Journal of Financial Stability 5 (2009) 298–319

Contents lists available at ScienceDirect

Journal of Financial Stability

journal homepage: www.elsevier.com/locate/jfstabil

Asset prices and banking distress: A macroeconomic approach

Goetz von Peter*

Research and Policy Analysis, Bank for International Settlements, Centralbahnplatz, CH-4002 Basel, Switzerland

ARTICLE INFO

Article history:
Received 15 April 2008
Received in revised form 24 October 2008
Accepted 21 January 2009
Available online 3 February 2009

JEL classification:
E5
E31
G12
G21
G33

Keywords:
Asset prices
Inside money
Default
Credit crunch
Financial instability
Banking crisis

ABSTRACT

This paper links banking with asset prices in a dynamic macroeconomic model, to provide a simple characterization of financial instability. In contrast with historical bank runs, recent banking crises were driven by deteriorating bank assets. Hence, in contrast with bank run models, this paper focuses on the interaction of falling asset prices, bank losses, credit contraction and bankruptcies. This interaction can explain credit crunches, financial instability, and banking crises, either as fundamental or as self-fulfilling outcomes. The model distinguishes between macroeconomic and financial stability. Its simplicity helps understand balance sheet effects and delivers closed-form solutions without resorting to linearization. For instance, the critical threshold beyond which an asset price decline triggers financial instability can be related explicitly to the structural parameters of the economy.

1. Introduction

Many episodes of banking distress are driven by the deterioration of bank assets. Clearly, major dislocations can occur even if no bank runs on any significant scale take place. Recent examples include the Japanese and Nordic banking crises, as well as the current global financial crisis. At the heart of these episodes is the unstable interaction of falling asset prices, bank losses, credit contraction and

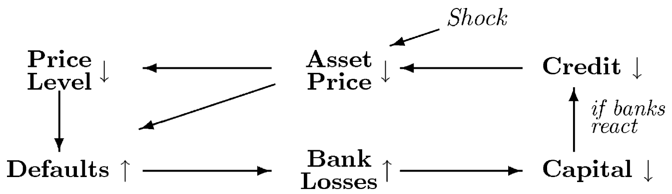
* Tel.: +41 61 280 8326.
E-mail address: Goetz.von.Peter@bis.org.

1572-3089/$ – see front matter
doi:10.1016/j.jfs.2009.01.001

wide-spread bankruptcies. This interaction, widely noted in policy circles, is not captured by leading approaches to financial instability, such as the theory of bank runs and the financial accelerator. Those theories also treat financial and macroeconomic stability as largely the same. Yet in reality they need not coincide nor be addressed by the same authorities or instruments.[1] The ongoing financial crisis, for instance, witnessed financial instability unrelated to – and in advance of – any deterioration in output or inflation.

This paper addresses these issues by focusing directly on the relation between asset prices and the banking system. This is a central relation, and a major policy concern, in many episodes of financial instability. We propose a simple overlapping-generations model where assets to play a central role, as in Kiyotaki and Moore (1997), and where banks exist to intermediate credit and payments, as in McAndrews and Roberds (1999) or Skeie (2008). We contrast the unconstrained case, where bank credit is perfectly elastic to demand, with the case where banks react to losses by reducing credit. The latter captures the fact that many circumstances in practice prevent banks from raising their leverage arbitrarily. One reasons is capital adequacy regulation; another reason – and one that also applies to investment banks – is risk management, such as limits to value-at-risk (Adrian and Shin, 2008b). Constraints on leverage may also arise from agency problems making bank capital necessary for monitoring loans (e.g. Holmström and Tirole, 1997).

With these ingredients, the model develops the mechanism depicted below. Firms purchase productive assets (real estate) on bank credit. Next period, they resell the assets to the next generation of firms, and sell their output at the prevailing price level. This gives rise to a natural debt structure in which households keep deposits with banks whose assets consist of debt claims on firms (mortgages). We then let a shock set off the dynamics. When expected productivity declines, the forward-looking asset price falls to reflect the reduced future return on assets. As a result, old firms suffer a loss on assets sold. The associated wealth effect reduces consumption spending and the price level may fall as well. When these declines are large, firms end up in default and losses spill over to the banking system and diminish bank capital. In this unconstrained case, fundamentals map uniquely into balance sheets and outcomes, so banking crises occur only for very large shocks.



The situation is more fragile in the case where banks react to losses by reducing credit. Their attempt to keep leverage from rising produces feedback from the banking system to asset markets, causing further losses in the aggregate. The interaction between asset prices and bank losses can now give rise to a range of financial extremes, either as fundamental or as self-fulfilling outcomes.

This is because the effect of falling asset prices on the banking system is indirect, non-linear, and involves feedback. It is indirect, because banks get exposed to asset prices even if they hold none of the traded assets, but their borrowers do. The effect is non-linear, because small losses largely 'pass through' the bank balance sheet, affecting passive money and credit aggregates. But larger losses constrain bank lending [capital crunch], or cause an unstable contraction of credit [financial instability], which propels the system toward collapse [banking crisis]. At that point, the credit and payment mechanism ceases to function and the economy reverts to autarky. This can occur for much smaller shocks than was possible in the unconstrained equilibrium, since losses hurt banks regardless whether or not asset prices reflect fundamental value.

[1] Macroeconomic stability refers to the stability of the price level and of output (e.g. Woodford, 2003). Financial stability is elusive to define, but its absence is associated with collapsing financial institutions at the system level (Allen and Wood, 2006). One clear and relevant definition of financial stability is "the smooth, uninterrupted operation of both credit and payment mechanisms" (Federal Reserve Bank of St. Louis, 2002). In our model, the banking system combines these functions, and its stability is thus equivalent to financial stability.

The model's main appeal is the simplicity with which these links are articulated. In spite of dynamic general equilibrium, explicit solutions and balance sheet effects are found without resorting to linearization.[2] For instance, we solve for the critical threshold beyond which an asset price decline triggers financial instability. Hence the vulnerability to financial instability can be related directly to the structural parameters of the economy. As these parameters differ from those governing inflation and output, the model can distinguish between macroeconomic and financial stability. The paper therefore links banking, asset prices, losses and default within a tractable model that can generate financial extremes under well-defined circumstances.

In producing a full range of outcomes, this paper differs from the separate – mostly microeconomic – theories that have been devised to describe such outcomes. Compared to *capital crunch* models (e.g. Holmström and Tirole, 1997; Gersbach, 2002), ours emphasizes losses as a driver of bank capital, and relates them to endogenous macroeconomic variables. Compared to models of *banking crises* building on the inherent fragility of bank liabilities (e.g. Diamond and Dybvig, 1983; Allen and Gale, 1998; Diamond and Rajan, 2001, 2006), ours provides an *asset-based* explanation of banking distress: in taking a macroeconomic approach, we link bank assets to firms, and firms' financial position to asset prices and macroeconomic aggregates. This goes beyond Diamond and Rajan (2006) where an exogenous production delay leads to banking distress because of a depositor run. Clearly, banks can be in distress even in the absence of depositor runs (which have become infrequent since the adoption of deposit insurance and central bank liquidity facilities). Recent experience in Japan, the Nordic countries and the current global financial crisis all point to the deterioration of bank assets as the underlying problem that then complicated banks' funding situation. Bank runs by depositors or wholesale markets are perhaps better viewed as a symptom, rather than the cause, of financial instability.[3]

Perhaps closest to our perspective is the *financial accelerator* literature, inspired by narratives of financial crises.[4] Nevertheless, the formal models exclude the financial extremes studied here: either default is ruled out by restrictions on contracts (Kiyotaki and Moore, 1997) or made inconsequential to diversified lenders (Bernanke et al., 1999).[5] In the few models with financial intermediaries, the approach is either computational (Goodhart et al., 2006) or confined by linearization to the neighborhood of the steady state (Chen, 2001; Christiano et al., 2003). In contrast to financial accelerator models, ours allows wide-spread default to affect the banking system and thereby credit supply. It also delivers closed-form solutions, such as the critical threshold beyond which an asset price decline will trigger financial instability.

