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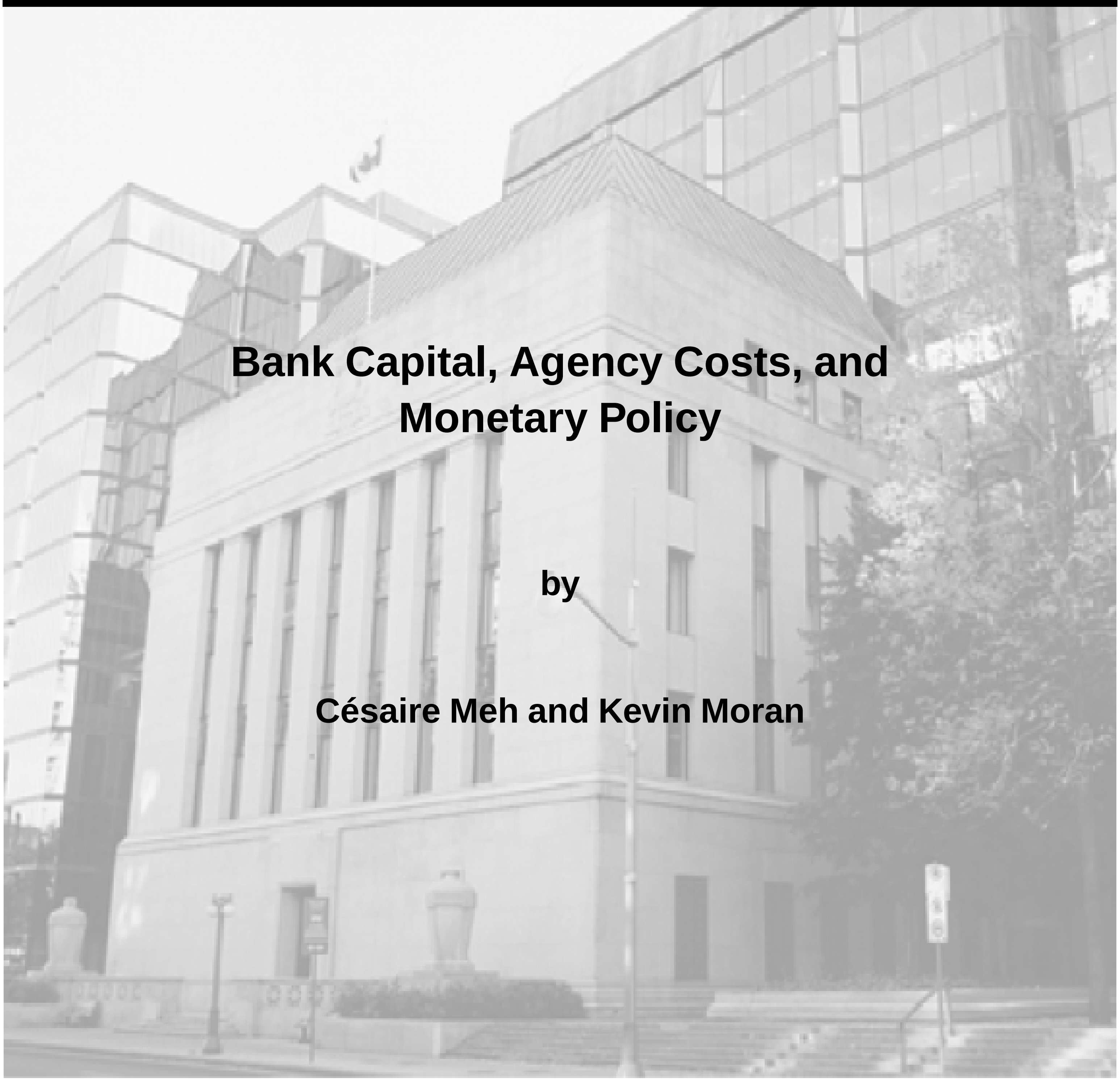

Bank Capital, Agency Costs, and Monetary Policy

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Abstract

Evidence suggests that banks, like firms, face financial frictions when raising funds. The authors develop a quantitative, monetary business cycle model in which agency problems affect both the relationship between banks and firms and the relationship between banks and their depositors. As a result, bank capital and entrepreneurial net worth jointly determine aggregate investment, and are important determinants of the propagation of shocks.

The authors find that the effects of monetary policy and technology shocks are dampened but more persistent in their model than in an economy where the information friction that banks face is reduced or eliminated. After documenting that the bank capital-asset ratio is countercyclical in the data, the authors show that their model, in which movements in this ratio are market-determined, can replicate the countercyclical ratio.

JEL classification: E44, E52, G21
Bank classification: Business fluctuations and cycles; Financial institutions; Transmission of monetary policy

Résumé

D'après les indications disponibles, les banques, comme les entreprises, seraient confrontées à des frictions financières lorsqu'elles mobilisent des fonds. Les auteurs ont donc mis au point un modèle monétaire quantitatif du cycle économique dans lequel il existe une asymétrie d'information aussi bien entre les banques et les entreprises qu'entre les banques et les déposants. Il s'ensuit que les capitaux propres des banques et la valeur nette des entreprises déterminent conjointement le niveau global de l'investissement et jouent un rôle important dans la propagation des chocs.

Les auteurs relèvent que les effets de la politique monétaire et des chocs technologiques sont moins importants mais plus persistants dans leur modèle que dans une économie où les frictions informationnelles touchant les banques sont limitées, voire exclues. Après avoir établi, données à l'appui, que le ratio de couverture des actifs des banques par les capitaux propres évolue en sens inverse du cycle, les auteurs montrent que leur modèle, où ce ratio est déterminé par le marché, parvient à en reproduire le comportement anticyclique.

Classification JEL : E44, E52, G21
Classification de la Banque : Cycles et fluctuations économiques; Institutions financières; Transmission de la politique monétaire

1 Introduction

A large literature has recently emerged that analyzes the quantitative importance of agency costs in otherwise-standard business cycle models. Contributions to this literature usually specify a *single* information friction, which affects the relationship between financial intermediaries (banks) and their borrowers (firms) and limits the amount of external financing that firms can obtain. In such a context, the net worth of firms becomes an important element in the propagation of shocks, because of its ability to mitigate the information friction.[1]

Evidence, however, suggests that banks themselves are subject to financial frictions in raising loanable funds. Schneider (2001) reports that regional and rural U.S. banks appear to be financially constrained relative to banks that operate in urban centres. Further, a large body of evidence suggests that poorly capitalized banks have limited lending flexibility, a fact consistent with the presence of financial frictions at the bank level.[2] Moreover, Hubbard, Kuttner, and Palia (2002) show that differences in the capital positions of individual banks affect the rate at which their clients can borrow. These facts imply that bank capital (bank net worth) might contribute to the propagation of shocks and that therefore its evolution should be analyzed jointly with that of firm net worth.

This paper undertakes such an analysis. We develop a quantitative model that studies the link between the evolution of bank capital and entrepreneurial net worth on the one hand, and monetary policy and economic activity on the other. The framework we employ is a monetary, dynamic general-equilibrium version of Holmstrom and Tirole (1997) that features two sources of moral hazard: the first affects the relationship between banks and their borrowers (firms or entrepreneurs), and the second influences the link between banks and their own source of funds (depositors). The first source of moral hazard arises because entrepreneurs, who produce the economy's capital good, can privately choose to undertake riskier projects in order to enjoy private benefits. To mitigate this problem, banks require entrepreneurs to invest their own net

[1]This literature originates in the theoretical work of Bernanke and Gertler (1989) and Williamson (1987), and is exemplified by Carlstrom and Fuerst (1997, 1998, 2001) and Bernanke, Gertler, and Gilchrist (1999). Other contributions include Cooley and Nam (1998) and Fuerst (1995). The mechanism described in these papers has often been described as the "financial accelerator."

[2]See, for example, the discussions about the "capital crunch" of the early 1990s (Bernanke and Lown 1991; Peek and Rosengren 1995; Brinkmann and Horvitz 1995), and the evidence (Peek and Rosengren 1997, 2000) that shocks to the capital position of Japanese banks resulting from the late 1980s crash in the Nikkei had negative effects on their lending activities in the United States.

worth in the projects. The second source of moral hazard stems from the fact that banks, to which depositors delegate the monitoring of entrepreneurs, may not adequately do so to lower their costs. In response, depositors demand that banks invest their own net worth—that is, bank capital—in the financing of entrepreneurial projects.

We embed this framework within a standard monetary model that we calibrate to salient features of the U.S. economy. Our findings are as follows. First, we show that the presence of bank capital affects the economy's response to shocks. Specifically, the effects of monetary policy and technology shocks are dampened and slightly more persistent in our model than in an economy where the information friction that banks face is eliminated and, as a consequence, bank capital is not present. This is consistent with evidence that monetary policy contractions will depress lending and economic activity more significantly when bank capital is low.[3] In addition, a sensitivity analysis reveals that varying the severity of this financial friction modifies the impact of economic shocks. Second, after documenting that the bank capital-asset ratio is countercyclical in the data, we show that our model, in which movements in this ratio are market-determined rather than originating from regulatory requirements, can replicate the countercyclical ratio.

Intuitively, the mechanism featured in this paper functions as follows. A contractionary monetary policy shock raises the opportunity cost of the external funds that banks use to finance investment projects. In response, the market requires that banks and firms finance a bigger per-unit share of investment projects with their own net worth; i.e., bank capital-asset ratios must increase and entrepreneurial leverage must fall. Since bank capital and entrepreneurial net worth are largely predetermined (they consist of retained earnings from preceding periods), bank lending must be reduced and thus aggregate investment must fall. In turn, lower aggregate investment depresses the earnings of banks and entrepreneurs, thereby reducing future bank capital and entrepreneurial net worth, the declines of which continue to propagate the shock over time after the initial impulse to the interest rate has dissipated. Note that, in contrast to the existing "accelerator" literature, the joint evolution of entrepreneurial net worth and bank capital affects how much external financing firms can raise, and therefore the scale of the

[3] Van den Heuvel (2002b) reports that the capital position of a state's banking system is negatively related to the subsequent reaction to that state's output following monetary policy shocks. Kishan and Opiela (2000) report that poorly capitalized banks experience more significant declines in their lending following monetary contractions. In a related result, Kashyap and Stein (2000) show that banks that hold more liquid securities are able to limit the reductions in lending following similar contractions.

investment projects undertaken. In the experiments where the financial friction that banks face is reduced, banks hold less capital (none if the friction is completely eliminated), and bank lending therefore relies relatively more on household deposits. In such circumstances, the increase in the price of these deposits that a contractionary shock causes leads to bigger adverse effects on investment and output.

Our paper is related to others that study the link between bank capital and economic activity. Van den Heuvel (2002a) analyzes the relationship between bank capital, regulatory requirements, and monetary policy. In his model, bank capital is held as a buffer stock against the eventuality that regulatory requirements will bind in the future, as opposed to our model, where bank capital serves to mitigate the financial friction faced by banks. Moreover, the production, savings, and monetary sides of Van den Heuvel's (2002a) model are not fully developed, whereas we present a detailed general-equilibrium model. Unlike in Chen's (2001) paper, which also constructs a dynamic version of Holmstrom and Tirole (1997), our paper studies quantitatively the link between bank capital and monetary policy, by embedding the double moral hazard environment in a standard monetary version of the neoclassical model.[4] Other recent papers that consider bank capital in dynamic frameworks include Smith and Wang (2000) and Berka and Zimmermann (2002). The role assigned to bank capital in those papers, however, differs from the role it plays in our paper.[5]

The remainder of this paper is organized as follows. Section 2 describes the basic structure of the model. To reduce the complexity and focus the discussion on the financial contract that links banks, entrepreneurs, and households, we assume that households are risk-neutral and that only entrepreneurs require external financing. The model is calibrated in section 3. Section 4 reports the implications of the basic model for the effects of wealth shocks, monetary policy, and technology shocks on economic activity. Section 5 extends the model, by introducing risk aversion in household preferences and requiring bank financing in both sectors (capital-good and consumption-good production) of the economy. It shows that the main qualitative features of the results are not affected by these extensions. Section 6 describes our two main findings: (i)

[4]Another difference is the presence of physical capital in our model.

[5]In Smith and Wang (2000), bank capital plays the role of a buffer stock that allows banks to continue servicing the liquidity requirements of long-lived financial relationships with firms. In Berka and Zimmermann (2002) bank capital is valued because of exogenously imposed capital adequacy requirements. See also Stein (1998), Bolton and Freixas (2000), and Schneider (2001).

the presence of bank capital affects the amplitude and the persistence of shocks, and (ii) the market-generated capital-asset ratio is countercyclical. Section 7 concludes.

