, \end{aligned}$$

where the constant δ^* is defined for later use. Only δ_0 is implicitly defined by $\omega(\delta_0) = \Pi$ using (23).

Thresholds τ_i. The fundamental shock can be backed out from (22) written as $1 - \tau_i = (1 - \delta_i)/p_{t+1}$, using δ_i found above. This yields explicit τ_i when $p_{t+1} = \overline{p}_{t+1}$ (which is independent of τ). To simplify notation, we use δ^* to express $\delta_{Div} = \delta^*/R$, $\delta_K = \delta^*/R + (R-1)/R$, and $\overline{p}_{t+1} = (1-\delta^*)^{\gamma/(\gamma-1)}$. Thus, the thresholds τ_i are given by

$$\begin{aligned} 1 - \tau_{Div} &= (1 - \delta^*/R)\,/\,(1-\delta^*)^{\gamma/(\gamma-1)} \\ 1 - \tau^* &= (1-\delta^*)^{1/(1-\gamma)} \\ 1 - \tau_K &= (1-\delta^*)^{1/(1-\gamma)}\,/R. \end{aligned} \quad (33)$$

There are no explicit solutions for δ_0 and τ_0 (unless one assigns γ a number). Since $\delta_0 < \delta_{Div}$, it follows that $\tau_0 \in (0, \tau_{Div})$.

Vulnerability. To show that the thresholds in (33) are decreasing in $\{\alpha, \beta, \gamma\}$, note first that δ^* is. In each case of (33), τ_i and δ^* are related positively. Since all τ_i depend on α only through δ^*, it follows that $\tau_i'(\alpha) < 0$. Also $\tau_i'(\beta) < 0$ is easily shown, since the presence of $R = \beta^{-1}$ increases the right of (33), further reducing τ_{Div}, τ_K. We also have $\tau_i'(\gamma) < 0$, because apart from reducing δ^*, γ also raises the exponents in (33). The remaining threshold is implicitly defined by $\omega(\delta(\tau_0), p_t(\tau_0)) = \Pi$. Using steady state relations, the difference can be written as $\delta(\tau_0)\alpha/(R-1) + \alpha - p_t(\tau_0) = 0$, where the left is increasing in τ_0. Hence, raising α and β (lowering R) decreases the τ_0 necessary for the equality to hold. Similarly, raising γ reduces τ_0, because it raises $\delta(\tau)$ and $p_t(\tau)$ for any τ. Therefore, the greater $\{\alpha, \beta, \gamma\}$, the smaller all thresholds τ_i. ■

[72] To show $\omega(1) > RK + \Pi$, note that $\delta(1) = 1$ and $p_t(1) = \overline{p}_t \leq 1$ for any γ. Therefore, (17) implies $\omega(1) > qH$. To show $qH > RK + \Pi$, use firm leverage (12) to replace $\Pi = \frac{1-\alpha}{\alpha}(R-1)qH$, and use bank leverage (13) to replace $qH = A = RK/(R-1)$. Canceling 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.

3. Capital-Constrained Equilibria

Asset price decline. The capital crunch and the banking crisis are fixed points of (26), where the asset price decline (hence credit demand) coincides with the contraction required by the capital constraint (hence credit supply). They can only occur when $\lambda > (R-1)\,K$, so the goods market solution (24) obtains, irrespective of τ.[73] Thus we find $\{q_t, R_t\}$ consistent with (26) and (27), given $\{\overline{p}_t, \overline{s}_t\}$ and $\{\overline{p}_{t+1}, \overline{s}_{t+1}\}$. Expressing (26) in deviations from steady state,

$$\delta q H \geq \begin{cases} 0 & \text{if} \quad \lambda \leq (R-1)\,K \\ \frac{R}{R-1}\left[\lambda(\delta) - (R-1)\,K\right] & \text{if} \quad (R-1)\,K \leq \lambda \leq RK \\ qH & \text{if} \quad \lambda \geq RK. \end{cases}$$

The first line never binds, as explained. The third line defines the systemic banking crisis with $\delta = 1$. The second line defines the capital crunch. Using (17) and (24) yields (29), that is, $\delta = R[(R-1)K + \Pi - (1 - (R/\alpha)^{-\gamma})\,y]/(qH)$. Upon replacing the ratios with those in (11)-(13), we obtain δ^* in (28).