An important question is how the results depend on contractual arrangements (which our macroeconomic approach keeps as simple as possible). The assumption that firms issue debt is not essential for the main results, because bank losses would be larger and more immediate under equity financing. By contrast, that banks finance themselves with debt *is* an essential assumption, since this translates losses directly into falling capital, precipitating a credit contraction with adverse consequences. The paper shares with other models the assumption that bank deposits are fixed in nominal value (e.g. Allen and Gale, 1998; Diamond and Rajan, 2006). Since bank deposits in our model serve as the means of payment, it may be regarded as natural that they are tied to the unit of account.[6] It can happen in bank run models that nominal deposits remove bank runs (Skeie, 2008), or make runs inconsequential, even desirable, with appropriate monetary intervention (Allen and Gale, 1998; Diamond and Rajan,

[2] This simplicity is made possible by the overlapping generations structure, and by our inside money approach to banking, where the credit apparatus is frictionless until low bank capital interferes with the elastic provision of credit. While there is a cost of abstracting from frictions and uncertainty, these features would tend to exacerbate the linkages modeled here.

[3] Even views on the Great Depression, the classic case for banking panics (Friedman and Schwartz, 1963), are being revised in the light of new evidence on the deterioration of bank assets (Gorton, 1988; Calomiris and Mason, 2003). In the 168 banking crises documented by Caprio and Klingebiel (2003), non-performing loans are the most common theme.

[4] Fisher (1933), Bernanke (1983), Mishkin (1991), Calomiris (1993, 1995) all emphasized that falling asset values can impair borrowers' balance sheets to the point of interrupting the intermediation of credit.

[5] In Bernanke et al. (1999), the spread paid by successful firms compensates for any loan losses from defaulting firms, and aggregate risk is offset by state-contingent loan rates. Hence lenders face no losses and are ignored in the analysis.

[6] Equity-like payment instruments are uncommon in practice: commercial banks are unsuited for providing them, and households are averse to uncertainty in settlement (Goodhart, 1995a).

2006). This underscores that focusing on banks' *asset* side is helpful for understanding the continued occurrence of banking distress.

The paper proceeds as follows. Section 2 discusses the Nordic banking crises which highlight the importance of the variables we model. Section 3 presents the basic model in perfect foresight, and section 4 studies the effects of a productivity shock on asset prices, borrowers, and on the banking system. Section 5 considers the feedback from the banking system to the macroeconomy, characterizes financial extremes and explores how financial vulnerability depends on structural parameters. Before concluding, the final section briefly discusses the perspective the model can bring to monetary and regulatory policy.

2. The Nordic banking crises

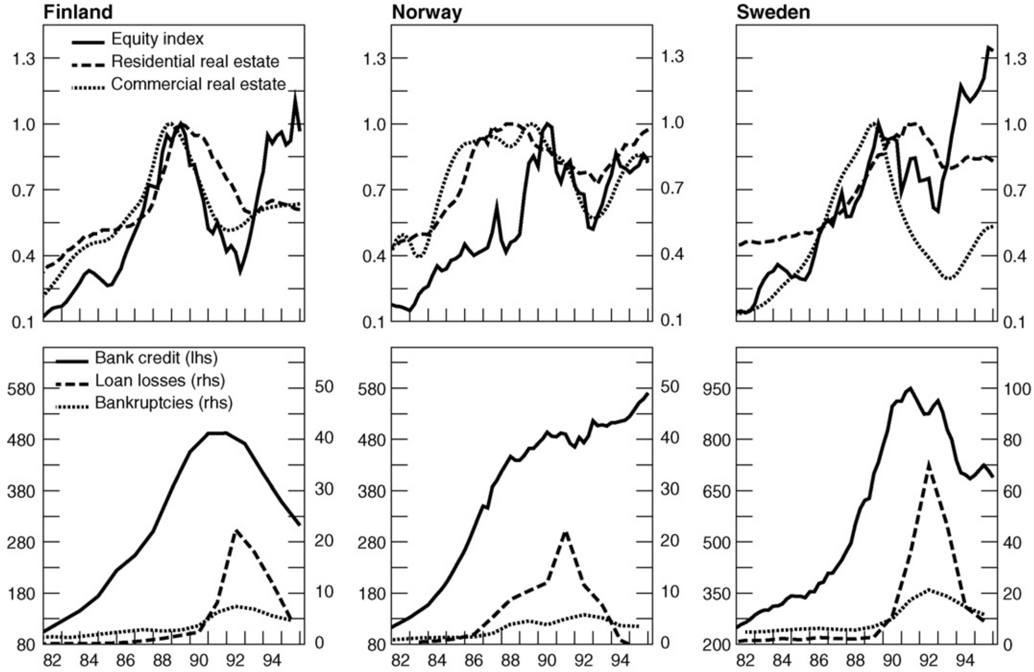
The relation between asset prices and banking distress was at the heart of numerous financial crises. The Nordic banking crises of the early 1990s constitute an important case in point. The crises suffered by Finland, Norway, and Sweden followed a similar pattern.[7] Systematic deregulation during the 1980s fueled a credit boom. Banks' aggressive expansion was sustained by optimistic expectations of firms' future productivity, while accounting and risk management systems did little to restrain lending (Moe et al., 2004). The rapid increase in bank lending was initially treated by regulators as a natural adjustment to a new regime (Berg, 1998). But the accompanying asset price boom set the stage for a spectacular decline in asset prices across asset classes. Equity and commercial real estate in particular fell by some 40–70% in all three countries. The common exposure to falling asset prices led to wide-spread losses and default. Bankruptcies shot up, reaching 4–5 times the numbers of a decade earlier. Non-performing loans rose to 9–11% of GDP (Drees and Pazarbaşioğlu, 1998), and loan losses soared correspondingly (Fig. 1).

The timing of first banking problems reflected country-specific factors, but the relation between falling asset prices and banking distress inflicted a common pattern across the three economies. Some 60–80% of loan losses were vis-à-vis firms, and default rates were particularly high in the real estate sector (Drees and Pazarbaşioğlu, 1998). As in other crises, real estate and mortgages thus played a central role. For instance, commercial real estate amounted to 15% of lending in Sweden, yet accounted for 40–50% of bank losses (Englund, 1999). Similarly, the Finnish savings banks, with a traditional concentration in real estate, had expanded faster than commercial banks—once the downturn seized the real estate sector, they faced greater losses and contracted credit more than did commercial banks (Vihriälä, 1997).

Real estate prices and bank lending were closely intertwined in both the boom and the bust phase (Berg, 1998). As losses materialized across the whole banking system, signs of a capital crunch surfaced. In Sweden, credit contracted by 28% from peak to trough, while loan-to-value ratios fell from 90% to 60%, far below the pre-boom level of 75% (Englund, 1999). In Finland, the credit contraction even reached 36%, where the depletion of bank capital, and the concurrent tightening of capital regulation, also contributed to a capital crunch (Vihriälä, 1997). In each of the three countries, the banking crisis reached systemic proportions. The largest banks experienced serious solvency problems (Sandal, 2004). In view of the size of losses, policymakers recognized that an unstable banking system could entail the collapse of credit and payments that would hurt the economy. To avert such a collapse, comprehensive recapitalizations were undertaken, accompanied by other support measures (Bäckström, 1997; Vihriälä, 1997; Sandal, 2004).

The Nordic banking crises highlight the important role played by the interaction of credit, asset prices, bankruptcies, bank losses and capital, variables that are rarely considered jointly in existing models. Econometric cross-country studies detect patterns between these variables that are broadly in line with the mechanism described in this paper. Bankruptcies and loan losses in the Nordic countries are well explained by financial fragility (debt/GDP) interacted with adverse surprises (Pesola, 2001). Bankruptcies are also Granger-caused by bank credit and house prices in what resembles a 'financial cycle' as opposed to a business cycle (Hansen, 2003). In fact, the Nordic crises of the 1990s saw more

[7] Denmark's banking problems were similar in nature, but less severe in their consequences.



	Finland	Norway	Sweden
Equity price (% decline)	67	48	40
Residential reale state (% decline)	40	27	20
Commercial reale state (% decline)	48	43	70
Bankruptciesin peak year (% of 1982-84 mean)	496	493	422
Loan losses in peakyear(% of lending)	4.7	4.5	7.9
Cumulative bank credit contraction (%)	36	6	28

Fig. 1. Asset prices and banking distress in the Nordic countries. *Sources*: see Data appendix. The asset price series are normalized by their peaks between 1985 and 1991 to show percent declines. Bank lending and loan losses are in billions of markka, krone, and krona. Bankruptcies are in thousands.

banking distress, yet less macroeconomic instability, than the crises of the 1920s and 1930s, and much of this difference can be attributed to the greater effect of leverage and asset prices during the 1990s (Bäckström, 1997; Gerdrup, 2003). It is therefore useful to distinguish between macroeconomic and financial stability, as central banks indeed commonly do.