2 The Model

2.1 The environment

There are three classes of risk-neutral agents in the economy: households, entrepreneurs, and bankers, with a population mass of η^h, η^e, and η^b, respectively, where $\eta^h + \eta^e + \eta^b = 1$. In addition, there is a monetary authority that conducts monetary policy by targeting interest rates.

There are two distinct sectors of production. In the first, many competitive firms produce the economy's final good, using a standard constant-returns-to-scale technology that employs physical capital and labour services as inputs. Production in this sector is not affected by any financial frictions.

In the second sector, entrepreneurs produce a capital good that will augment the economy's stock of physical capital. Contrary to the first sector, the production environment in the capital-good sector is characterized by two distinct sources of moral hazard, and the resulting agency problems limit the extent to which entrepreneurs can receive external funding to finance their production. First, the technology available to entrepreneurs is characterized by idiosyncratic risk that is partially under the (private) control of the entrepreneur. Monitoring entrepreneurs is thus necessary to limit the riskiness of the projects they engage in. Second, the monitoring activities performed by the agents capable of undertaking them, the bankers, are themselves not publicly observable. Moreover, a given bank cannot choose projects to finance in a manner that diversifies away the risk to its loan portfolio, thus implying that a bank can fail.

To limit the impact of these financial imperfections, households (the ultimate lenders in this economy) require that both entrepreneurial net worth and bank capital be invested in a project before they can be induced to deposit their own money towards the funding of entrepreneurs' projects. The joint evolution of entrepreneurial net worth and bank capital thus becomes an important determinant in the reaction of the economy to the shocks that affect it.

Households are infinitely lived; they save by holding physical capital and money. They divide their money holdings between what they send to banking institutions and what they keep as cash; a cash-in-advance constraint for consumption rationalizes their demand for cash. Households cannot monitor entrepreneurs or enforce financial contracts, and therefore lend to them only indirectly, through their association with a bank that acts as delegated monitor. Bankers and entrepreneurs face a constant probability of exiting the economy; surviving individuals save by holding capital, whereas those who receive the signal to exit the economy consume their accumulated wealth. Exiting entrepreneurs and bankers are replaced by newly born individuals, so that the population masses of the three classes of agents do not change. Figure 1 illustrates the timing of events that unfold each period in our model. In section 2.2 we will describe in greater detail these events, the optimizing behaviour of each type of agent, and the connections between them.

2.2 Households

Each household enters period t with a stock, M_t, of money and a stock, k_t^h, of physical capital. The household is also endowed with one unit of time, which is divided between leisure, work, and the time cost of adjusting the household's financial portfolio. At the beginning of the period, the current value of the aggregate technology and monetary shocks is revealed.

The household then separates into three different agents with specific tasks. The household *shopper* takes an amount, M_t^c, of the household's money balances, travels to a retail market, and purchases consumption goods (c_t^h) for the household. The *financier* gets the remaining amount of money balances, $M_t - M_t^c$, which, along with X_t (the household's share of the current injection of new money from the central bank), will serve as the household's contribution to the financing of entrepreneurial projects. The return from this financing is risky: entrepreneurial projects financed with the help of the household's funds could fail. In such a case, those funds are lost completely; the probability that this will happen is denoted by $\tilde{\alpha}$ (the determination of $\tilde{\alpha}$ is discussed below). Finally, the household's *worker* travels to the final-good sector and sells the household's labour services (h_t) at a real wage, w_t^h, and the household's physical capital (k_t^h), which carries a (real) rental rate of r_t^k.

We assume that an unanticipated monetary injection is distributed to the households' financiers rather than to the shoppers. The monetary injection therefore enters the economy through the financial markets, creating an imbalance between the amount of liquidity present in financial markets and what is available in the final-good market. In principle, households could correct this imbalance by reducing the amount of liquidity they send to financial markets (i.e., increasing M_t^c), but the costs inherent in adjusting financial portfolios limits the extent to which they are prepared to do so. As a consequence, some of the imbalance remains, leading to a reduction in the opportunity cost of funds in the financial market and thus downward pressure on nominal interest rates. This *limited-participation* assumption is used in several recent quantitative models of monetary policy, such as in Dotsey and Ireland (1995), Christiano and Gust (1999), and Cooley and Quadrini (1999).

The maximization problem of a representative household is as follows:

$$\max_{\{c_t^h, M_{t+1}, M_t^c, h_t, k_{t+1}^h\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[c_t^h - \chi \frac{(h_t + v_t)^\gamma}{\gamma} \right], \tag{1}$$

where β is the time discount of households, c_t the household's consumption, h_t its labour effort, and $v_t \equiv \frac{\phi}{2}\left(\frac{M_t^c}{M_{t-1}^c} - \varphi\right)^2$ the time cost of adjusting the household financial portfolio.[6] The expectation is taken over uncertainty about aggregate shocks to monetary policy and technology as well as over the idiosyncratic shocks that affect each household (the success or failure of the projects that the household will indirectly finance through its association with a banker). The risk-neutrality behaviour that characterizes this utility function implies that households value only expected returns and do not seek to smooth out their consumption patterns.[7] The maximization is subject to both the cash-in-advance constraint,

$$c_t^h \leq \frac{M_t^c}{P_t}, \tag{2}$$

and the budget constraint,

$$\frac{M_{t+1}}{P_t} + q_t k_{t+1}^h = s_t \frac{r_t^d}{\tilde{\alpha}} \left(\frac{M_t - M_t^c + X_t}{P_t} \right) + \frac{M_t^c}{P_t} - c_t^h + w_t^h h_t + \left(r_t^k + q_t(1-\delta) \right) k_t^h. \tag{3}$$

The cash-in-advance constraint (2) states that the real value of the shopper's cash position ($\frac{M_t^c}{P_t}$) must be sufficient to cover planned expenditures of consumption goods (c_t^h). The budget constraint (3) expresses the evolution of the household's assets, with the sources of income on the

[6] We follow Christiano and Gust (1999) in using units of time to express the costs of adjusting financial portfolios.

[7] The assumption of risk-neutrality is important for the financial contract between households, banks, and entrepreneurs, as discussed in section 2.5.

right-hand side of the equation, and the assets purchased on the left. The first source of income is the (real) return from the deposits $(M_t - M_t^c + X_t)$ invested by the household in the bank. We denote the expected return of these deposits by r_t^d. Hence, since $\tilde{\alpha}$ is the probability of success of the entrepreneurial projects financed by the bank, the realized return is $\frac{r_t^d}{\tilde{\alpha}}$ if the project is successful (an outcome indicated by $s_t = 1$), and 0 otherwise ($s_t = 0$). Three additional sources of income are also present: any leftover currency from the shopper's activities $(\frac{M_t^c}{P_t} - c_t^h)$, the wage and capital rental income collected by the worker $(w_t^h h_t + r_t^k k_t^h)$, and the real value of the undepreciated stock of capital $q_t(1-\delta)k_t^h$, where q_t is the value of capital at the end of the period in terms of final goods. Total income is then transferred into financial assets (end-of-period real money balances, M_{t+1}/P_t), or holdings of physical capital (k_{t+1}^h).

The first-order conditions of the problem with respect to c_t^h, M_{t+1}, M_t^c, h_t, and k_{t+1}^h are as follows:

$$1 = \lambda_{1t} + \lambda_{2t}, \tag{4}$$

$$\frac{\lambda_{2t}}{P_t} = \beta E_t \left[\frac{\lambda_{2,t+1} r_{t+1}^d}{P_{t+1}} \right], \tag{5}$$

$$\frac{\lambda_{2t} r_t^d}{P_t} + \chi (h_t + v_t)^{\gamma-1} v_1 (\cdot_t) = \frac{\lambda_{1t} + \lambda_{2t}}{P_t} - \beta^h E_t \left[\chi (h_{t+1} + v_{t+1})^{\gamma-1} v_2 (\cdot_{t+1}) \right], \tag{6}$$

$$\chi (h_t + v_t)^{\gamma-1} = \lambda_{2t} w_t^h, \tag{7}$$

$$\lambda_{2t} q_t = \beta^h E_t \left[\lambda_{2,t+1} (r_{t+1}^k + q_{t+1}(1-\delta)) \right]. \tag{8}$$

In these expressions, λ_{1t} represents the Lagrange multiplier of the cash-in-advance constraint (2) and λ_{2t} a similar multiplier of the budget constraint (3).

Equation (4), which equates the sum of the two Lagrange multipliers to 1, reflects the fact that the marginal utility of consumption is constant for the risk-neutral household. Equation (5) states that, by choosing an extra unit of currency as a savings vehicle, the household is forgoing a utility value of $\frac{\lambda_{2t}}{P_t}$; the household is compensated, in the next period, with the return from holding this extra unit of currency (the gross nominal interest rate, r_{t+1}^d), a return which, when properly deflated, discounted, and expressed in utility terms, is valued at $\beta E_t \left[\frac{\lambda_{2,t+1} r_{t+1}^d}{P_{t+1}} \right]$. Equation (6) states that, by choosing to keep an extra unit of currency for use in the final-good sector, the household forgoes the return that would have been associated with this extra unit if it had been sent to the financial sector (r_t^d), and must pay adjustment costs valued at

$\chi(h_t + v_t)^{\gamma-1} v_1(\cdot_t)$. In return, the household receives the current utility value of this extra liquidity $(\lambda_{1t} + \lambda_{2t})$, and relaxes the next period's expected portfolio adjustment costs by an amount valued at $\beta E_t \left[\chi(h_{t+1} + v_{t+1})^{\gamma-1} v_1(\cdot_{t+1})\right]$. Equations (7) and (8) are standard; because $\lambda_2 < 1$, however, inflation introduces a distortion in labour-supply decisions.

2.3 Final-good production

The final-good sector features perfectly competitive producers that transform physical capital and labour inputs into the economy's final good. The production function they use exhibits constant returns to scale and is affected by serially correlated technology shocks. Aggregate output, Y_t, is given by:

$$Y_t = z_t F(K_t, H_t^h), \tag{9}$$

where z_t is the technology shock, K_t the aggregate stock of physical capital, and H_t^h the aggregate labour inputs from households. No financial frictions are present in this sector; therefore, the usual first-order conditions for profit maximization apply and the aggregate profits of final-good producers are zero. The constant-returns-to-scale feature of the production function implies that we can concentrate on economy-wide relations, which will coincide with the firm-level relations.

We assume that the technology shock evolves according to a standard AR(1) process, so that:

$$z_t = \rho_z \, z_{t-1} + \epsilon_t^z, \; \epsilon_t^z \sim (0, \sigma^z). \tag{10}$$

The competitive nature of this sector implies that the rental rate of capital and the wage are equal to their respective marginal products:[8]

$$r_t^k = z_t F_1(K_t, H_t^h); \tag{11}$$

$$w_t^h = z_t F_2(K_t, H_t^h). \tag{12}$$

[8] To ensure that bankers and entrepreneurs can always pledge a positive (but possibly very small) amount of net worth in the financial contract negotiations, we also assume that the aggregate production function includes a small role for labour inputs from entrepreneurs and bankers, which entitles them to small wage payments every period. Since those wages have no effects on the dynamics of the model, we ignore them, in keeping with Carlstrom and Fuerst (1997, 2001). Similarly, Chen (2001) assumes that entrepreneurs and bankers are entitled to modest levels of endowment each period.

2.4 Capital-good production

Each entrepreneur has access to a production technology that uses units of the final good as input and generates capital goods if successful. Specifically, an investment of size i_t units of final goods will contemporaneously yield a publicly observable return of Ri_t units of physical capital if the project succeeds, but zero units if it fails; the investment size i_t is specified in the lending contract and chosen jointly by the entrepreneur and their financial backers.

Entrepreneurs can influence the riskiness of the projects they undertake; they may pursue a project that has a low probability of success because of the private benefits that stem from it and which accrue solely to them. Specifically, we follow the formulation of Holmstrom and Tirole (1997) and Chen (2001) and assume that three types of project exist, each carrying a different mix of public return and private benefits.[9] First, the *good* project involves a high probability of success (denoted α^g) and zero private benefits. Second, the low private benefit project, while associated with a lower probability of success α^b ($\alpha^b < \alpha^g$), generates private benefits proportional to the investment size and equal to $b\,i_t$. Third, the high private benefit project, while also associated with the low probability of success α^b, brings to the entrepreneurs higher private benefits $B\,i_t$, with $B > b$. Table 1 summarizes the probability of success and private benefits associated with the three types of projects. Given that the two latter projects have the same probability of success but different levels of private benefits, entrepreneurs would prefer the last project (which has a higher private benefit), regardless of the financial contract.