Fundamentals. The declines $\delta = 1$ and δ^* are *fundamental* if $\tau = 1$ and τ^*, respectively (using (22) as in appendix 2). However, any $\tau < 1$ allows $\delta = 1$, and any $\tau < \tau^*$ also allows $\delta = \delta^*$ as self-fulfilling equilibria, while $R_t > R$ is determined by (27). By contrast, any $\tau > \tau^*$ implies $\delta(\tau) > \delta^*$, which can satisfy (26) only if $\delta = 1$. (Note that $\tau < \tau^*$ also admits the fundamental equilibrium of proposition 2, since (26) does not bind.)

Interest rate spread. The banking system's dividend policy implies $K_{t+i} = K_t$, hence the capital constraint binds permanently if it binds in t. The constrained asset price therefore remains constant after t, and (27) becomes $q_t H = \alpha\,(1-\tau)\,\overline{p}_{t+1} y / \,(R_t - 1)$. Dividing by $qH = \alpha p y/(R-1)$ and using $\overline{p}_{t+1} = (1-\delta^*)^{\gamma/(\gamma-1)}$ allows to solve for the loan rate as

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

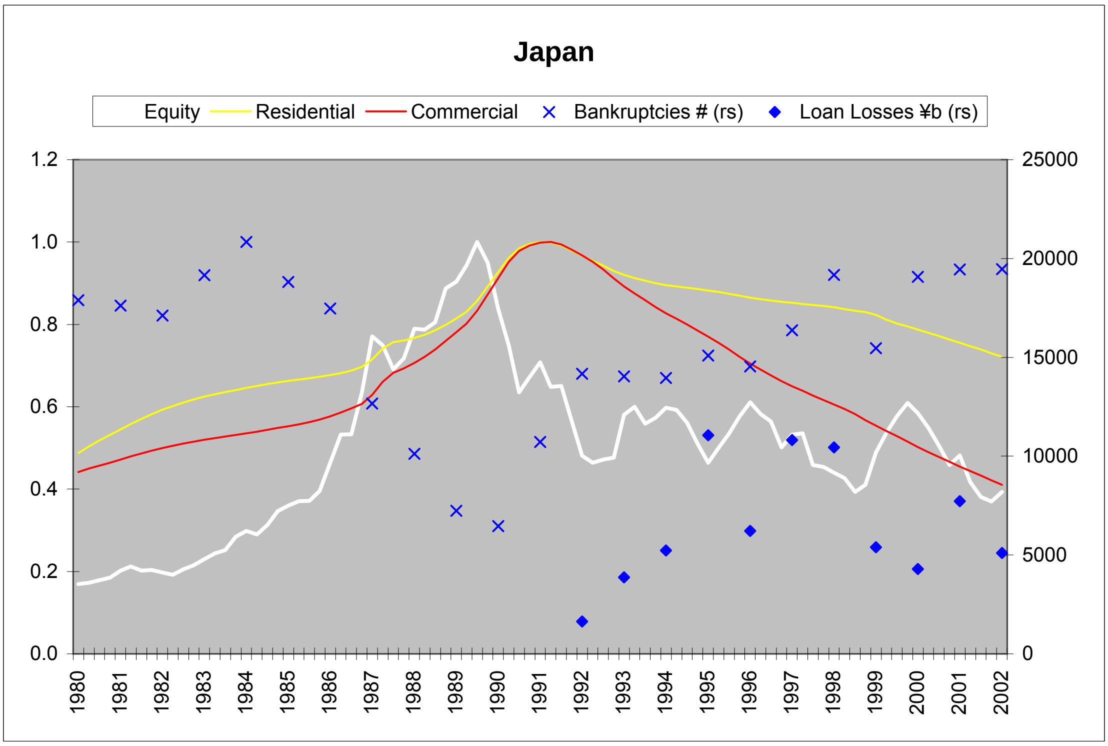
In a fundamental equilibrium, particular fundamentals $\{\tau^*, 1\}$ bring about the declines $\{\delta^*, 1\}$, while $R_t = R$. By contrast, in a self-fulfilling equilibrium, a particular loan rate $R_t(\tau)$ brings about $\{\delta^*, 1\}$, while $\tau < \tau^*$. Accordingly, we have following equilibria,