The relation between asset prices and banking distress has been central in many other episodes. Japan's experience during the lost decade (1990s) shares many features with the Nordic crises: the 'non-performing loans problem', resulting from falling asset prices, almost completely characterized the state of the Japanese financial system (e.g. Ueda, 2003). Both crises were driven by the deterioration of bank assets rather than by depositor runs, a mechanism that played no significant role in either episode.

The current financial crisis is also centers on bank losses due to falling asset prices (originally housing and subprime mortgage products). Following securitization, banks today hold a greater share of mortgage exposures as mortgage-backed securities, but this changes the basic mechanism only superficially: bank losses show up as mark-to-market losses on mortgage-related securities, instead of loan losses on mortgages. Recent experience indicates that such losses can materialize rather quickly, since the pricing of mortgage-backed securities is forward-looking and need not be in line with fundamentals (such as actual delinquencies). These observations motivate our departure from the bank run paradigm of banking distress, towards a simple macroeconomic approach interacting credit, asset prices, bankruptcies, and bank losses.

3. The basic model

The model is a flexible-price overlapping generations model with real assets and consumption goods. Firms, households and banks are of unit measure. Households are the lenders in this economy; their Euler equation, along with goods market clearing, will govern the real interest rate and price levels. Firms use real assets to produce and sell consumption goods; their productivity, along with future prices, will determine the fundamental value of assets. The banking system arises to help households and firms attain the optimal pattern of exchange by offering deposits and holding commercial mortgages.[8] Firms and banks are treated as separate from households, consuming their profits and dividends, respectively, as in Diamond and Rajan (2006). This simple ownership structure makes sure that borrowing takes place and that the incidence of losses matters.

3.1. Setup

3.1.1. Firms

Firms are run by owner-entrepreneurs who own a technology f to which they dedicate their specific labor. Firms earn normal profits, which can be understood as an implicit wage for the entrepreneur's specific labor, subsumed in f. Accordingly, f exhibits decreasing marginal productivity in the other factor of production which is capital (productive assets). We assume that production takes time, and that assets are purchased, not rented.[9] Since entrepreneurs start off without wealth they must borrow to purchase assets. Assets can be thought of as units of land, as in Kiyotaki and Moore (1997), or as commercial real estate, and the corresponding liabilities as mortgages. The assumption that firms issue debt rather than equity is not essential for the results.[10]

The typical firm of generation $t-1$ buys assets h_{t-1}, and uses them to produce $y_t = f(h_{t-1})$ consumption goods. Next period, the goods are sold at the goods price p_t, and assets are resold, undepreciated, at the asset price q_t. After selling output and assets, the firm repays its debt b_{t-1} at gross interest rate $R_{t-1} > 1$, and the remainder is paid out as profits Π_t as the firm closes. The owner-entrepreneur uses these profits to buy consumption goods c_t^f from other firms. The owner-entrepreneur thus maximizes profits (hence consumption) subject to the period budget constraints,

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

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

The last line rules out negative consumption: the firm operates under limited liability. The firm's demand for productive assets is found from the first-order condition equating the marginal revenue product with 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 an incentive to become leveraged.

8 An equivalent model with *residential* mortgages results when replacing firms holding productive assets by households holding utility-yielding assets (housing).

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

10 This case is explored below, following Eq. (25).

3.1.2. Households

Alongside firms, there are overlapping generations of households who derive utility from consuming goods. Assuming operative bequests, households are treated as infinitely-lived. They are endowed at date 0 with the fixed supply H of productive assets. Their home production technology g (concave) is less efficient than that of firms, $g'(0) < f'(H)$, so households have little productive use for assets: they sell the assets to the first generation of firms, and solve a standard intertemporal consumption problem with initial wealth q_0H,

$$\max_{\{c_t\}} \sum_{t=0}^{\infty} \beta^t u(c_t^h) \quad \text{s.t,} \qquad s_0 + D_0 = q_0H \qquad s_t + D_t = R_{t-1}D_{t-1} \quad \forall t \geq 1, \tag{3}$$

where $s_t \equiv p_t c_t^h$ represents spending on consumption, and D_t denotes 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, the nominal interest rate equals the inverse rate of time preference, $R = \beta^{-1}$, and household spending equals $s = (R-1)D$, the permanent income from wealth $D = qH/R$. To specify how households deviate from this perpetuity rule outside the steady state, we posit CRRA utility $u(c) = (c^{1-\gamma} - 1)/(1-\gamma)$, and specify a path for R_t.

3.1.3. The banking system

Households are the lenders in this economy, and every period new firms enter as borrowers. Efficient intertemporal exchange requires that the productive assets be passed down successive generations of firms, in exchange for part of the output they produce (see Fig. 2). To do this, agents need a means of payment for purchasing goods and assets from each other.

In this setting banks arise to facilitate payments. Households and firms can pay for goods and assets through the transfer of deposits. The balance sheet mechanics for the banking system as a whole work as follows. Every period t, the banking system creates (by book-keeping entry) deposits worth q_th_t, enabling new firms to purchase assets by paying these deposits to old firms. Old firms then use the 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 $p_tf(h_{t-1})$, leaving profits consistent with (1) which entrepreneurs then spend on goods of other firms. Going backward to period 0, the first payment q_0H is received by the initial sellers of assets (households), who hold their wealth on deposit to finance their spending s_t every period. The bank balance sheet, recorded at the close of markets each period, therefore consists of loans to firms, worth q_tH, and liabilities in the form of household deposits D_t and bank capital K_t.

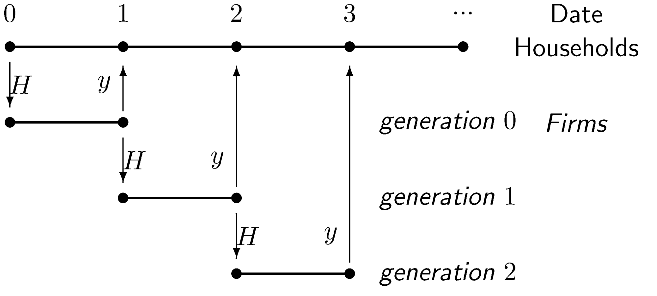


Fig. 2. Intertemporal exchange.

The banking system starts with $K = s_0$ worth of capital.[11] Competitive behavior among banks equalizes loan and deposit rates, so bank capital evolves as $K_t = R_{t-1}K_{t-1} - Div_t$. (See Gersbach and Uhlig, 2006 for a banking model of Bertrand competition.) Suppose the banking system follows the simple dividend policy of paying out its profits, if positive, to the owners (bankers) who spend these dividends on consumption goods. As a result, bank capital remains constant at $K_t = K$ in the absence of losses,[12]

$$\mathrm{Div}_t = (R_{t-1} - 1)K_{t-1}. \tag{5}$$

3.1.4. Remarks on banking

Deposits initially provided as a means of payment end up being held across periods. The banking system in this simple model thus combines the functions of credit intermediation and payment system, and its stability is equivalent to financial stability (see footnote 1). Our inside money approach to banking is close to that of Black (1970), McAndrews and Roberds (1999) and Skeie (2008).[13] Banks intermediate all payments in this economy.

This approach makes plausible two common assumptions in the banking literature. First, that bank deposits are fixed in nominal value is more natural here than in models where deposits do not serve as means of payment (e.g. in Allen and Gale, 1998). Second, the assumption that bankers have superior skills to collect from borrowers (e.g. in Diamond and Rajan, 2001, 2006) is realistic here, since firms receive sales revenue to their bank account and banks apply these inflows against firms' debt before firms have a chance to spend them on goods.[14] In an economy without banks, exchange involving circulating media (cash, IOUs) would invite strategic default: firms could sell their assets and default on their debt to buy more goods. Intermediation thus makes debt enforceable, allowing firms to pledge their future sales revenue in (1), which is not possible in Kiyotaki and Moore's (1997) setting.

Finally, note how our approach relates the size of the banking system to macroeconomic aggregates. By granting credit, the banking system creates inside money—the quantity of money and credit is demand-determined. The size of the bank balance sheet therefore equals loan demand, which is q_tH, the aggregate value of assets turning over in the market every period.

3.2. 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 maximize (1), households maximize (3), the banking system follows (5) implying a path for bank capital $\{K_{t+1}\}_{t=0}^{\infty}$, and the asset and goods markets clear every period. The goods price p_t is also the price level, since firms of the same generation, and the goods they produce, are identical. A steady state with stable prices requires that the nominal interest rate in (4) equal $R = \beta^{-1}$, the natural rate. We assume that the banking system also lends and borrows at this rate outside the steady state; this captures the idea that resets on mortgages and deposit accounts are infrequent and slow relative to asset price dynamics.[15]

3.2.1. Asset market equilibrium

All firms have identical technologies and face the same prices; all choose h_{t-1}^d in (2). Hence aggregate asset demand also has this form every period from 0 onward. Assets are in fixed supply H and do not

[11] Think of bankers giving up some consumption to build initial bank capital. They are endowed with consumption goods in $t = 0$. Since firms only start selling their production at date 1, households spend s_0 of their deposits to purchase from this endowment. Bankers thereby obtain claims on banks which constitute bank capital.