Table 1: Projects Available to the Entrepreneur

Project	Good	Low private benefit	High private benefit
Private benefits	0	bi_t	Bi_t
Probability of success	α^g	α^b	α^b

Bankers have access to a monitoring technology that can limit the extent to which entrepreneurs are able to engage in risky projects. The technology can detect whether the entrepreneurs have undertaken the project with high private benefit, but it cannot distinguish between the other two projects.[10] This implies that, if banks use monitoring technology, the en-

[9]The presence of three projects enables us to model a situation where bank monitoring is imperfect and cannot completely eliminate the asymmetric information problem.

[10]Following Holmstrom and Tirole (1997) and Chen (2001), we interpret the monitoring activities of bankers to

trepreneur will not undertake the project with high private benefits, an outcome that is socially preferable because of the following assumption about returns:

$$q\alpha^b R + B - (1+\mu) < 0 < q\alpha^g R - (1+\mu), \tag{13}$$

where μ is the monitoring cost of banks. Equation (13) states that, even after accounting for the private benefit it provides, the economic return from the third project is negative. In contrast, it is economically viable to pursue the good project.

Monitoring costs are assumed to be proportional to the size of the project; μi_t units of the final good are spent on monitoring when a project of size i_t is financed.[11] The monitoring activities of bankers are not, however, publicly observable. This creates an additional source of moral hazard that affects the relationship between bankers and their depositors (the households).

The nature of the monitoring technology is assumed to imply that all projects funded by a given bank either succeed together or fail together. This perfect correlation implies that each bank faces an idiosyncratic risk of failure that cannot be diversified away.[12] The solution of the model is therefore straightforward, but it can be relaxed at a cost of added complexity; for the above mechanism to remain, it is necessary that the correlation not be zero.[13]

An entrepreneur with a net worth of n_t who undertakes a project of size $i_t > n_t$ needs to rely on external financing from banks worth $l_t^d = i_t - n_t$. The bank provides this funding with a mix of deposits that it collects from the households (d_t), as well as its own net worth (capital) a_t. Once the costs of monitoring the project ($= \mu i_t$) are taken into account, the bank is able to lend an amount $l_t^s = a_t + d_t - \mu i_t$. Banks engage their own funds to mitigate the moral hazard problem that affects their relationship with depositors; in doing so, they have an incentive to monitor entrepreneurs, in order to limit erosion of their capital position. This reassures depositors, who

mean that they inspect cash flows, balance sheets, etc., or verify that firm managers conform with the covenants of a loan. This interpretation differs from the one assigned to monitoring costs in the literature on costly state verification (CSV), where the costs are associated with bankruptcy-related activities.

[11] The proportionality in the monitoring costs as well as in the private benefits makes the aggregation of all contracts straightforward.

[12] The assumption of perfect correlation in the returns of bank assets is the opposite of the extreme assumption in Diamond (1984) and Williamson (1987), where bank assets are perfectly diversified so that banks do not fail and can be encouraged to monitor without their own capital. Ennis (2001a) presents a model where banks may choose to diversify at a cost, and where large, diversified banks and small, non-diversified ones coexist.

[13] The assumption that a given banker cannot diversify perfectly across all their lines of business can be interpreted as a situation where they have specialized their activities within a given sector of the economy, or a given geographical area; in such a situation, the risk of failure will naturally be positively correlated across all projects.

can then provide more of their own funds towards the financing package.

2.5 Financial contract

We concentrate on equilibria where intermediation occurs and the financial contracts lead entrepreneurs to undertake only the good project; α^g thus represents the probability of success of all projects and the probability that households' deposits are repaid ($\tilde{\alpha} = \alpha^g$). We also assume the presence of interperiod anonymity, which implies that only one-period contracts are feasible and allows us to abstract from the complexities that arise from dynamic contracting.[14] The contract specifies how much each of the three participants should invest in the project and how much they should be paid as a function of the project's outcome. One optimal contract will have the following structure: (i) the entrepreneur invests all their net worth, while the bank and the households put up the balance, $i_t - n_t$, (ii) if the project succeeds, the unit return, R, is distributed between the entrepreneur ($R_t^e > 0$), the banker ($R_t^b > 0$), and the households ($R_t^h > 0$), and (iii) all agents receive nothing if the project fails.

Recall that an investment of size i_t returns $R\,i_t$ units of capital good if it is successful, and nothing if it fails. The expected value (in final-good terms) of the entrepreneur's share of the return is thus $q_t \alpha^g R_t^e i_t$ if the good project is chosen, where q_t is the relative price of capital goods in terms of final goods. The financial contract that links the entrepreneur, the banker, and, implicitly, the household seeks to maximize the entrepreneur's expected return, subject to constraints that ensure that entrepreneurs and bankers behave as agreed and that the funds contributed by the banker and the household earn (market-determined) required rates of return. More precisely, an optimal contract is given by the solution to the following optimization program:

$$\max_{\{i_t, R_t^e, R_t^b, R_t^h, a_t, d_t\}} q_t \alpha^g R_t^e i_t, \tag{14}$$

[14]One-period contracts are also used by Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999). General-equilibrium models that focus on dynamic contracting are described in Gertler (1992), Smith and Wang (2000), and Cooley, Marimon, and Quadrini (2003).

subject to

$$
\begin{aligned}
R &= R_t^e + R_t^h + R_t^b, && (15)\\
q_t\alpha^g R_t^b i_t - \mu i_t &\geq q_t\alpha^b R_t^b i_t, && (16)\\
q_t\alpha^g R_t^e i_t &\geq q_t\alpha^b R_t^e i_t + q_t b i_t, && (17)\\
q_t\alpha^g R_t^b i_t &\geq r_t^a a_t, && (18)\\
q_t\alpha^g R_t^h i_t &\geq r_t^d d_t, && (19)\\
a_t + d_t - \mu i_t &\geq i_t - n_t. && (20)
\end{aligned}
$$

Equation (15) simply states that the shares promised to the three different agents must add up to the total return. Equation (16) is the incentive compatibility constraint for bankers, which must be satisfied for monitoring to occur. It states that the expected return from monitoring, net of the monitoring costs, must be at least as high as the expected return from not monitoring, a situation in which entrepreneurs would choose the project with high private benefits and a low probability of success. Equation (17) is the incentive compatibility constraint of entrepreneurs; because bankers monitor, entrepreneurs cannot choose the high private benefit project, but must be induced to choose the good project over the low private benefit one. This is achieved by promising entrepreneurs an expected return that is at least as high as the expected return they would get, inclusive of private benefits, if they were to choose the low private benefit project. Equations (18) and (19), the participation constraints of bankers and households, respectively, state that when these agents engage bank capital and deposits a_t and d_t, they are promised shares of the project's return that are sufficient to attain the (market-determined) required rates of return on bank capital and household deposits (denoted r_t^a and r_t^d, respectively). Equation (20) indicates that the loanable funds available to a banker (its own capital and the deposits it attracted), net of the monitoring costs, must be sufficient to cover the external funding requirements of the entrepreneur.[15]

In equilibrium, the constraints (16) to (19) hold with equality, so that the shares are given

[15] In what follows, we consider only contracts in which (20) holds with equality, because those contracts dominate others in which the inequality is not binding when funds are invested in the good project.

by:

$$
\begin{aligned}
R_t^e &= \frac{b}{\Delta\alpha}, &(21)\\
R_t^b &= \frac{\mu}{q_t \Delta\alpha}, &(22)\\
R_t^h &= R - \frac{b}{\Delta\alpha} - \frac{\mu}{q_t \Delta\alpha}, &(23)
\end{aligned}
$$

where $\Delta\alpha = \alpha^g - \alpha^b > 0$ and $R_t^j > 0$ for $j = e, b, h$.

Note from (21) and (22) that the size of the shares allocated to the entrepreneur and the bank is determined by the severity of the moral hazard problem that characterizes their actions. In particular, were the private benefits, b, and the monitoring costs, μ, to increase, the per-unit share of the project's return allocated to entrepreneurs and bankers would also have to increase for those agents to continue to have an incentive to behave as agreed. In turn, (23) shows that the per-unit share of projects that can be credibly promised to households as payments for their deposits is limited by the extent of these moral hazard problems; were b and μ to increase, this maximal payment to households would decrease.

The introduction of (23) into the participation constraint of households (19) holding with equality leads to the following:

$$
r_t^d d_t = q_t \alpha^g \left(R - \frac{b}{\Delta\alpha} - \frac{\mu}{q_t \Delta\alpha} \right) i_t. \tag{24}
$$

Next, eliminating d_t from (24) using the resource constraint (20), and dividing both sides by i_t, leads to the following:

$$
r_t^d \left[(1+\mu) - \frac{a_t}{i_t} - \frac{n_t}{i_t} \right] = q_t \alpha^g \left(R - \frac{b}{\Delta\alpha} - \frac{\mu}{q_t \Delta\alpha} \right). \tag{25}
$$

Equation (25) illustrates the mechanism that will lead monetary policy shocks to have an effect on the leverage of the economy. An increase in the required rate on deposits, r_t^d, does not affect (all things equal) the maximal per-unit share of the project's return that can be credibly promised to households (the right-hand side of (25)). This increase must be compensated for by a reduction in the contribution of households' funds to the financing; i.e., by an increase in the contributions of bank capital (a_t/i_t) and entrepreneurial net worth (n_t/i_t). At the aggregate level, since bank capital and entrepreneurial net worth do not react immediately to the shock, the adjustment must occur through a reduction in the size of the projects that are financed; i.e., by a decrease in investment.

Solving for i_t in the preceding equation leads to the following relation between the size of the project undertaken, on the one hand, and entrepreneurial net worth and the bank's capital position, on the other:

$$i_t = \frac{n_t + a_t}{G_t}, \tag{26}$$

where G_t is as follows:

$$G_t = 1 + \mu - \frac{q_t \alpha^g}{r_t^d} \left(R - \frac{b}{\Delta\alpha} - \frac{\mu}{\Delta\alpha q_t} \right). \tag{27}$$

In equilibrium, the investment, i_t, must be positive, so G_t must be positive (since a_t and n_t are positive). Therefore, rates of return and prices should be such that:

$$q_t \alpha^g \left(b + \mu / q_t \right) / \Delta\alpha > q_t \alpha^g R - r_t^d (1 + \mu), \tag{28}$$

where condition (28) says that the sum of expected shares paid to the entrepreneur and banker is higher than the expected unit surplus of the good project.

With the size of the investment project determined, we can define the bank capital-asset ratio for this individual contract, as follows:

$$ca_t = \frac{a_t}{(1 + \mu) i_t - n_t}. \tag{29}$$

The quantity i_t in (26) represents the amount of consumption good invested in the production of the capital good. Thus, the expected output of new capital is $i^s(n_t, a_t, r_t^d; q_t) = \alpha^g R i_t$. Once aggregated (see section 2.8), this can be interpreted as the supply curve for the investment good. Note that, since $\frac{\partial G_t}{\partial q_t} = -\frac{\alpha^g (R - b/\Delta\alpha)}{r_t^d} < 0$, this supply curve is upward sloping. Further, (26) makes clear that increases in a_t or n_t shift this supply curve to the right, whereas the intuition discussed above with respect to equation (25) shows that increases in r_t^d shift the curve to the left.[16]

2.6 Entrepreneurs

Entrepreneurs manage investment projects and seek to maximize the expected value of their lifetime utility. They face a constant probability of exiting the economy; this probability is

[16]The demand for the capital good is implicitly defined by the first-order condition of the household problem (equation (8)).

denoted as $1-\tau^e$, so that τ^e is the probability of surviving until the next period. The assumption of finite horizons for entrepreneurs is one way to guarantee that entrepreneurs will never become sufficiently wealthy to overcome financial constraints.[17] We calibrate τ^e such that, in the steady state, entrepreneurs continue to rely on external financing for their activities. Further, entrepreneurs are risk-neutral and are thus willing to accept very low or zero consumption for many periods in return for relatively high consumption in the future, conditional on their survival. The expected lifetime utility is therefore as follows:

$$E_0 \sum_{t=0}^{\infty} (\beta \tau^e)^t c_t^e, \tag{30}$$

where c_t^e denotes entrepreneurial consumption.

Entrepreneurs that must exit the economy receive the signal to do so at the end of the period. Thus, surviving and exiting entrepreneurs participate similarly in the period's activities (financial contract, capital-good production, etc.). They differ, however, in their saving decisions: exiting entrepreneurs consume all available income, whereas surviving ones save for the future. Exiting entrepreneurs are replaced, at the beginning of the following period, by newborn agents; in this manner, the measure of entrepreneurs within the total population remains constant at η^e.