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

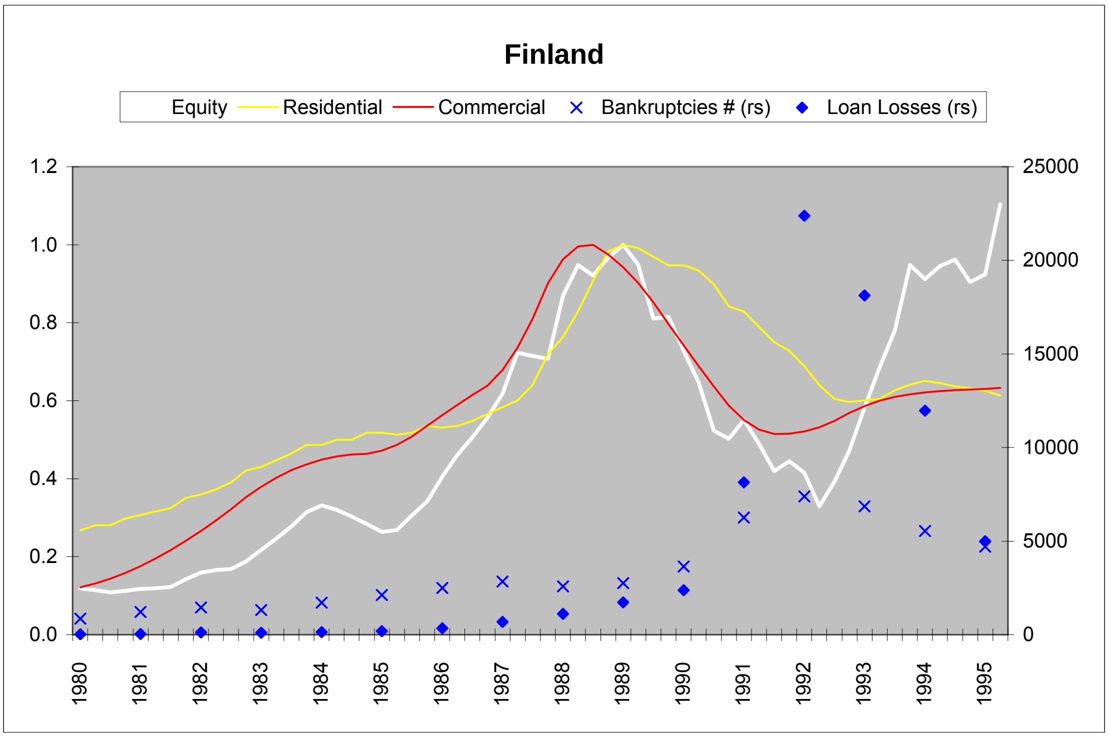
The spread provides a measure of the degree to which a capital crunch equilibrium is self-fulfilling. This is why the spread is decreasing in τ: better fundamentals are associated with a larger spread. One can think of $1-\tau$ as the strength of the economy (hence credit demand), and $1-\tau^*$ as the 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 $\tau \to 0$. ■

[73] 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.