[12] Such a dividend policy is necessary for a steady state with constant capital to exist.

[13] In other overlapping generations models, circulating media are used instead: outside money (Samuelson, 1958), private IOUs (Sargent and Wallace, 1982), or bank notes (Champ et al., 1996).

[14] Consistent with this view, Mester et al. (2007) provide evidence that banks use the payments information available through their checking accounts to monitor borrowers. A related point, that a purchase using credit identifies the buyer, is made by Kahn et al. (2005).

[15] The assumption is lifted in section 5 where banks react more actively. Note also that assuming $p_0 = 1$ dispenses with nominal price level indeterminacy (see Woodford, 2003). This can be implemented by a central bank standing ready to buy and sell goods at a fixed price of $p_0 = 1$ (Skeie, 2008).

depreciate. Market clearing requires that asset demand h_t^d equal supply, or $f'^{-1}([Rq_t - q_{t+1}]/p_{t+1}) = H$. This allows to relate the user cost of holding assets to the future price level,

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

where $y \equiv f(H)$ is aggregate output, and $\alpha \equiv f'(H)H/y$ is output elasticity.[16] In equilibrium, firms always spend α of expected sales revenue on the user cost of holding assets, and pay out the remainder as profits to their owners,

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

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

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

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

3.2.2. Goods market equilibrium

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

$$\begin{aligned} &s_t = \alpha p_t y - (R-1), \text{ with} \\ &s_0 = \alpha \beta y \quad \text{given} \quad p_0 = 1. \end{aligned} \tag{9}$$

Successive goods market clearing conditions are connected by the Euler Eq. (4),

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

With high intertemporal elasticity of substitution ($\gamma < 1$), households spend more when goods are cheap. We focus on this case to have a higher real interest rate encourage saving, and to include the fixed-price limit as $\gamma \to 0$.[17] A perfect foresight equilibrium must 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.*

The price level remains constant at $p = p_0 = 1$.[18] So do asset prices, 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. 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 $K = s = (R-1)D$. Both firms and the banking system are therefore leveraged,

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

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

16 Since H is constant, so is α. Decreasing returns already implies $\alpha \in (0, 1)$; we impose the slightly stronger condition $\alpha > (R-1)$ as a lower bound on the marginal productivity of assets.
17 The main effect of $\gamma > 1$ would be to deepen the asset price decline.
18 Substituting s_t and s_{t+1} into (10) yields an expression of the form $g(p_t) = g(p_{t+1})$ where the function g is increasing.

The economy remains in steady state because the world looks identical going forward from any t. Firms are leveraged because they use credit to purchase and resell productive assets. The value of assets exceeds that of output since assets are durable and produce every period's output. In contrast to Kiyotaki and Moore (1997), however, our model also contains a banking system which is, realistically, leveraged as it intermediates a large volume of credit and payments. In summary, the basic model produces a natural debt structure: households hold deposits with banks whose assets consist of commercial mortgages enabling young firms to purchase productive assets on credit, hence the volume of mortgages equals the market value of assets.

4. Effect on the banking system

There can be no financial distress in a perfect foresight equilibrium. We now discard this assumption by introducing a productivity shock, and measure the resulting dynamics relative to this benchmark. In this section we derive the *fundamental* equilibrium in which asset prices reflect the productive value of assets. This allows to trace out the effect of falling asset prices on the banking system. In this equilibrium, only very large shocks can produce a *banking crisis* which interrupts the credit and payment mechanism that banks provide. In the next section, we also admit self-fulfilling equilibria where asset prices are driven by credit availability. This allows to study feedback from the banking system to asset prices, and gives rise to *capital crunches* and *financial instability*.

4.1. Reactions to a shock

An unexpected productivity shock reduces future total factor productivity permanently by $\tau \in [0, 1]$.[19] A relevant interpretation in the context of the Nordic and the Japanese banking crises is that agents realize that productivity will be lower than that priced into current valuations. Going forward, firms will face the technology $y_{T+1} = (1-\tau)f(h_T)$ for $T \geq t$ in producing future output. There are no further shocks after t. In what follows, we derive how the different agents in the model react to arbitrary dynamics in macroeconomic variables, and then aggregate those reactions to determine the equilibrium dynamics.

New firms (entering in t) will value assets less, because they are now less productive. Asset demand (2) now becomes

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

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

Old firms, by contrast, face a situation of debt-deflation. In $t-1$ they had borrowed qH, assuming that in t they would sell goods and assets at continued steady state prices 1 and q, respectively. From (1), cash flows ex post satisfy

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

Debt is predetermined, but the ability to repay, on the right side, is not. If it falls short of debt, the difference is defaulted on and results in a non-performing loan to the banking system,

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

since limited liability prevents $\Pi_t = p_t c_t^f$ from turning negative. An equivalent expression for non-performing loans is $\lambda = \max\{0, \omega - \Pi\}$, which compares firms' ability to withstand unexpected losses, Π, with total losses

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

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

[19] Our results are not specific to this shock; a redistribution from firms to households, for instance, would have similar effects. Kiyotaki and Moore (1997) and Allen and Gale (2000) also work with zero-probability shocks.

The banking system must write off losses on non-performing loans when firms default. (Aggregate bank losses would be the same if mortgages were repackaged into mortgage-backed securities: banks would face equivalent mark-to-market losses.) 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 bank losses. We assume that the banking system can issue no new equity while its capital position is being affected by the short-run dynamics.[20] Hence when bank losses are large, dividends become zero and bank capital falls by $\lambda-(R-1)K$,

$$\begin{array}{ll|l} K_t = & Div_t = & \text{when} \\ \hline K & (R-1)K-\lambda & \lambda \leq (R-1)\,K \\ RK-\lambda & 0 & \lambda \geq (R-1)\,K. \end{array} \tag{18}$$

Thereafter, the dividend policy (5) again makes both future dividends and capital remain constant, namely $Div_{t+i}=(R-1)K_{t+i}$ and $K_{t+i}=K_t$.

4.2. Fundamental equilibrium

The new equilibrium values are now determined by aggregating agents' reactions. Asset market equilibrium is derived as before, where (6) and (7) become

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

Subsequent asset market conditions are of the same form. Goods market equilibrium again equates the value of aggregate supply with aggregate spending. Due to the possibility of default, spending inherits the piece-wise structure from (16) and (18),

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

The first line applies when bank losses remain small. One observes a *wealth effect*: the lower p_t and q_t, the lower aggregate spending. Once firm profits are zero, further losses affect aggregate demand through reduced bank dividends, until they too are zero. Once both firm profits and bank dividends are zero, only households continue spending and the second line applies.[21] Goods market clearing in $t+1$ equates the value of (reduced) output with the sum of household spending, 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 Eq. (10) completes goods market equilibrium. We can now show, in the next two propositions, how worsening fundamentals lead to falling prices and deteriorating balance sheets.

Proposition 2 (Falling prices).

(a) *The dynamics are short-lived: a new steady state is reached in* $t+1$.
(b) *The dynamic adjustment to a greater shock* τ (*worse fundamentals*) *involves*

[20] The assumption is somewhat less objectionable here than in the context of Rochet (1992) or van den Heuvel (2007) since evidence suggests that banks find it difficult to raise equity when sustaining losses.
[21] 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.

- *a greater asset price decline:* $\delta'(\tau) > 0$,
- *more deflation:* $p_t'(\tau) \leq 0$ *until the price level reaches a floor* $\bar{p}_t$.