At the beginning of period, t, a fraction, τ^e, of the total number of entrepreneurs present are therefore agents who have survived the preceding period, possibly carrying with them accumulated assets: the stock of physical capital that such a surviving entrepreneur holds is denoted by k_t^e. The remaining fraction $(1-\tau^e)$ of entrepreneurs are newborn agents, who begin the period with no assets.

During the early part of the period, each entrepreneur travels to the final-good sector, where they rent their holdings, if any, of physical capital (at rate r_t^k). This source of income, plus the value of the undepreciated part of the physical capital, constitutes the net worth that entrepreneurs can pledge towards financing the investment projects in the second part of the

[17] Another way to guarantee that entrepreneurs do not become self-financed is to assume that they are infinitely lived but discount the future more heavily than households do. Carlstrom and Fuerst (1997) use this approach.

period. Entrepreneurial net worth is thus given by[18]:

$$n_t = r_t^k k_t^e + q_t(1-\delta)k_t^e. \tag{31}$$

In the second part of the period, after meeting with a banker and (implicitly) the household's financier, each entrepreneur engages in an investment project of size i_t, the maximum that financial backers will allow; recall from (26) that the size of the project is related to net worth, n_t, by $i_t = \frac{n_t+a_t}{G_t}$. As the spot market for capital opens, this entrepreneur can sell some of this capital to purchase consumption, or save it for the next period. The following accumulation equation emerges:

$$c_t^e + q_t k_{t+1}^e \leq s_t\, q_t R_t^e i_t(n_t, a_t; G_t), \tag{32}$$

where s_t is the indicator function that takes a value of 1 if the entrepreneur's project was a success and returned the share R_t^e to the entrepreneur, or 0 if the project failed and returned nothing to the three participants. Successful, surviving entrepreneurs could, in principle, allocate part of their income to consumption, and part to saving. However, the risk-neutrality feature of their preferences, and the high (expected) internal return from their assets, lead them, in equilibrium, to postpone consumption and save all of their available income. Successful, exiting entrepreneurs, on the other hand, do not wish to save any capital but simply to consume all proceeds from their activities before exiting. This optimizing behaviour is summarized by the following set of consumption and savings decisions:

$$c_t^e = \begin{cases} q_t R_t^e i_t(n_t, a_t; z_t) & , \quad \text{if exiting and successful,} \\ 0 & , \quad \text{otherwise,} \end{cases} \tag{33}$$

$$k_{t+1}^e = \begin{cases} R_t^e i_t(n_t, a_t; z_t) & , \quad \text{if surviving and successful,} \\ 0 & , \quad \text{otherwise.} \end{cases} \tag{34}$$

2.7 Bankers

Like entrepreneurs, bankers are risk-neutral agents who face a constant probability of exit from the economy (their exit rate is denoted by $1-\tau^b$).[19] Exiting bankers are replaced by new agents

[18] Because we assume that all entrepreneurs receive a very small wage, entering entrepreneurs have a non-zero stock of net worth.

[19] As with the entrepreneur's problem, bankers' finite-horizon assumption ensures that they do not become too wealthy and financially unconstrained. A small τ^b will guarantee that, in the aggregate, bank net worth (bank

who enter the economy with no assets. The entering rate of new bankers is such that their population is constant over time. They seek to maximize the expected value of their lifetime utility, as follows:

$$E_0 \sum_{t=0}^{\infty} (\beta \tau^b)^t c_t^b, \tag{35}$$

where c_t^b denotes bank consumption. The bankers' specificity arises from the technology that allows them to monitor entrepreneurs, a function that is delegated to them by the households (the ultimate lenders).

Bank capital, similarly to entrepreneurial net worth, is the sum of rental income and the market value of the undepreciated physical capital held by surviving agents at the beginning of period t:

$$a_t = r_t^k k_t^b + q_t(1-\delta)k_t^b. \tag{36}$$

In the second part of the period, a banker who has succeeded in attracting deposits d_t and pledging a_t of their own capital can finance a project of size i_t. The banker's share of the return from a successful project consists of $R_t^b i_t$ units of the capital good, which can be used to buy consumption or be saved:

$$c_t^b + q_t k_{t+1}^b \leq s_t \, q_t R_t^b i_t(n_t, a_t; G_t), \tag{37}$$

where s_t indicates whether the projects funded by the banker were all successful ($s_t = 1$) or all failed ($s_t = 0$); recall our assumption of perfect correlation across the outcomes of all projects funded by a given banker. The incentives bankers have to save and consume are very similar to those of entrepreneurs, as the following set of consumption and savings decisions illustrates:

$$c_t^b = \begin{cases} q_t R_t^b i_t(n_t, a_t; G_t) & , \text{ if exiting and successful,} \\ 0 & , \text{ otherwise,} \end{cases} \tag{38}$$

$$k_{t+1}^b = \begin{cases} R_t^b i_t(n_t, a_t; G_t) & , \text{ if surviving and successful,} \\ 0 & , \text{ otherwise.} \end{cases} \tag{39}$$

2.8 Aggregation

The linear nature of the production function for capital goods, the private benefits, and the monitoring technology permits us to construct aggregate investment by simply adding up the

capital) remains scarce.

individual projects undertaken by each entrepreneur (the same aggregation procedure applies to all the other variables except prices). We denote all aggregate variables by uppercase letters, as opposed to the individual variables that are represented by lowercase variables. The linearity features of the model also imply that only the first moments of the distributions of entrepreneurial net worth, n_t, and bank capital, a_t, matter for the economy; keeping track of the distribution of net worth and capital across entrepreneurs and bankers is therefore not required. Aggregate investment (I_t) is thus:

$$I_t = \frac{N_t + A_t}{G_t}, \tag{40}$$

where N_t and A_t denote aggregate entrepreneurial net worth and aggregate bank capital, respectively, and G_t was defined in equation (27). Notice that a fall in either A_t or N_t leads to a decrease in current investment, for given values of G_t. Further, the bank capital-asset ratio as defined in (29) can be aggregated to yield the following economy-wide measure:

$$CA_t = \frac{A_t}{(1+\mu)I_t - N_t} = \frac{\frac{A_t}{N_t}}{(1+\mu)\frac{I_t}{N_t} - 1}. \tag{41}$$

The aggregation of (31) and (32), as well as of (34) and (39), yields the following expressions for the aggregate levels of entrepreneurial net worth and bank capital and the laws of motion for K^e_{t+1} and K^b_{t+1}:

$$N_t = \left(r^k_t + q_t(1-\delta)\right) K^e_t; \tag{42}$$

$$K^e_{t+1} = \tau^e \alpha^g R^e_t I_t; \tag{43}$$

$$A_t = \left(r^k_t + q_t(1-\delta)\right) K^b_t; \tag{44}$$

$$K^b_{t+1} = \tau^b \alpha^g R^b_t I_t. \tag{45}$$

The law of motion for aggregate entrepreneurial net worth, N_{t+1}, and aggregate bank capital, A_{t+1}, are found by combining equations (40) to (45), yielding:

$$N_{t+1} = \left(r^k_{t+1} + q_{t+1}(1-\delta)\right) \tau^e \alpha^g R^e_t \left(\frac{A_t + N_t}{G_t}\right), \tag{46}$$

$$A_{t+1} = \left(r^k_{t+1} + q_{t+1}(1-\delta)\right) \tau^b \alpha^g R^b_t \left(\frac{A_t + N_t}{G_t}\right). \tag{47}$$

Equations (46) and (47) show that banking capital and entrepreneurial net worth are interrelated. Notably, equation (47) shows that aggregate bank capital at time $t+1$ depends on the current values of both entrepreneurial net worth and bank capital. Therefore, a shock that affects either of N_t or A_t will have consequences for the future values of bank capital.

The aggregation of (33) and (38) across all entrepreneurs and bankers yields the following expressions for aggregate consumption by these agents:

$$C_t^e = (1-\tau^e)q_t\alpha^g R_t^e I_t(N_t, A_t), \tag{48}$$

$$C_t^b = (1-\tau^b)q_t\alpha^g R_t^b I_t(N_t, A_t). \tag{49}$$

2.9 Monetary policy

We denote the supply of money in the economy at the beginning of period t as $\overline{M_t}$, and the injection of new money during period t as X_t, giving $\overline{M_{t+1}} = \overline{M_t} + X_t$.

As in Christiano and Gust (1999), monetary policy is interpreted as targeting a given value for the nominal deposit rate, r_t^d, and adjusting money supply in a manner that is consistent with this target. This targeting of the interest rate is represented by the following expression, or rule:

$$r_t^d/r^d = (y_t/y)^{\rho_y}(\pi_t/\pi)^{\rho_\pi}e^{\epsilon_t^{mp}},\ \epsilon_t^{mp} \sim (0, \sigma^{mp}), \tag{50}$$

where r^d, y, and π are the steady-state values of r_t^d, y_t, and π_t, respectively, and ϵ_t^{mp} is an i.i.d. monetary policy shock; that is, instances where monetary authorities depart from the systematic portion of their rule (50).[20]

When $\rho_y > 0$, and $\rho_\pi > 0$, monetary policy follows a Taylor (1993) rule in which the central bank increases the nominal interest rate in response to deviations of output and inflation from their steady-state values.

2.10 The competitive equilibrium

The recursive, competitive equilibrium for the economy consists of (i) decision rules for c_t^h, M_{t+1}, M_t^c, h_t, and k_{t+1}^h that solve the maximization problem of the household as expressed in (1) to (3), (ii) decision rules for H_t and K_t that are consistent with the first-order conditions in (11)

[20] Taking logs of the rule in (50) leads to a form more familiar in the literature:

$$\log(R_t^d/R^d) = \rho_y \log(y_t/y) + \rho_\pi \log(\pi_t/\pi) + \epsilon_t^{mp}.$$

and (12), (iii) decision rules for i_t, R_t^e, R_t^b, R_t^h, a_t, and d_t that solve the maximization problem associated with the financial contract in (14) to (20), (iv) the saving and consumption decision rules of entrepreneurs in (33) and (34) and of bankers in (38) and (39), and (v) the following market-clearing conditions:

(a) In the labour market, aggregate demand by final-good producers equals the sum of the individual supply decisions of households:

$$H_t = \eta^h h_t. \tag{51}$$

(b) Total demand for physical capital by final-good producers equals the sum of individual holdings of capital:

$$K_t = \eta^h k_t^h + \eta^e k_t^e + \eta^b k_t^b. \tag{52}$$

(c) In the market for final goods, aggregate production equals aggregate consumption and aggregate investment, including monitoring costs:

$$Y_t = C_t^h + C_t^e + C_t^b + (1+\mu)I_t, \tag{53}$$

where C^h denotes aggregate households' consumption.

(d) In the market for capital goods, aggregate net demand equals the production from successful investment projects:

$$K_{t+1} = (1-\delta)\,K_t + \alpha^g R I_t. \tag{54}$$

(e) Total demand for funds from bankers equals the sum of households' deposits and monetary injections from the central bank:

$$\frac{q_t\alpha^g\left[R - b/\Delta\alpha - \mu/q_t\Delta\alpha\right]I_t}{r_t^d} = \frac{\overline{M_t} - M_t^c + X_t}{P_t}. \tag{55}$$

Finally, the equilibrium rate of return on bank capital is given by the following equation:

$$r_t^a \quad = \quad \frac{\alpha^g\mu\left(1 + N_t/A_t\right)}{G_t\Delta\alpha}. \tag{56}$$

3 Calibration

The model's parameters are calibrated in a manner that ensures certain features of the non-stochastic steady state approximately match their empirical counterparts. Further, whenever possible, we follow the calibration procedures of recent contributions to the literature on agency costs (Carlstrom and Fuerst 1997; Bernanke, Gertler, and Gilchrist 1999; Cooley and Quadrini 1999), to facilitate the comparison of our results with the results of those models.

The discount factor, β, is set at 0.99, so that the average real rate of return on deposits is around 4 per cent.[21] We set γ, the curvature parameter on labour effort in the utility function, to a value of 2.0; this implies that the steady-state wage elasticity of labour supply is 1. The scaling parameter, χ, is determined by the requirement that steady-state labour effort be 0.3.

The production technology in the final-good sector is assumed to take the Cobb-Douglas form

$$Y_t = z_t K_t^{\theta_k} {H_t}^{\theta_h}, \tag{57}$$

where the technology shock, z_t, follows an AR(1) process:

$$z_t = \rho_z \, z_{t-1} + \epsilon_t^z, \; \epsilon_t^z \sim (0, \sigma^z). \tag{58}$$

We set θ_k to 0.36 and θ_h to 0.64. The autocorrelation parameter, ρ_z, is 0.95; σ^z, the standard deviation of the innovations to z_t, is fixed at 0.01.