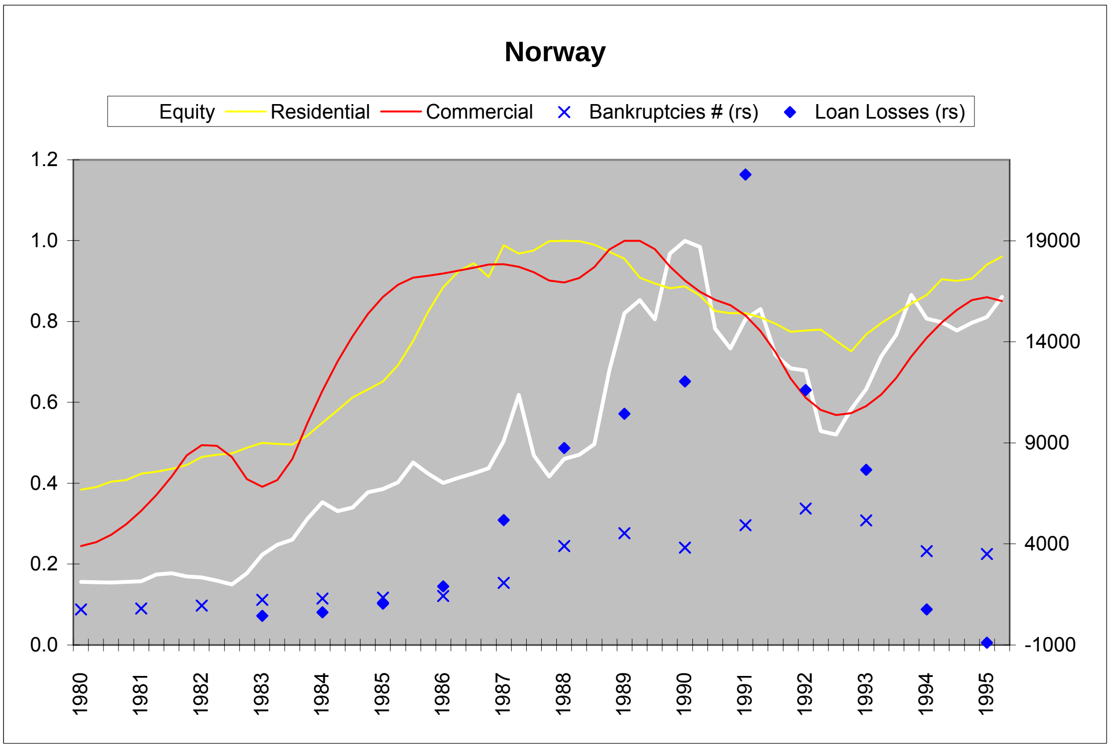
Figure 10: Asset Prices, Bankruptcies and Loan Losses