Connecting successive s_{t+i} using the Euler equation (10) implies a constant price level, hence a new steady state, from $t+1$ onward (see Appendix A.1). Intuitively, the dynamics are short-lived due to the overlapping-generations structure: old firms, whether or not they default, exit the economy in t. 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 (Proposition 1). The transitional dynamics occur in the periods t and $t+1$. The asset price q_t falls because the shock reduces the productivity with which assets will be used. Solving (19) forward and inserting the new steady state price level $p_{t+1}(\tau)$ yields

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

Comparing with (11) shows that the fundamental asset price falls by the proportion

$$\delta(\tau) = \tau p_{t+1} + (1 - p_{t+1}) > 0 \quad \text{for } \tau > 0. \tag{22}$$

This decline produces a wealth effect, because firm profits and bank dividends contribute to aggregate demand. The goods market (20), upper line, can be simplified to

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

The wealth effect reduces firm profits and bank dividends, and the price level falls to attract extra spending by households ($s_t - s = \delta(\tau)qH$). By spending more on goods, households spend away more of their deposits, leaving banks with less liabilities to carry over, consistent with the reduced value of bank assets. (This is akin to deposit withdrawals in banking models where deposits do not serve as means of payment.) The consequence is deflation, since $\gamma < 1$ in (23). But deflation in this model is temporary; the price level $p_{t+1}(\tau)$ reverts to $p_{t+1} \geq 1$ (see Appendix A.1). It is also limited by the fact that 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,

$$\bar{p}_t = \left(\frac{R}{\alpha}\right)^{-\gamma} < 1, \quad \bar{s}_t = \bar{p}_t y = s\left(\frac{R}{\alpha}\right)^{1-\gamma}. \tag{24}$$

Proposition 3 (Deteriorating balance sheets).

(a) *Total losses* $\omega(\tau)$ *and bank losses* $\lambda(\tau)$ *increase monotonically in the shock* $\tau \in [0, 1]$.
(b) *The space of fundamentals* $[0, 1]$ *falls into four ranges, delimited by thresholds* τ_i *according to how losses are borne: small losses are borne by firms, larger losses are shared.*
(c) *On bank balance sheets, the reduction in credit is matched by*
- *a contraction of inside money for any* $\tau > 0$, *and*
- *a decline in bank capital when* τ *exceeds a threshold* τ_{Div}.

That losses are increasing in τ follows directly from Proposition 2. That losses are borne hierarchically is a result of the nature of standard debt, together with agents' limited ability to absorb losses. Each transition is marked by a threshold i, which can be expressed equivalently as τ_i, δ_i, or λ_i, since the mapping from fundamentals to outcomes is unique. The explicit thresholds appear in Appendix A.2.

The intuition is that greater adverse shocks cause greater losses as macroeconomic conditions (especially asset prices) deteriorate—loss-given-default is endogenous. Losses then 'cascade' down the debt structure (see Fig. 3).

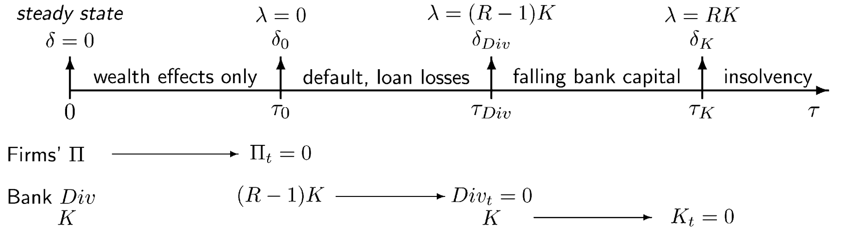


Fig. 3. Deteriorating balance sheets.

- When $\tau < \tau_0$, the asset price decline is small enough to cause no defaults. Losses are borne by firms alone, whose profits fall from Π to Π_t.
- When $\tau > \tau_0$, firms default and pass on further losses as non-performing loans λ. Over this second range, the banking system absorbs bank losses by reducing its dividend payout.
- When $\tau > \tau_{Div}$, bank losses exceed normal bank profits, $\lambda > (R-1)K$, and the difference is written off bank capital.
- Finally, when $\tau > \tau_K$, the volume of bank losses wipes out bank capital, $K_t < 0$. With the banking system insolvent, any additional losses are ultimately borne by depositors.

It now becomes apparent how falling asset prices affect the banking system. Recall the balance sheet identity $q_t H \equiv D_t + K_t$. As fundamentals deteriorate, credit demand falls since new firms borrow less for purchasing less-valued assets, hence the size of the banking system shrinks ($q_t H < qH$). But if bank assets contract, so must liabilities. For shocks below τ_{Div}, bank losses are small and bank capital remains intact ($RK - \lambda - Div_t = K$). Hence deposits must fall to match the decline in credit; indeed, from (23) deposits equal $D_t = RD - s_t = D - \delta qH$.[22] As deposits are the 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 in steady state.[23] For shocks exceeding τ_{Div}, the asset price falls by more than δ_{Div}, bank losses exceed bank profits and bank capital declines as a result. Deposits remain at $\bar{D}_t = RD - \bar{s}_t$, since household spending and the price level remain constant at (24). Thus bank 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 noteworthy: it obtains even when the banking system holds none of the traded assets—its exposure to asset prices is entirely *indirect*, through the condition of its borrowers.

Note that the assumption of firms issuing debt rather than equity is not essential for the results. If banks financed firms by purchasing their equity, any losses to firms would *immediately* translate into bank losses. Equity financing would give banks a share (say $\theta < 1$) of firms' revenue $p_t y + q_t H$ in (15). But this implies positive unexpected losses as soon as prices fall below their steady state values, and these losses tend to be larger than under debt financing.[24] The impact on bank capital in (25) would be larger and more immediate, similar to the exposure banks would face when holding the traded assets

[22] 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.

[23] The model is consistent with the 'credit counterparts' determination of the money supply: inside money expands by loan extension and contracts by loan repayment.

[24] Relative to expected repayments, banks would lose $\lambda^e = \theta[(1-p_t)y + \delta qH]$ which is positive whenever $p_t < 1$ or $\delta > 0$. By contrast, λ in (16) turns positive only when prices fall by *more* than δ_0 and $(1-p_0)$, respectively (see Fig. 3 and Appendix A.2). Moreover, if debt and equity yield the same return to banks in steady state (hence in expectation), then holding equity hurts banks more than holding debt, as $\lambda^e = \lambda + (1-\theta)[p_t y + q_t H]$. This is because under debt financing banks recover the maximum feasible repayment when firms default, not just the fraction θ thereof.

directly. Hence, our assumption that firms issue debt allows to talk of default, but it is not essential for the results in this paper. By contrast, the assumption that banks issue fixed-value deposits is essential, because this is what translates bank losses directly into falling capital in (25).

The banking system turns insolvent ($K_t = 0$) when the asset price falls by δ_K and bank losses reach $\lambda = RK$. Even larger fundamental shocks than τ_K are conceivable, whereupon depositors would start bearing losses. At the limit $\tau \to 1$, assets lose their productive use, their price collapses to zero, and so does credit demand ($\delta(1) = 1$, $q_t H = 0$). In response, depositors spend as much as they can of their deposits on goods ($\bar{s}_t = \lambda - RK$), and their remaining deposits are engulfed by negative net worth, $K_t = -\bar{D}_t$. This is consistent with the household budget constraint, since there is no future goods market: the collapse of the banking system destroys the credit and payment mechanism that had enabled firms and households to produce and allocate resources efficiently. The assets of defaulting firms are repossessed by households, and the economy reverts to autarky where households' inefficient home production yields output as low as $g(H)$, with adverse consequences on the welfare of all agents.

This concludes 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 can be described 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 if the banking system books only loans and holds none of the traded assets directly.

5. Feedback from the banking system

This section shows that banks' effort to keep their leverage from rising can be self-defeating in general equilibrium, producing a spiral of credit contraction, falling asset prices and mounting losses. This unstable interaction qualifies as financial instability. In the previous sections bank behavior remained passive: as asset prices and bank capital fell, credit demand was accommodated at R, so the value of assets was driving money and bank capital. This elastic credit specification allowed to examine causality from asset prices to banking, without any feedback. However, as bank capital fell one-for-one with credit in (25), the capital-asset ratio rapidly deteriorated. Banks in reality are not indifferent to this ratio: capital regulation, risk management or agency problems prevent banks from raising their leverage indefinitely. To maintain their leverage during downturns, they actively shrink their balance sheets in response to falling asset prices; indeed, empirical evidence suggests that the leverage of financial institutions in aggregate is even *procyclical* (Adrian and Shin, 2008a). Incorporating this behavior results in a new channel whereby the state of the banking system *feeds back* onto asset prices.

5.1. Constrained equilibria and financial instability

Suppose the banking system seeks to hold leverage fixed, for any of the reasons noted earlier. (Allowing procyclical leverage would only strengthen results.) For concreteness, we assume that banks maintain a minimum capital-asset ratio equal to that in steady state; given (13), this ratio equals $R/(R-1)$. Two new considerations arise. First, credit supply cannot exceed a multiple of bank capital

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

where (25) was used along with the restriction that bank assets cannot be negative. This capital constraint defines the maximum permissible bank lending for a any level of losses, hence capitalization. Second, if credit is constrained so are asset prices, since assets are purchased on credit. Eq. (8) becomes,

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

We call this equation credit-constrained asset pricing. Viewed as an asset pricing formula, the lending rate $R_t > R$ discounts the market's forward-looking asset valuation down to the constrained asset price. Equivalently, viewed as credit demand, the lending rate rises to bring credit demand down to constrained credit supply. (Raising the user cost in (19) reduces the size of the loans firms can afford.)