Monetary policy is assumed to take the form of the original Taylor (1993) rule, so that $\rho_\pi = 1.5$ and $\rho_y = 0.5$. The average rate of money growth (and thus the steady-state inflation rate) is set at 5 per cent on an annualized basis, a value close to post-war averages in many industrialized countries. The standard deviation of the innovations to the rule σ^{mp} is also set to 0.01.

The parameters that remain to be calibrated (α^g, α^b, b, R, μ, τ^e, τ^b) are linked more specifically to the capital-good production and the financial relationship that links entrepreneurs to banks and households. We set α^g to 0.9903, so that the (quarterly) failure rate is 0.97 per cent, as in Carlstrom and Fuerst (1997). We set the remaining parameters so that the steady-state properties of the model display the following characteristics: (i) a capital-asset ratio (CA)

[21] Recall our interpretation of deposits not as literal bank deposits but rather as relatively illiquid assets that provide a higher return than the most liquid assets, like cash.

of around 15 per cent (close to the average ratio for U.S. banks in 2002, according to BIS data); (ii) a leverage ratio (the size of entrepreneurial projects relative to their accumulated net worth, I/N) of 2.0; (iii) a 5 per cent ratio of bank operating costs to bank assets (BOC), which matches the developed economies' estimate in Erosa (2001); (iv) a net return on bank capital (bank equity, ROE) equal to 15 per cent on an annualized basis, a figure close to those reported in Berger (2003) for the late 1990s; and (v) ratios of aggregate investment to output and capital to output of 0.2 and 4, respectively. Table 2 shows the numerical values of the parameter that emerge from the calibration. In particular, the parameter that governs the importance of banks' monitoring costs, μ, is equal to 0.025.

We conduct some experiments where μ is either increased (to $\mu = 0.010$) or decreased ($\mu = 0.001$). Where it is increased, the information friction between banks and depositors is more severe; where it is decreased, the information friction is less severe. Note that, as a result, depositors require that banks engage more of their own net wealth in financing a project of a given size, so that the steady-state value of the capital-asset ratio is first increased (to just over 30 per cent) and then decreased (to 6 per cent). Section 6.1 examines the implications of these changes in parameter values for the effects of monetary policy tightening.

Once all parameter values are chosen, an approximate solution to the model's dynamics is found by linearizing all relevant equations around the steady state, using the methodology described by King and Watson (1998).

4 Quantitative Findings

4.1 Wealth shock

The first experiment consists of a one-time wealth transfer from bankers to households, the results of which are illustrated in Figure 2. This experiment might be useful to consider the effects of shocks that redistribute wealth between the agents in an economy (such as those featured in the "debt-deflation" stories). Alternatively, the experiment can be thought of as approximating exogenous decreases in bank capital, such as those suffered by the branches of Japanese banks that operate in the United States, examined by Peek and Rosengren (1997, 2000).

Table 2: Parameter Calibration

		Household preferences			
	χ	γ	ϕ	β	
	2.75	1.5	5.0	0.99	
		Final-good production			
δ	θ_k	θ_h	θ_e	θ_b	ρ_z
0.02	0.36	0.6399	$5 \cdot 10^{-5}$	$5 \cdot 10^{-5}$	0.95

		Capital-good production			
	μ	α^g	α^b	R	b
Baseline	0.025	0.97	0.67	0.5	0.09
More severe friction	0.05	0.97	0.67	0.5	0.06
Less severe friction	0.001	0.97	0.67	0.5	0.06

Resulting steady-state characteristics				
	CA	I/N	BOC	ROE
Baseline	15%	2.0	5%	15%
More severe friction	31%	1.91	11%	15%
Less severe friction	6%	2.06	2%	15%

The shock examined is a one-time decrease of 10 per cent in bank asset holdings (K_t^B) that is redistributed to households.[22] As a result of this redistribution, bank capital declines immediately (recall equation (44), which links the capital position of banks to their asset holdings); see Figure 2. Bank capital is thus scarcer economy-wide and the required return on bank capital rises accordingly. This leads the financial contract to rely relatively less on bank capital to finance projects (leading to a decline in the capital-asset ratio of banks) and relatively more on entrepreneurial net worth (entrepreneurial leverage therefore falls). Since entrepreneurial net worth is, to a large extent, predetermined, the fall in leverage must occur through sizable declines in bank lending and aggregate investment. The decline in aggregate investment leads to subsequent prolonged periods of depressed levels of bank capital and entrepreneurial net worth, since bank capital and entrepreneurial net worth depend on lagged aggregate investment through retained earnings. These low levels of capital and net worth themselves lead to further periods of low bank lending and investment, in the interrelated manner described by equations

[22]Since bank asset holdings represent a very small portion of households' asset holdings in our model, the positive wealth shock for households is negligible.

(40) to (45). Note that these negative effects of shocks to the capital position of banks on bank lending and investment accord well with the evidence presented in Peek and Rosengren (1995) for American banks, and in Peek and Rosengren (1997, 2000) for branches of Japanese banks operating in the United States.

4.2 Monetary policy tightening

Figure 3 shows the basic model's response to a one percentage point contractionary monetary policy shock ($\epsilon_t^{mp} = -0.01$; recall equation (50)). This shock increases the opportunity cost of the deposits that form part of the external financing that banks arrange for entrepreneurs. This increase in the cost of deposits leads banks to tighten lending, which in turn causes a fall in the scale of the investment projects entrepreneurs are able to undertake. This reduction in project scales means that both entrepreneurs and banks cannot leverage their net worth as much as they could before. This is reflected in the fall of the leverage ratio, I_t/N_t, and in the increase in the capital-asset ratio of banks. This countercyclical movement in the capital-asset ratio is market-determined.

Intuition about this result can be developed using equation (25), repeated here for convenience:

$$r_t^d\left((1+\mu) - \frac{a_t}{i_t} - \frac{n_t}{i_t}\right) = q_t\alpha^g\left(R - \frac{b}{\Delta\alpha} - \frac{\mu}{q_t\Delta\alpha}\right).$$

This equation states that the per-unit share of a project's return that can be credibly promised to households for deposit repayments (the right-hand side of the equation) is limited by the double moral hazard problem. This limitation on payments to households means that the increase in r_t^d must be met with a reduced reliance on deposits (a decrease in d_t) to finance a project of a given size. In turn, this means that banks and entrepreneurs are required to invest more of their own net worth in financing that project: the ratios a_t/i_t and n_t/i_t must increase, which means that the bank capital-asset ratio increases while entrepreneurial leverage falls. Because the levels of entrepreneurial net worth, n_t, and bank capital, a_t, are for a large part predetermined (they consist of accumulated, retained earnings from past periods: recall equations (42) and (44), most of the adjustment is borne by a decrease in the size of investment projects that bankers can finance; i.e., decreases in lending and in project scale, i_t.

Another way to interpret this result is to notice that the increase in the deposit rate, r_t^d, worsens the moral hazard problem that affects the relationship between banks and households: as depositors need to be better remunerated for their deposits, it becomes harder for the contract to ensure that their participation constraint will keep the contract incentive-compatible. To alleviate this worsening of moral hazard, banks pledge more of their own capital in the financial contract.

Aggregate investment thus falls on impact, while the price of new capital increases slightly, as it would following a standard adverse supply shock. Earnings of banks and entrepreneurs also fall, following the reduced scale of investment projects. Because entrepreneurial net worth and bank capital consist of past retained earnings, which in turn depend directly on the scale of past investment projects, the initial fall in investment leads to extended declines in the stock of entrepreneurial net worth and bank capital. These declines help propagate the shock over time, as the interest rate returns to its steady-state level immediately after the impact period. Low net worth and bank capital continue to restrict the scale of investment projects for several periods, which leads to persistent declines in total physical capital and thus output.

4.3 Adverse technology shock

Figure 4 illustrates the effect of a negative technology shock ($\epsilon_t^z = -0.01$; recall equation (10)) on the economy. The reduced productive capacities of the final-good producers imply that the rental rate on physical capital will be low for several periods in the future (recall that the technology shocks are persistent). This lowers the demand for physical capital and, were the supply curve of investment goods not to shift, would result in sharp drops in q_t, the price of newly created capital goods, and in investment.

The adverse technology shock also produces significant upward pressures on inflation; considering the rule followed by monetary authorities (50), this implies that nominal interest rates must rise. The rise in interest rates acts as a negative shift in the supply of investment goods, following the intuition sketched out in the preceding section. In the experiment illustrated in Figure 4, the inflationary pressures and the associated supply shift are significant enough to force an increase in the price of capital goods, q_t, as well as an even sharper drop in investment.

These reduced levels of investment lead to lower values for entrepreneurial net worth and bank capital in the subsequent periods, which, through their negative impact on the supply of investment goods, continue to propagate the shock for several periods afterwards.

5 The Extended Model

The financial contract that links banks, entrepreneurs, and households, which makes the production of capital goods possible, is key to the role bank capital plays in the propagation mechanism of monetary policy. To this point, however, the quantitative model in which we embed the financial contract has lacked the complexity to make our analysis comparable with those contained in standard monetary versions of the real-business cycle model; e.g., Christiano and Gust (1999) and Cooley and Quadrini (1999). We extend the model to make this comparison possible.

Specifically, we assume that households are risk-averse, that the cash-in-advance constraint faced by households is more involved than the one we have described so far, and that financing from banks is required not only for entrepreneurs but also for final-good producers. These extensions require modifications to the model's equations.

First, the introduction of risk aversion in the utility of households implies that their intertemporal maximization problem is as follows:

$$\max_{\{c_t^h, M_{t+1}, M_t^c, h_t, k_{t+1}^h\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[log(c_t^h) - \chi log(1 - h_t - v_t) \right], \tag{59}$$

where h_t is hours worked and v_t the time costs of adjusting financial portfolios. The presence of risk aversion means that households are seeking to smooth their consumption paths, an objective that was absent from the basic model. Consumption smoothing implies that households are less ready to experience big swings in consumption to take full advantage of the low price of investment goods, for example, which will have an impact on the economy's response to monetary shocks. Further, the smoothing motive has important implications for the behaviour of the labour supply, and therefore for the determination of the economy's total output.

The assumption of risk aversion, however, does not lend itself well to the definition of the financial contract in equations (14) to (20), which depends on the risk-neutrality of all three parties to the contract. To resolve this difficulty, we introduce an insurance scheme that allows households to insure themselves perfectly against all idiosyncratic risk related to the financial contract (this follows Andolfatto 1996 and Cooley and Quadrini 1999). The return on their deposits is supplemented by the (net) receipts from this insurance, so that the (risk-free) rate of return on financial assets is r_t^d. This effectively renders the households risk-neutral with respect to the financial contract, because idiosyncratic risk has been diversified away and the production of capital goods does not feature any aggregate risk.[23] For the other household decisions (regarding labour supply, physical capital holdings, etc.), the insurance scheme allows us to treat the model as a representative agent model. Appendix A provides further details.

The second added feature to the optimization problem of households is that the cash-in-advance constraint is comparable with those used in recent monetary models (as in Cooley and Quadrini 1999). We assume that the current wage income of households is available for purchasing consumption in the current period. This feature eliminates the distortion to households' labour-supply decision that expected inflation causes in the basic model. Further, we assume that the (net) purchases of physical capital undertaken by households must be made with cash. Inflation therefore distorts the investment demand of households, which in the basic model introduced a distortion in their labour-supply decisions.

The combination of risk aversion (and perfect insurance) with wage income and physical capital purchases in the cash-in-advance constraint leads us to rewrite equations (2) and (3) so that the new cash-in-advance constraint is as follows:

$$c_t^h + q_t\left(k_{t+1}^h - (1-\delta)k_t^h\right) \leq \frac{M_t^c}{P_t} + w_t^h h_t, \tag{60}$$

and the budget constraint becomes:

$$\frac{M_{t+1}}{P_t} = \frac{M_t^c}{P_t} + w_t^h h_t - c_t^h - q_t\left(k_{t+1}^h - (1-\delta)k_t^h\right) + r_t^d\left(\frac{M_t - M_t^c + X_t}{P_t}\right) + r_t^k k_t^h. \tag{61}$$

The assumption that wage income is present in the cash-in-advance constraint begs the question of how final-good producers can pay the households' wage income in cash. This issue gives rise to the third extension of the basic structure. We postulate that final-good producers also borrow funds from banking institutions, to pay for their wage bill. No information asymmetry problem is involved in these types of loans. As a result, bank capital is not necessary to conduct this type of lending, because moral hazard and monitoring are not an issue.[24] Although

[23] See Carlstrom and Fuerst (1998, 587) for further discussion on the requirement that all participants in contracts similar to those in our model be risk-neutral. We could have, alternatively, followed Carlstrom and Fuerst (1997) and assumed the existence of a mutual fund that pools all savings from households and invests those funds in banks, thus diversifying away idiosyncratic risk.