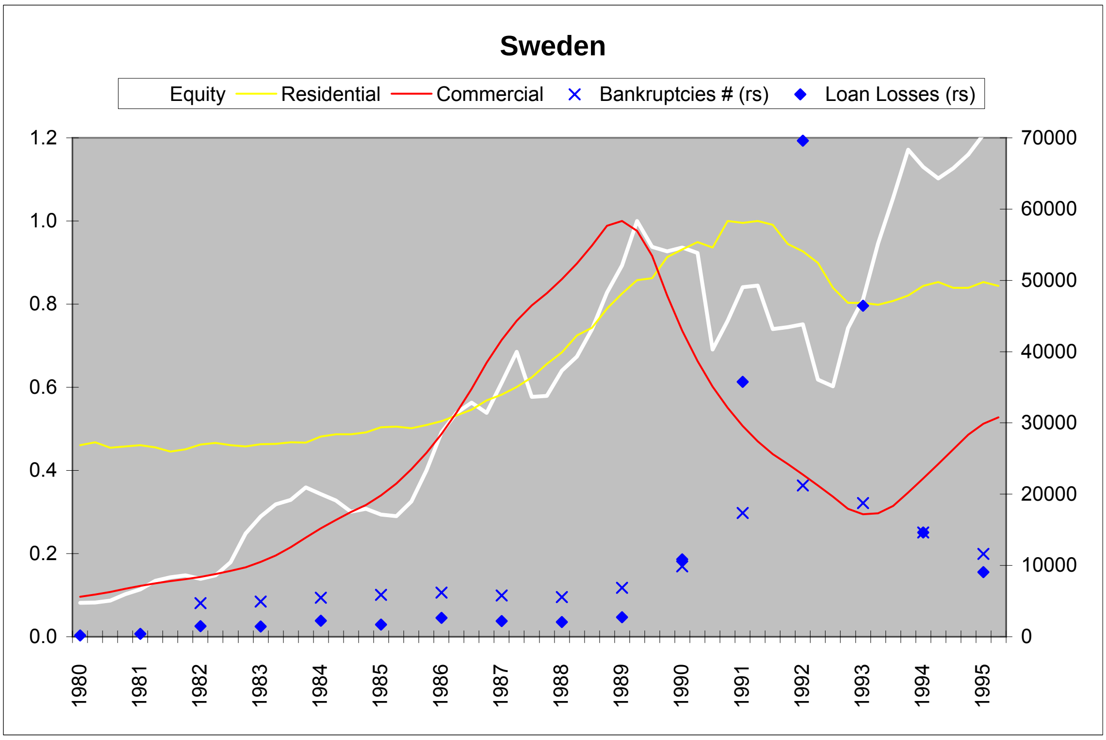
Sources: BIS asset price database; Teikoku Databank America, Inc; Financial Services Agency; Japan Real Estate Institute.
Equity = Topix, all shares. Residential = land prices, nationwide. Commercial = all urban districts, avg. land price per sqm.
All graphs express asset prices relative to their peaks between 1985-92.
Bankruptcies and loan losses are measured on the right scale (rs).
The number of corporate bankruptcies was kindly provided by Teikoku Databank America, Inc.
Loan losses are "total losses on disposal of non-performing loans" in billions of Yen, and comprise large banks (city banks, long-term credit banks, and trust banks) since 1992 (FSA table 4).



Sources: BIS asset price database; Bank of Finland.
Equity = Helsinki stock exchange, all shares (HEX). Residential = existing dwellings, nationwide, price per sqm.
Commercial = capital value of office property (75% in Helsinki).
Loan losses and the number of corporate bankruptcies are again measured on the right scale.
Loan losses are in millions of Finnish markka, net of subsequent recoveries, and are recorded at banking group level (including all commercial banks).



Sources: BIS asset price database; Norges Bank, and Statistics Norway.
All graphs express the asset price series relative to their peaks between 1985-92. Bankruptcies and loan losses relate to the right scale.
Equity = Oslo stock exchange, 25 companies (OBX). Residential = existing houses or flats, nationwide.
Commercial = capital value of office property (84% in Oslo).
The number of bankruptcies include both corporate and personal, as recorded by the Register of Bankruptcies.
Loan losses are in millions of Norwegian krone, and comprise realized loan losses, net of recoveries, by commercial and savings banks operating in Norway (excluding branches abroad, but including foreign banks).



Sources: BIS asset price database; Sveriges Riksbank, and Statistics Sweden.
Equity = Stockholm stock exchange, all shares (SAX). Residential = owner-occupied one-and two dwelling buildings, nationwide.
Commercial = capital value of office property (68% in Stockholm).
The number of bankruptcies reported by Statistics Sweden includes limited liability companies and small firms (private firms and partnerships).
Loan losses are in millions of Swedish krona, and comprise realized loan losses net of recoveries for all banks (including savings and cooperative banks).
As for the other Nordic countries, loan losses are not converted to a common currency because the devaluations of 1992 would artificially reduce their value.

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