A *constrained equilibrium* is a set of endogenous prices $\{p_{t+i}, q_{t+i}, R_{t+i}\}_{i=0}^{\infty}$ that satisfies the capital constraint (26), the choices of households, firms (14)–(16) and the banking system (18), and hence the equilibrium conditions of the goods market (20)–(21), the asset market (27) and thus the credit market. The main feature of such an equilibrium is that asset prices are now driven by credit availability, hence ultimately by bank capital. But this only happens when $\lambda > (R-1)K$, so the goods market obeys (24) regardless of τ. Thus, as shown in Appendix A.3, one finds $\{q_t, R_t\}$ consistent with (26)–(27), given $\{\bar{s}_t, \bar{p}_t, \bar{p}_{t+1}\}$.

This allows us to show how feedback from banking to asset prices can lead to capital crunches, financial instability and banking crises as fundamental or as self-fulfilling equilibria. A *capital crunch* occurs when the supply of bank credit becomes restricted by capitalization. *Financial instability* refers to an unstable contraction of credit which propels the system toward the collapse of the credit and payment functions it provides.

Proposition 4 (Capital crunches, financial instability, and banking crises).
When banks seek to hold their leverage fixed, then

(a) *For good fundamentals ($\tau \leq \tau^*$),*
- *the fundamental equilibrium can still occur, 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) *When asset prices fall below a critical threshold δ^*, the interaction between asset prices and bank losses produces financial instability.*

The results are best illustrated with reference to Fig. 4, which plots credit demand, supply and bank capital against the asset price decline δ. The thick line represents the capital constraint (26). It does not bind when bank capital remains intact, because lower asset prices (higher δ) mean that credit demand q_tH is smaller than admissible lending qH anyway. However, once capital falls, admissible lending declines very steeply: to keep bank leverage constant, each new loss reduces admissible lending by

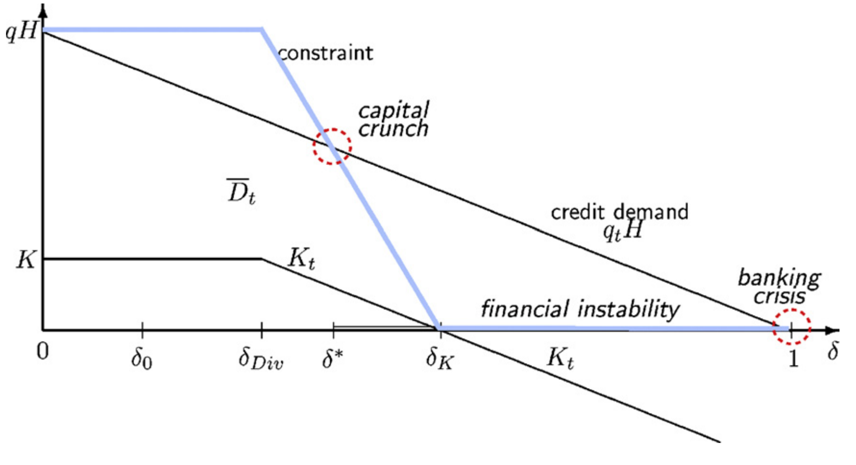


Fig. 4. Financial extremes.

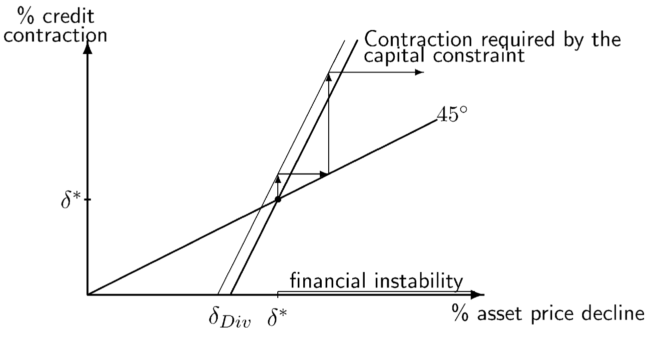


Fig. 5. Financial instability.

a factor of $R/(R-1)$. The constraint becomes binding once the asset price decline reaches the critical threshold

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

At this point the capital crunch sets in (see (30) below). Since the asset price decline necessarily exceeds δ^* if the shock exceeds τ^*, the space of fundamentals [0, 1] falls into two areas.

Good fundamentals ($\boldsymbol{\tau} \leq \boldsymbol{\tau}^*$): When assets are priced at their fundamental value (22), the capital constraint does not bind ($\delta(\tau) < \delta^*$), so the fundamental equilibrium found earlier remains an equilibrium. However, the capital constraint binds *whenever* $\delta \geq \delta^*$, whether or not this decline is fundamental. Hence self-fulfilling credit crunches and banking crises are also possible. Fig. 4 shows the fixed points of (26) where credit contraction and asset price decline are mutually consistent. The capital crunch ($\delta = \delta^*$) and the banking crisis ($\delta = 1$) are the two self-fulfilling equilibria where the asset price decline generates exactly the measure of bank losses $\lambda(\delta)$ that forces bank lending to contract by δ percent, thus validating the asset price decline. This may happen even as $\tau \to 0$; the system can always jump to a constrained asset price. (This is easy to imagine when banks hold mortgage-backed securities whose market price jumps on expectations.) Self-fulfilling equilibria are associated with an interest rate spread (derived in Appendix A.3). Interestingly, in a self-fulfilling capital crunch, the stronger the fundamentals, the greater the spread required to bring down healthy credit demand to constrained credit supply,

$$\frac{R_t(\tau)-1}{R-1} = \frac{1-\tau}{1-\tau^*} > 1 \quad \text{for}\ \tau < \tau^*. \tag{29}$$

Poor fundamentals ($\boldsymbol{\tau} > \boldsymbol{\tau}^*$): When the shock is large, $\delta(\tau)$ can only exceed δ^* and the capital constraint necessarily binds. Financial instability then propels the system toward a systemic banking crisis as the only possible outcome, as illustrated in Fig. 5. Consider the point that defines the capital crunch,

$$\delta^* = \frac{R}{(R-1)}\left[\underbrace{\delta^* qH + (1-\overline{p}_t)\,y - \Pi}_{\lambda(\delta^*)} - (R-1)\,K\right]/(qH). \tag{30}$$

The 45°-line states that credit and asset values move together, since assets are financed by credit. The slope of the right hand side is far steeper in δ, because constant leverage requires every loss to be met by a multiple contraction of credit. The capital crunch equilibrium is therefore unstable: given δ^*, a slight deterioration of bank losses requires a credit contraction to comply with the capital constraint. But reduced credit deepens the asset price decline and $\delta > \delta^*$ confronts banks with further losses. This requires another cut in credit, setting off a new round of losses with further contractionary effects. Bank losses accrue at a faster rate than the contraction of bank credit can keep up with.

This interaction between asset prices and bank losses yields a natural characterization of financial instability as an unstable credit contraction accompanied by falling asset prices and mounting bank losses. Financial instability occurs in the space between two equilibria, the unstable capital crunch and the stable banking crisis. Banks' attempt to keep their leverage constant is self-defeating in equilibrium. Financial instability is inevitable if fundamentals are sufficiently poor ($\tau > \tau^*$), but it can materialize whenever $\delta > \delta^*$. Absent recapitalization, the process comes to a halt only when credit and asset prices have collapsed in a systemic banking crisis. We have encountered this outcome as a fundamental equilibrium before, but here it occurs for a broader range of shocks $(\tau^*, 1]$, and may even occur as a self-fulfilling equilibrium for any $\tau > 0$. The real effects are equally severe since the credit and payment mechanism ceases to function.[25]

5.2. Comparative statics: vulnerability

All outcomes studied above occur when fundamentals or asset prices exceed certain thresholds. This allows us to define 'financial vulnerability' as the sensitivity of the banking system to falling asset prices, and to relate this notion to structural features of the economy using comparative statics. Specifically, a banking system is more vulnerable to a given asset price decline δ the smaller the thresholds $\{\tau_i, \delta_i\}$, where these thresholds are functions of the structural parameters $\{\alpha, \beta, \gamma\}$. Recall that α relates to firm leverage, as higher marginal productivity encourages firms to spend more on assets. The interest rate equals $R = \beta^{-1}$, the inverse rate of time preference of households. Finally, lower intertemporal elasticity of substitution $(1/\gamma)$ leads to greater 'deflationary tendency' as households are less willing to increase spending when prices fall.[26]

Proposition 5 (Balance sheet vulnerability).
The banking system is more vulnerable to falling asset prices in the presence of

- *higher marginal productivity* (α) *i.e. greater leverage,*
- *higher time preference* (β) *i.e. lower interest rates, and*
- *greater deflationary tendency* (γ).