[24] As defined, these loans to final-good producers are similar to those that are featured in standard models from the limited-participation literature; see Christiano and Gust (1999) and Cooley and Quadrini (1999). Such loans are often considered to correspond to the "working capital" or "lines of credit" of big firms.

we could envision banks in our basic model engaging in the two types of lending, we instead assume, without loss of generality, that there are two types of financial intermediaries. First, banks, as described to this point, lend to entrepreneurs and use their monitoring technology to resolve the moral hazard that affects production in that sector. The private nature of this monitoring gives rise to the need for bank capital. Second, banking agents (brokers) transfer funds from households to final-good producers, without encountering any information problems and thus without holding any capital. Defining these two types of lending and financial intermediaries is reminiscent of the modelling framework of Bernanke and Gertler (1985). Note that each financial intermediary must offer households the same rate of return on deposits for the two types of lending to coexist in equilibrium. Further, because the second type of lending is costless, brokers make zero profits.

Consequently, the market-clearing condition for deposits reflects the fact that total supply, which arises from households' savings decisions and monetary injections (represented by $\frac{\overline{M_t}-M_t^c+X_t}{P_t}$), must be divided by the two different classes of lending. Equation (55) thus becomes:

$$\frac{[R-b/\Delta\alpha-\mu/q_t\Delta\alpha]\,I_t}{r_t^d}+w_t^hH_t=\frac{\overline{M_t}-M_t^c+X_t}{P_t}, \tag{62}$$

where the added demand for deposits is associated with the wage bill of final-good producers ($w_t^hH_t$).

The market-clearing wage rate for households must reflect the fact that wage costs are borrowed, making the nominal interest rate a distortion that affects labour demand. Consequently, the complete model adds another dimension along which monetary policy contractions affect the economy, by reducing the demand for labour that stems from the activities of final-good producers. Equation (12) is replaced by the following:

$$w_t^h=z_tF_2(K_t,H_t)/r_t^l, \tag{63}$$

where r_t^l is the rate at which final-good producers are able to get funding from the financial brokers. Perfect competition and the fact that the activities of the brokers are costless ensure that $r_t^l=r_t^d$ in equilibrium.

The calibration of the complete model follows the steps detailed in section 3. Because the consumption-smoothing motive affects only the dynamic responses of the economy and not the features of the non-stochastic steady state, it does not impinge on the calibration.

A natural question is whether the effects of monetary policy tightenings that were identified and discussed in section 4.2 remain a feature of the extended model. To this end, Figure 5 reports the result of a contractionary shock that is similar to the one examined previously. First, the responses of the economy in the extended model, while qualitatively similar to those in the basic model (Figure 3), exhibit smoother paths. The limited intertemporal elasticity of substitution (compared with the risk-neutral case of the basic model) leads the economy to converge back to initial steady-state values much faster following the shock. Second, even though the size of the monetary policy shock is the same in the two experiments, in the extended model the actual increase in the nominal interest rate is modest relative to that in the basic model (Figure 3). This reduces the size of the leftward shift of the investment supply curve, thus limiting the downward pressures on aggregate investment and the upward pressures on q_t, the price of the capital good. Third, compared with Figure 3, the responses of investment in the extended model are characterized by a hump-shaped appearance.[25] The responses of the extended-model economy to a technology shock (not reported) exhibit the same qualitative features as those in Figure 4 for the basic model. As is the case for the monetary policy shocks, the interest rate response is much smaller than it is in Figure 4, which reduces the extent to which the investment supply shifts and alleviates (at least initially) the upward pressure on q_t.[26]

6 Bank Capital, Capital-Asset Ratios, and Monetary Policy

6.1 The importance of bank capital

To better assess the influence that bank capital has on the transmission of monetary policy shocks, Figure 6 compares the responses of two economies following the same contractionary monetary policy shock. First, the responses displayed in Figure 5 for the baseline economy are repeated (they are the full lines in Figure 6). The second set of responses (the dashed lines) reflect those of an economy where the financial friction between banks and their depositors is

[25] Our model is thus able to replicate the hump shape in the response of investment that Carlstrom and Fuerst (2001) report. We, however, are able to generate this hump shape in an environment with finite-lived agents, whereas Carlstrom and Fuerst find that only their framework with infinitely lived, impatient entrepreneurs generates a hump shape in investment.

[26] The responses of the extended-model economy to a technology shock are available from the authors on request.

eliminated: in such a case, the actions of banks are perfectly observable, so depositors know for sure whether banks monitor. As a result, banks are not required to engage their own new worth (their capital) in financing projects; bank capital becomes unnecessary and is therefore not held in equilibrium.

The alternative economy features higher entrepreneurial leverage than the baseline economy; i.e., G takes on a value of 0.51 in the baseline but only 0.48 in the alternative economy (G is approximately the inverse of entrepreneurial leverage). This implies that, for a given level of entrepreneurial net worth, the investment project size that an entrepreneur can undertake is significantly lower in the baseline economy; see equation (40).

Figure 6 shows that the effects of a given monetary policy shock are dampened in the case where bank capital is present, relative to the case where the absence of financial frictions renders bank capital unnecessary. Both the impact effect on aggregate investment (-0.39 per cent) and the maximal impact (-0.58 per cent) are reduced, from their levels of -0.58 per cent and -0.70 per cent, respectively. The responses of output are also reduced, but to a lesser extent. Thus, a given increase in the cost of deposits, r_t^d, because of the lower leverage of the baseline economy, leads to less significant tightening in bank lending, and less decreases in the scale of projects and aggregate investment. This is consistent with the discussion in Carlstrom and Fuerst (1998, 2001), in which the authors show that the introduction of a single source of agency cost in an otherwise-standard business cycle model dampens the effect of economic shocks relative to an environment where there are no agency costs. Moreover, the half-life of the shock on investment is increased (from 9 to 10 periods) when the financial friction on banks is operative and bank capital is present: there is therefore evidence that the persistence of shocks has increased.[27]

Figure 7 illustrates the same mechanism, but from a different angle: the severity of the financial friction is first increased (the dashed lines) and then decreased (the pointed lines). The figure shows that the response of investment and output to monetary policy shocks is significantly affected by the severity of the friction: the more severe the friction, the lower the amplitude of the responses, and, to some extent, the more persistent the response.[28]

[27] Again, this is consistent with the discussion and the experiments presented in Carlstrom and Fuerst (1998, 2001).

[28] Similar effects are present when the economy is subjected to technology shocks.

To build intuition for these differences in the amplitude and the persistence of the responses, consider again equation (25). When the information friction is eliminated, μ does not appear on the right-hand side of the equation and thus the value of this term is higher. This means that the per-unit share of an investment project that can be allocated to households is higher. For a given (steady-state) value of the nominal deposit rate, the financing of projects is now easier and relies relatively more on household deposits; the steady-state value of d_t/i_t is higher. This relatively big contribution of household deposits in the financing of projects makes it difficult to replace such deposits when their opportunity cost increases following monetary tightening. Another way to interpret this result is that an increase in deposit rates worsens the moral hazard problem between households and banks *less* in an environment where the agency problem is already severe; in such an environment, banks already hold relatively high stocks of capital, and pledging more of it per unit of investment project (to replace household deposits) is less difficult.

A given increase in r_t^d thus leads to more substantial decreases in aggregate investment in the economy, where banks face no financial frictions. In turn, this deeper decline in investment leads to similar, deeper declines in future entrepreneurial net worth and bank capital (through the retained-earnings effect), which continue to propagate the shock in subsequent periods, after the initial effects of the rate increase have dissipated.

6.2 Cyclical properties of the bank capital-asset ratio

Although there are no regulatory capital requirements in our model, we have shown that the market-generated bank capital-asset ratios will vary with the business cycle, reacting countercyclically to monetary and technology shocks. Since one objective of the 1988 Basle Accord on capital adequacy requirements was to facilitate, through harmonized measurement of capital adequacy and increased disclosure, the exercise of market discipline over banks, it is natural to ask whether our model, in which all movements in the capital-asset ratio are market-generated, can replicate some of the cyclical properties of bank capital-asset ratios.

Table 3 compares the available data for the United States with our model implications. First, we document the facts. Bank capital-asset ratios are measured as the sum of *tier1* and *tier2* capital over risk-weighted assets.[29] Panel A of Table 3 shows that measured bank capital-asset

[29] According to the Basle regulations, *tier1* capital consists of equity capital and published reserves from post-

ratios in the United States are roughly half as volatile as output, whereas investment and bank lending are approximately four times as volatile. The table also shows that capital-asset ratios are countercyclical, particularly with respect to investment and bank lending. Since bank capital moves fairly smoothly in the data, this countercyclical behaviour is intimately related to many discussions about the procyclical nature of bank lending. The key message from these data is that capital-asset ratios, although not very volatile, are significantly and negatively related to measures of bank lending and general economic activity.[30]

Turning to Panel B of the table, we find that our model, when subjected to monetary policy and technology shocks, replicates fairly well the countercyclical movements of the capital-asset ratio relative to investment, bank lending, and GDP. These similarities between the dynamic features implied by the model and those observed in the data indicate that market discipline may have played an important role in shaping the evolution of bank capital and the capital-asset ratio of banks over recent monetary history. This suggests that markets do have the ability to discipline banks and that this discipline should be promoted by increasing the importance of "Pillar 3" in the new Basle Accord.[31] Further, warnings about the proposals to make the new regulatory capital requirements themselves countercyclical should appeal to well-defined reasons for overcoming what may be optimal responses to economic shocks.

7 Conclusion

This paper has presented a monetary, quantitative, dynamic model of the interrelations between bank capital and entrepreneurial net worth on the one hand, and monetary policy and economic activity on the other. The model features two distinct sources of moral hazard. The first, which arises because entrepreneurs can privately influence the probability of success of the

tax retained earnings, whereas *tier2* capital consists of undisclosed reserves, asset revaluation reserves, general provisions, hybrid debt/equity capital instruments, and subordinated debt. The weights on different classes of assets range from zero on cash and other liquid instruments, to 50 per cent for loans fully secured by mortgage on residential properties, to 100 per cent on claims to the private sector. These data are averages for all U.S. banks and are from the BIS.

[30] An alternative measure of capital-asset ratios, which might match better with the corresponding measure in the model, is the ratio of capital over loans. The countercyclicality identified in Table 3 is also present when this alternative measure is used.

[31] The proposed new Basle Accords on capital requirements contain three "pillars": minimum regulatory requirements, supervision, and market discipline. See Rochet (2003) for a review of the debate over the three pillars of the new Basle Accord and a model in which the first and third of these pillars can interact.

Table 3: Cyclical Properties of the Capital-Asset Ratio: Model and Data

Variable	$\frac{\sigma(X)}{\sigma(GDP)}$	*Cross-correlation of the capital-asset ratio with:* X_{t-4}	X_{t-2}	X_{t-1}	X_t	X_{t+1}	X_{t+2}	X_{t+4}
Panel A: U.S. economy								
Capital-asset ratio	0.38	0.47	0.79	0.91	1	0.91	0.79	0.47
Fixed non-res. investment	4.41	−0.44	−0.48	−0.44	−0.38	−0.28	−0.20	−0.02
GDP	1	−0.47	−0.40	−0.27	−0.16	−0.00	0.08	0.12
Bank lending (C & I)	4.67	−0.42	−0.67	−0.75	−0.80	−0.76	−0.69	−0.40
Panel B: Model economy								
Capital-asset ratio	0.53	0.85	0.94	0.98	1	0.98	0.94	0.85
Fixed non-res. investment	2.60	−0.07	−0.21	−0.32	−0.44	−0.52	−0.57	−0.60
GDP	1	−0.12	−0.25	−0.35	−0.45	−0.47	−0.48	−0.47
Bank lending	2.70	−0.10	−0.25	−0.37	−0.51	−0.56	−0.59	−0.59

Note: For the U.S. economy, 1990Q1-2003Q1. Capital-asset ratio: *tier1* + *tier2* capital over risk-weighted assets (source: BIS); Fixed non-res. investment: fixed investment, non-residential, in billions of chained 1996 dollars (source: BEA); GDP: gross domestic product, in billions of chained 1996 dollars (source: BEA); Bank lending: commercial and industrial loans excluding loans sold (source: BIS). Investment and Bank lending are expressed as the log of real per-capita quantity. All series are detrended using the HP filter.

projects they engage in even in the presence of bank monitoring, leads banks to require that entrepreneurs invest their own net worth in the projects they undertake. The second, which is based on the fact that the monitoring activities of banks are themselves not publicly observable, induces households to require that banks invest their own capital in entrepreneurial projects before households deposit funds at banks. Entrepreneurial net worth and bank capital are thus key determinants of the propagation over time of shocks that affect the economy, even after the initial, direct impact of the original disturbances have faded away.

Quantitative simulations conducted with the model show that the presence of bank capital can have a significant impact on the amplitude and, to a lesser extent, the persistence of the effects of monetary policy shocks. Specifically, monetary policy contractions have dampened but more persistent effects in our model—where the financial friction between banks and their depositors constrains the leverage of entrepreneurs—than in an economy where the friction is eliminated and bank capital is not necessary. Further, the market-determined capital-asset ratio of banks reacts countercyclically to shocks, tightening credit when adverse shocks affect the economy; this countercyclical behaviour is also present in aggregate U.S. data.

In future work, we plan to experiment with a version of the model that would position the double incidence of moral hazard in the sector that produces the final good, rather than the current situation where the creation of new capital goods is affected by agency problems. Contrasting these two frameworks would allow us to better link our results to the comparisons Carlstrom and Fuerst (1998, 2001) make between their "output" and "investment" models. Further, it would be useful to analyze environments where the distribution of entrepreneurial net worth and bank capital matters for the aggregate implications of the model.

Second, a thorough examination of the role of bank capital in the transmission of economic shocks should account for the sizable heterogeneity in terms of size, capital position, or balance-sheet composition that is observed in the banking sector of most countries.[32] An environment where such heterogeneity can arise from the dynamic effects of idiosyncratic shocks could yield further insights into the importance of bank capital for monetary policy.

Finally, the introduction of externalities, possibly because the liabilities of banks circulate and are used as means of payments, holds much promise. Such a framework could lead to a potential role for government intervention in the banking sector, perhaps as the result of large bank failures that impact on the viability of the exchange mechanism.

[32]This heterogeneity is documented, for the United States, by Ennis (2001b).