Appendix A.2 confirms that greater values of $\{\alpha, \beta, \gamma\}$ lead to smaller thresholds $\{\tau_i, \delta_i\}$. The result is intuitive. It is the size of bank 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 losses, the size of which determines the outcome. Higher leverage and lower interest rates both increase asset valuation qH on which the decline δ acts. Similarly, higher γ leads to greater deflation for any given wealth effect δqH in (23). Meanwhile, firms' and banks' ability to withstand losses (Π and K) falls as α and β grow, since this raises firm leverage and lowers the return on bank capital. Hence, $\lambda(\delta)$ shifts up and precipitates worse outcomes; that is, adverse outcomes occur at smaller $\{\tau_i, \delta_i\}$.

Of particular interest is the threshold $\delta^*(\alpha)$, which may be called 'financial stability frontier'. Defined in (28), it is the critical threshold beyond which an asset price decline will trigger financial instability. Clearly, the greater borrower leverage, the smaller the asset price decline that produces financial instability (Fig. 6). Put differently, a given decline of, say, 10% causes financial instability in an economy where balance sheets are weak, yet hardly affects banks where balance sheets are strong. Lower interest rates shift the entire locus down: a banking system is more vulnerable when normal profits are low since these help buffer losses in (25). Note that leverage is essential for financial instability as it constitutes exposure to asset prices. By contrast, a deflationary tendency is not essential in this context: it exacerbates vulnerability ($\gamma \to 1 \Rightarrow \delta^* \to 0$), but its absence does not guarantee financial stability.

[25] This consequence of financial instability is consistent with the definition provided earlier (footnote 1).
[26] This accentuates deflation in (23)–(24). At the limit $\gamma \to 0$, spending is so responsive that the price level remains fixed, $p_t(\tau) = 1$.

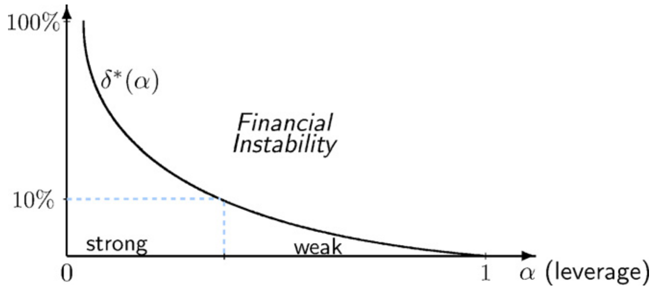


Fig. 6. Financial stability frontier.

6. Concluding remarks

6.1. Policy implications

The model distinguishes between macroeconomic and financial stability. Macroeconomic stability depends on the factors governing deflation and output (γ and τ). Financial stability, by contrast, depends on bank behavior in response to asset prices and bank losses (δ and λ). While financial and macroeconomic instability exacerbate each other, they *need* not occur together.[27] In (8) the unconstrained asset price falls only if future output or price levels do; but (26) shows that the asset price can instead become constrained by bank credit and trigger the adverse outcomes we examined. Thus a policy preventing deflation would not necessarily deliver financial stability.[28] Central banks in practice do recognize macroeconomic and financial stability as distinct, though not independent, concerns.

The question then arises how financial stability might affect the conduct of monetary policy. 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). The main exception identified in the policy literature is an asset price decline large enough to threaten financial stability (Mishkin and White, 2003), surely a factor in recent concerted monetary easing. Evaluating such a policy is difficult, since standard macroeconomic models contain no financial sector and are linearized around the steady state. These shortcomings do not apply to our model, but other extensions would be needed for a proper assessment. Even so, our finding of a financial stability threshold at least suggests that the optimal conduct of monetary policy is likely to change qualitatively beyond δ^* where the banking system turns unstable.[29]

The model also has regulatory implications. First, restrictions on direct asset holding might mitigate, but cannot eliminate, banks' effective exposure to asset prices: once borrowers default, asset prices directly affect bank capital since loss-given-default depends on the performance of collateral, the asset price. This indirect channel is relevant for stress-testing exercises, particularly so for real estate, the asset modeled in this paper, for its wide-spread use as collateral. Second, the model shows that financial instability, absent intervention, only comes to a halt with the collapse of the credit and payment mechanisms that banks provide. Given the role of bank capital in this process, some form of recapitalization appears necessary for restoring financial stability. Finally, the capital constraint resembles a capital adequacy requirement, and may accentuate credit contraction and procyclicality for the system as a whole (Goodhart, 1995b). Yet these effects should not be attributed to capital regulation even within the confines of our model. First, weaker regulation (a smaller capital requirement)

[27] Clearly, a large productivity shock τ may depress output without causing any bank losses, if leverage (α) and deflationary tendency (γ) are sufficiently low. Conversely, a self-fulfilling banking crisis may occur without deflation, and a self-fulfilling capital crunch produces neither deflation nor an output gap if $\gamma \to 0$ and $\tau \to 0$, respectively.

[28] Price stability may be conducive to financial stability, as claimed by Schwartz (1995) or Bordo and Wheelock (1998), but it is not sufficient to guarantee it.

[29] When cast in terms of interest rate rules, a threshold term might therefore be more relevant than the linear terms in asset prices examined in Bernanke and Gertler (1999) or Cecchetti et al. (2000).

would raise leverage, hence strengthen the credit contraction.[30] Second, similar results obtain if banks observe a leverage ratio for reasons other than regulation – such as risk management, monitoring, or market discipline – as empirical evidence indeed suggests (Adrian and Shin, 2008a). The essential link in the model is from losses to credit contraction, whether or not this link involves bank capital (see figure in Section 1). The results, more generally, need not be confined to banks—other intermediaries, mortgage and finance companies, mutual funds, even individual investors might similarly reduce their exposure in response to losses (Shleifer and Vishny, 1997; Shim and von Peter, 2007).

6.2. *Conclusion*

This paper linked banking with asset prices in a macroeconomic model, capturing capital crunches, financial instability, and banking crises as fundamental or self-fulfilling outcomes. In modeling banking distress without bank runs, we parted with the existing banking literature to capture salient features of recent financial crises, notably the deterioration of bank assets as a result of falling asset prices, bankruptcies and bank losses. In adopting a macroeconomic approach, we linked bank assets to firms, and firms' financial positions to macroeconomic conditions.

The characterization of such phenomena in a simple framework is hopefully a useful step in bringing financial stability issues to macroeconomic models. Yet the model's stylized nature involves limitations that future work should address. Important extensions, such as treatments of uncertainty, interbank markets and recapitalization options, are necessary before it is possible to draw any firm conclusions about how monetary and regulatory policy ought to respond to financial instability.

Acknowledgements

I thank Charlie Calomiris, Richard Clarida, Marc Giannoni, Glenn Hubbard, Perry Mehrling, Frederic Mishkin, and Bruce Preston for useful discussions. Criticism from anonymous referees helped improve the exposition. For their comments I am also grateful to Franklin Allen, Jeffery Amato, Claudio Borio, Andy Filardo, Charles Goodhart, Jamie McAndrews, Cyril Monnet, Jarmo Pesola, Rafael Repullo, William Roberds, Jean-Charles Rochet, Hyun Shin, Elu von Thadden, and Alexander Tieman. The views expressed are those of the author and not necessarily those of the Bank for International Settlements.

Appendix A

A.1. *Falling prices*

Using (20) and the balance sheet relation $(R-1)(qH-K)=(R-1)D=s$ yields (23), where the Euler equation assumes the form

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

This form is equivalent to (10) if the Euler equation holds between $t-1$ and t. The equivalence is also valid if, instead, any future price level p_{t+T} takes the proposed form. This normalization can be justified by requiring that a zero shock leaves the fundamental price level unchanged at $p=1$. We now find $p_{t+1}(\tau)$ and recover $\delta(\tau)$ and $p_t(\tau)$. Inserting (21) in (31) and using $K=\alpha y/R=s$,

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

Clearly $p_{t+1}(0)=1$, hence $\delta(0)=0$, and $p_t(0)=1$. A unique solution $p_{t+1}(\tau)$ is guaranteed by $\gamma<1$. The implicit function theorem confirms that $p'_{t+1}(\tau)<0$, and the chain rule on (22) implies $\delta'(\tau)>0$. From (23) then follows that $s_t(\tau)>0$, $p_t(\tau)<1$ and $p'_t(\tau)<0$. Deflation is temporary: households'

[30] A binding constraint is destabilizing whenever the coefficient on δ in (30) exceeds one. What improves stability is not a weaker constraint, but a larger buffer to prevent losses from making the constraint bind. For instance, greater bank profitability raises δ_{Div}, hence also $\delta^*=R\delta_{Div}$.

intertemporal budget constraint from (3) is $\sum_{i=0}^{\infty} s_{t+i}/R^i = RD$; with $s_{t+i} = s_{t+1}$ (the new steady state) it becomes $[s_{t+1} - s] = -(R-1)[s_t - s]$. Since $s_t > 0$ we have $s_{t+1} < 0$; thus $p_t(\tau) < 1$ also requires $p_{t+1}(\tau) > 1$ in (31). Finally, (24) is found by substituting $p_t y = s_t$ from (20) into (31); solving for p_t and replacing $s = \alpha y/R$ yields $\bar{p}_t$, and $\bar{s}_t = \bar{p}_t y$ follows. Using $[s_{t+1} - s] = -(R-1)[s_t - s]$ in (31) also yields $\bar{p}_{t+1} = (1 - (R-1)[(R/\alpha)^{1-\gamma} - 1])^{\gamma/(\gamma-1)}$, after replacing $\bar{s}_t = s(R/\alpha)^{1-\gamma}$.

A.2. Thresholds

Examining the extremes shows that interior thresholds must exist. At one extreme, since $\omega(0) = 0$, we have $\tau_i, \delta_i > 0$; at the other extreme, since $\omega(1) > RK + \Pi$, we have $\tau_i, \delta_i < 1$.[31] By continuity, there exist thresholds, ordered $0 < \tau_0 < \tau_{Div} < \tau_K < 1$, which delimit the four regions as shown in Fig. 3. The thresholds for bank losses, λ_i, are $\lambda = 0$, $\lambda = (R-1)K$, and $\lambda = RK$. Using (17) and (24) allows to translate λ_i into δ_i,

$$\begin{aligned}
\delta_{Div} &= \frac{R-1}{R}\left[\left(\frac{R}{\alpha}\right)^{1-\gamma} - 1\right] &&\rightarrow \quad 1 - \tau_{Div} = \frac{(1-\delta^*/R)}{(1-\delta^*)^{\gamma/(\gamma-1)}},\\
\delta^* &= (R-1)\left[\left(\frac{R}{\alpha}\right)^{1-\gamma} - 1\right] &&\rightarrow \quad 1 - \tau^* = (1-\delta^*)^{1/(1-\gamma)},\\
\delta_K &= \frac{R-1}{R}\left(\frac{R}{\alpha}\right)^{1-\gamma} &&\rightarrow \quad 1 - \tau_K = \frac{(1-\delta^*)^{1/(1-\gamma)}}{R}.
\end{aligned} \tag{32}$$

The critical τ_i have been backed out, given δ_i, from (22), written as $1 - \tau_i = (1 - \delta_i)/p_{t+1}$. This yields explicit τ_i when $p_{t+1} = \bar{p}_{t+1}$ which is independent of τ. To simplify notation, we have defined the constant δ^* to express $\delta_{Div} = \delta^*/R$, $\delta_K = \delta^*/R + (R-1)/R$, and $\bar{p}_{t+1} = (1-\delta^*)^{\gamma/(\gamma-1)}$. The remaining thresholds, δ_0 and τ_0, are implicitly defined by $\omega(\delta_0) = \Pi$ and (22), where $\delta_0 < \delta_{Div}$ implies that $\tau_0 \in (0, \tau_{Div})$.

To show that the thresholds in (32) are decreasing in $\{\alpha, \beta, \gamma\}$, note that δ^* is, while τ_i and δ^* are related positively. As all τ_i depend on α only through δ^*, $\tau_i'(\alpha) < 0$ follows. Also $\tau_i'(\beta) < 0$, since $R = \beta^{-1}$ increases the right hand side of (32) to reduce τ_{Div}, τ_K. Finally, $\tau_i'(\gamma) < 0$ because γ not only reduces δ^*, but also raises the exponents. The remaining threshold is defined implicitly by $\omega(\delta(\tau_0), p_t(\tau_0)) = \Pi$. Using steady state relations, the difference equals $\delta(\tau_0)\alpha/(R-1) + \alpha - p_t(\tau_0) = 0$, where the left hand side increases in τ_0. Hence, raising α, γ and β (lowering R) also decreases τ_0.

A.3. Constrained equilibria

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). Expressing (26) in deviations from steady state,

$$\delta qH \geq \begin{cases} \dfrac{R}{R-1}[\lambda(\delta) - (R-1)K] & \text{if}\,(R-1)K \leq \lambda \leq RK,\\ qH & \text{if}\,\lambda \geq RK. \end{cases}$$

Line two defines the systemic banking crisis with $\delta = 1$. Line one defines the capital crunch: using $\lambda = \omega - \Pi$ with (17) and (24) yields (30). Replacing the resulting ratios with those of (11)–(13) delivers δ^* in (28). The declines $\delta = 1$ and δ^* are fundamental if in (22) we have $\tau = 1$ and τ^*, respectively (Appendix A.2). However, any $\tau < 1$ admits $\delta = 1$, and any $\tau < \tau^*$ also admits $\delta = \delta^*$, as self-fulfilling equilibria for suitable $R_t > R$. By contrast, any $\tau > \tau^*$ implies $\delta(\tau) > \delta^*$, which satisfies (26) only if $\delta = 1$. (Clearly $\tau < \tau^*$ also admits the fundamental equilibrium of Proposition 2.) Finally, R_t is determined by

[31] To show $\omega(1) > RK + \Pi$, note that $\delta(1) = 1$ and $p_t(1) = \bar{p}_t \leq 1$ for any γ. Hence $\omega(1) > qH$ from (17). To show $qH > RK + \Pi$, use (12) to replace $\Pi = ((1-\alpha)/\alpha)(R-1)qH$, and (13) to replace $qH = A = RK/(R-1)$. Canceling RK then gives a strict inequality, since $\alpha > (R-1)$. Thus $\omega(1) > RK + \Pi$ for all α and γ considered.

(27). The banking system's dividend policy implies $K_{t+i} = K_t$: the capital constraint binds permanently if it binds in t. With $q_{t+i} = q_t$, (27) becomes $q_t H = \alpha(1-\tau)\bar{p}_{t+1} y/(R_t - 1)$. Dividing by $qH = \alpha p y/(R-1)$ and using $\bar{p}_{t+1} = (1-\delta^*)^{\gamma/(\gamma-1)}$ yields

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

In a fundamental equilibrium, the fundamentals $\{\tau^*, 1\}$ bring about the declines $\{\delta^*, 1\}$, so with $R_t = R$ there is no spread. In a self-fulfilling equilibrium, the loan rate R_t brings about $\{\delta^*, 1\}$, while $\tau < \tau^*$. In particular, inserting $\delta = \delta^*$ and using (32) yields the spread associated with the self-fulfilling capital crunch shown in Eq. (29).

Data appendix

All asset price series are from the Bank for International Settlements database as of 2005. Finland: Equity = Helsinki stock exchange, all shares (HEX). Residential = existing dwellings, nationwide, price per sqm. Commercial = capital value of office property (75% in Helsinki). Norway: Equity = Oslo stock exchange, 25 companies (OBX). Residential = existing houses or flats, nationwide. Commercial = capital value of office property (84% in Oslo). Sweden: Equity = Stockholm stock exchange, all shares (SAX). Residential = owner – occupied 1–2 dwelling buildings, nationwide. Commercial = capital value of office property (68% in Stockholm).

Bank lending, loan losses, and the number of bankruptcies are from Bank of Finland, Norges Bank and Statistics Norway, Sveriges Riksbank and Statistics Sweden. Loan losses are net of recoveries. Bank lending and loan losses are: for Finland, at the banking group level including all commercial banks; for Norway, commercial and savings banks operating in Norway (including foreign banks, excluding branches abroad); for Sweden: all banks, including savings and cooperatives (excluding mortgage lenders and finance companies). The number of bankruptcies include all corporate, and for Norway also personal, bankruptcies.

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