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Figure 1. Timing of Events

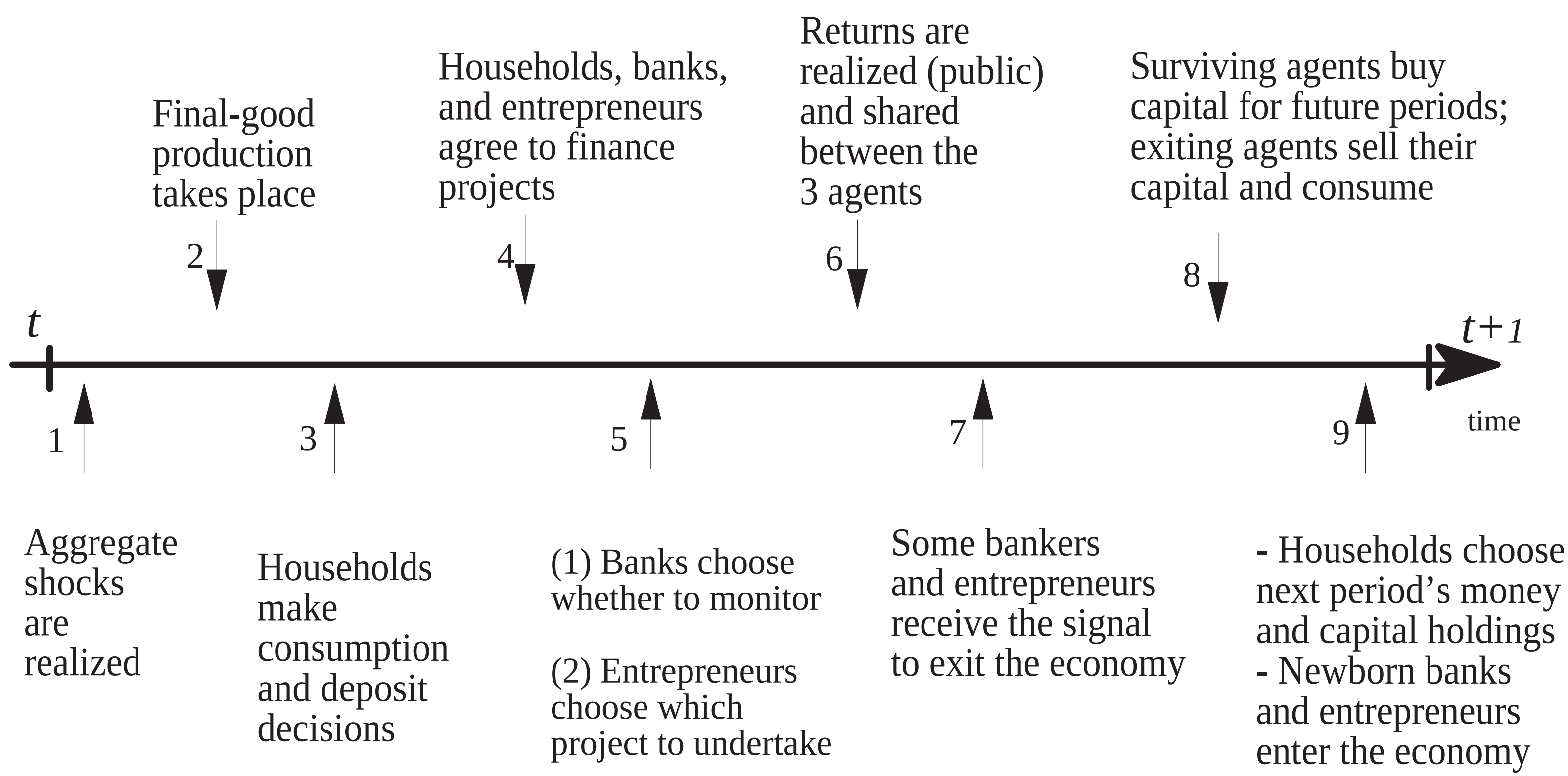


Figure 2. Negative Wealth Shock on Bank Capital: Basic Model

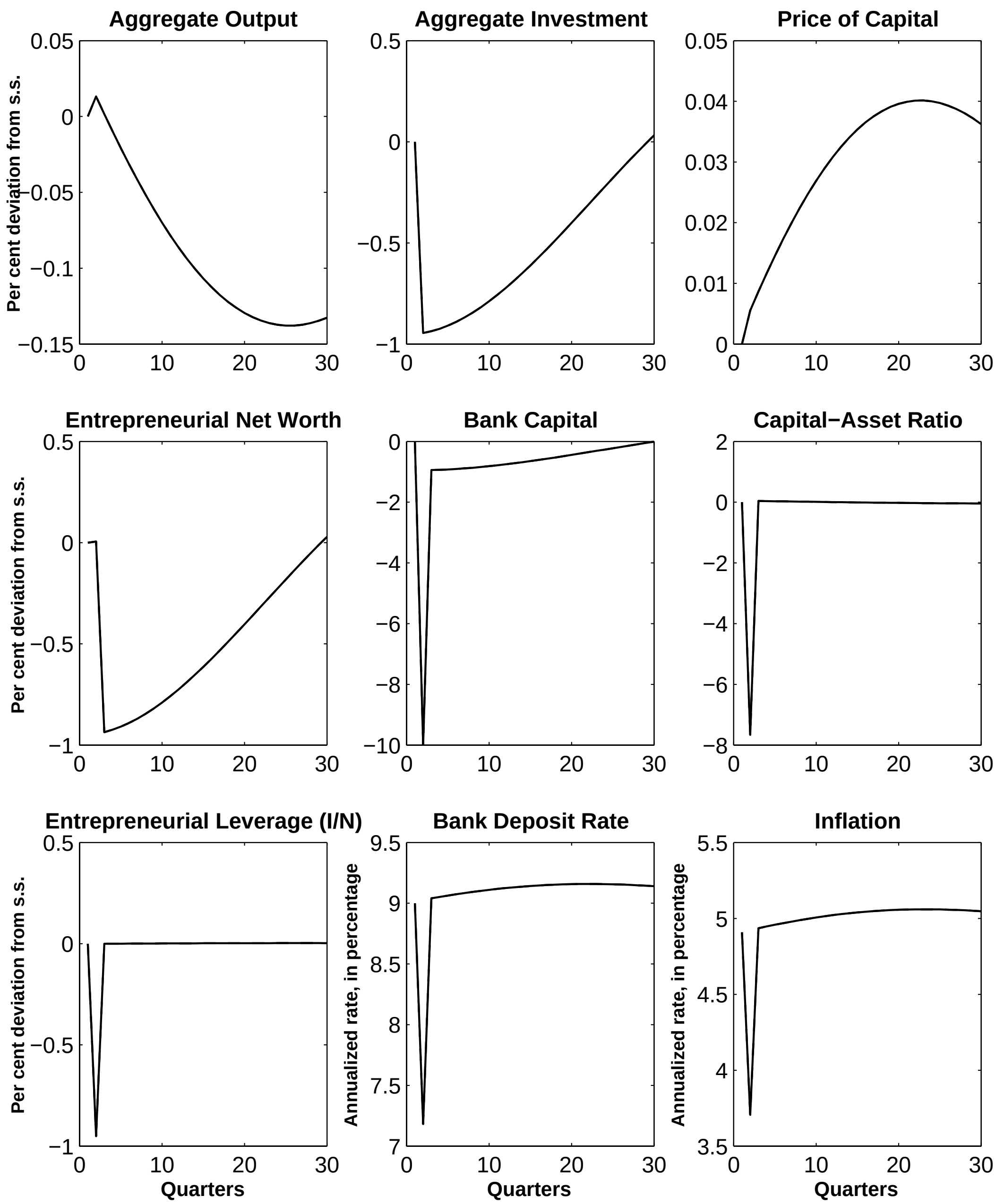


Figure 3. Contractionary Monetary Policy Shock: Basic Model

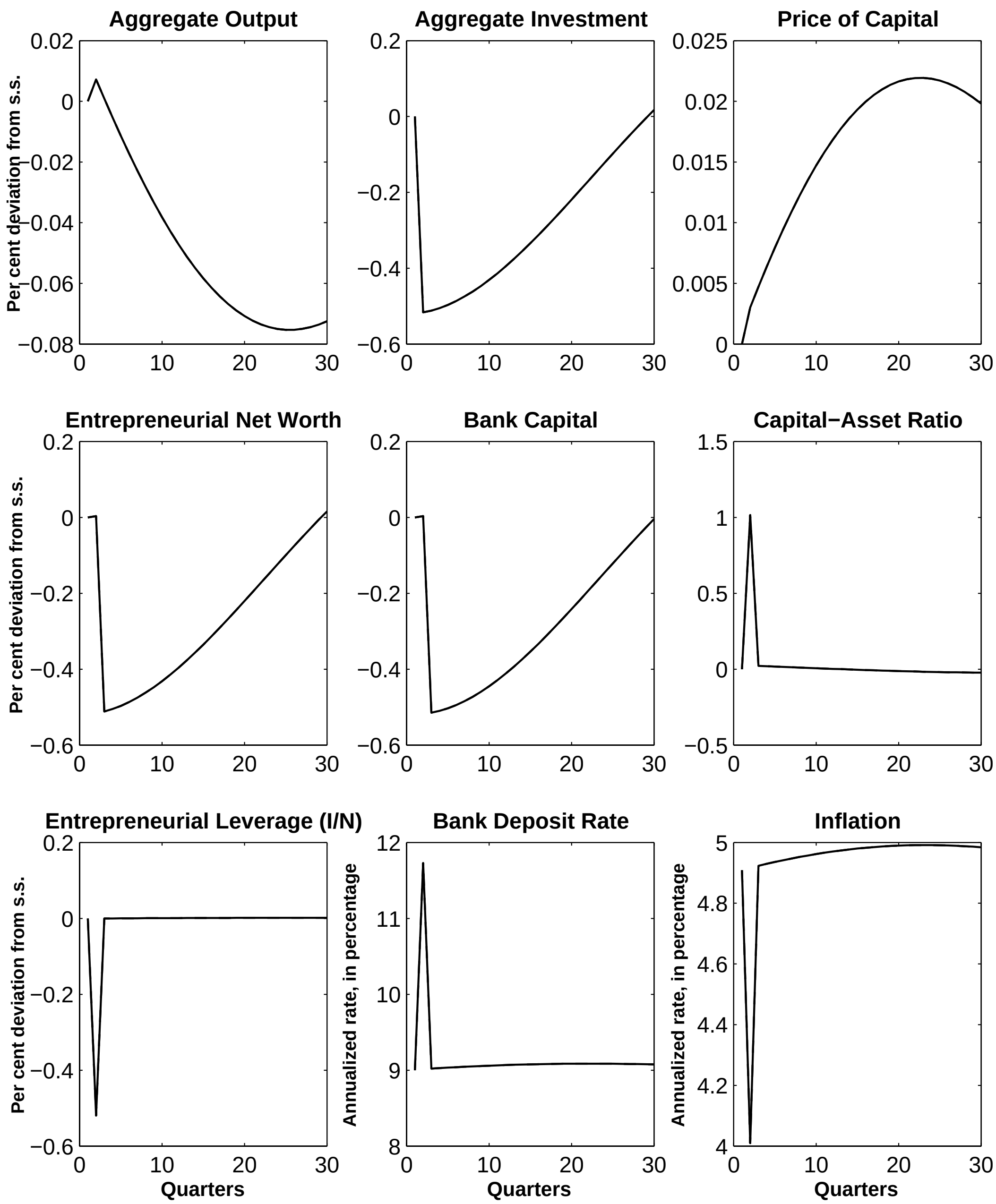


Figure 4. Adverse Technology Shock: Basic Model

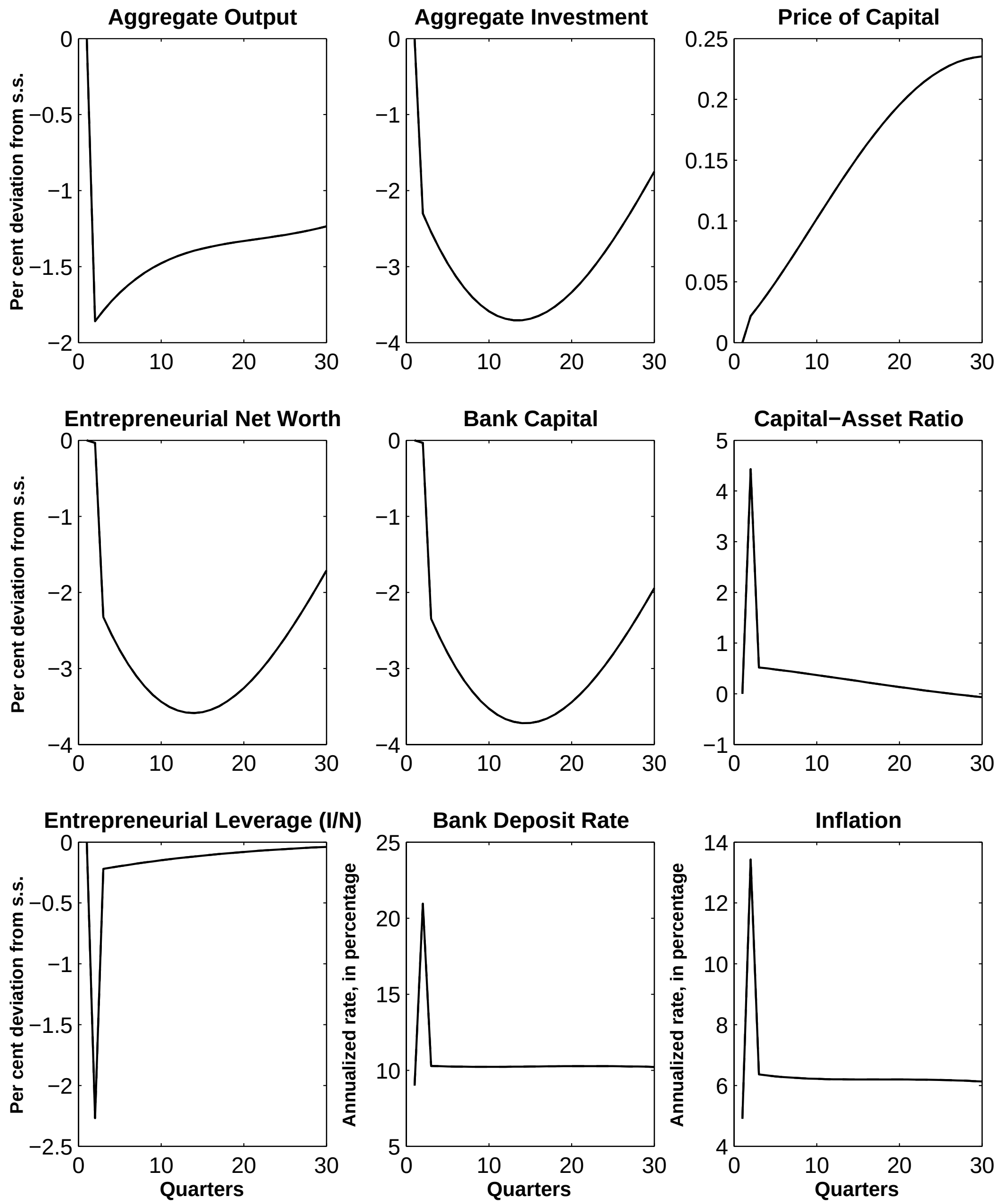


Figure 5. Contractionary Monetary Policy Shock: Extended Model

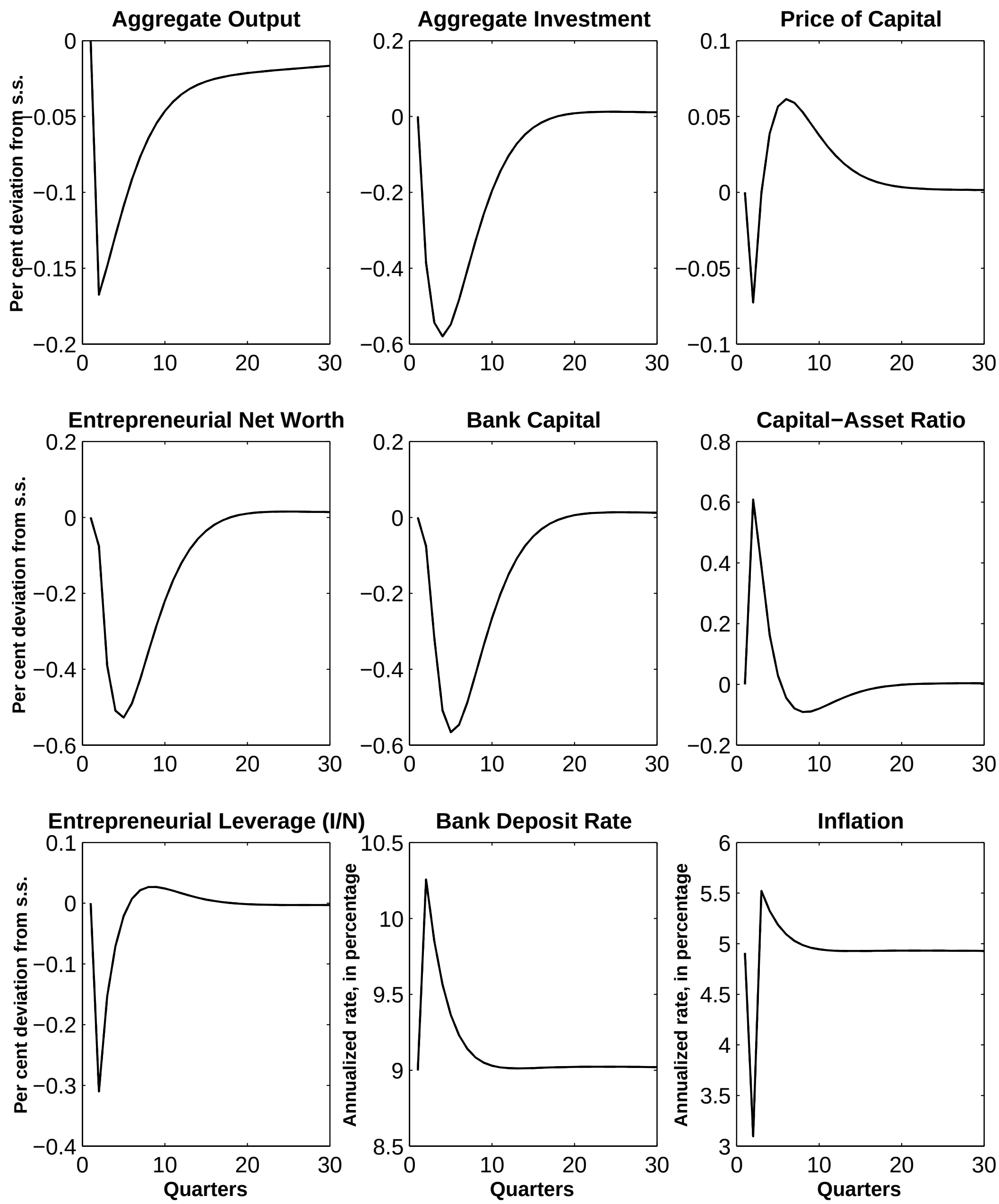


Figure 6. Contractionary Monetary Policy Shock: The Importance of Bank Capital

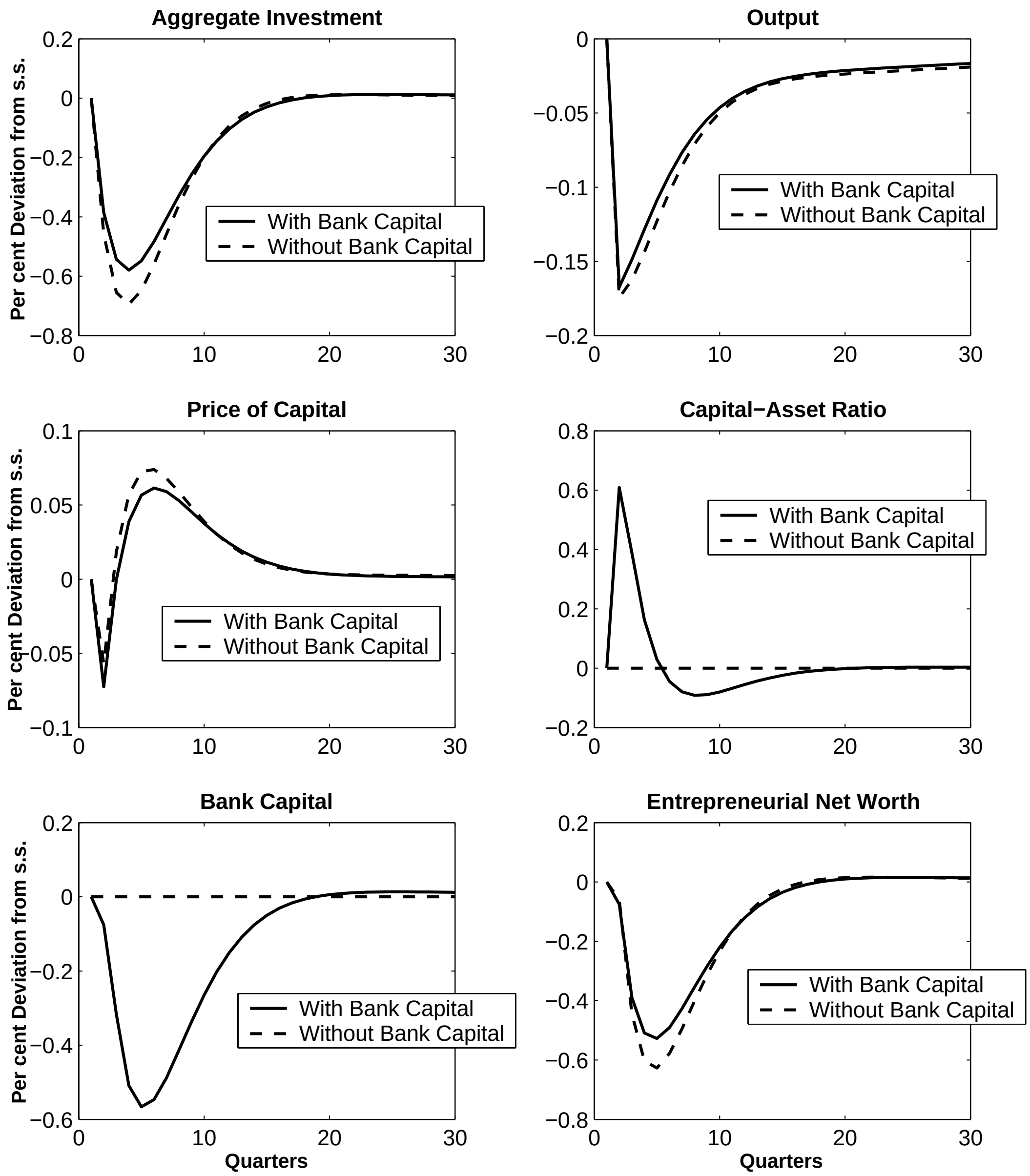
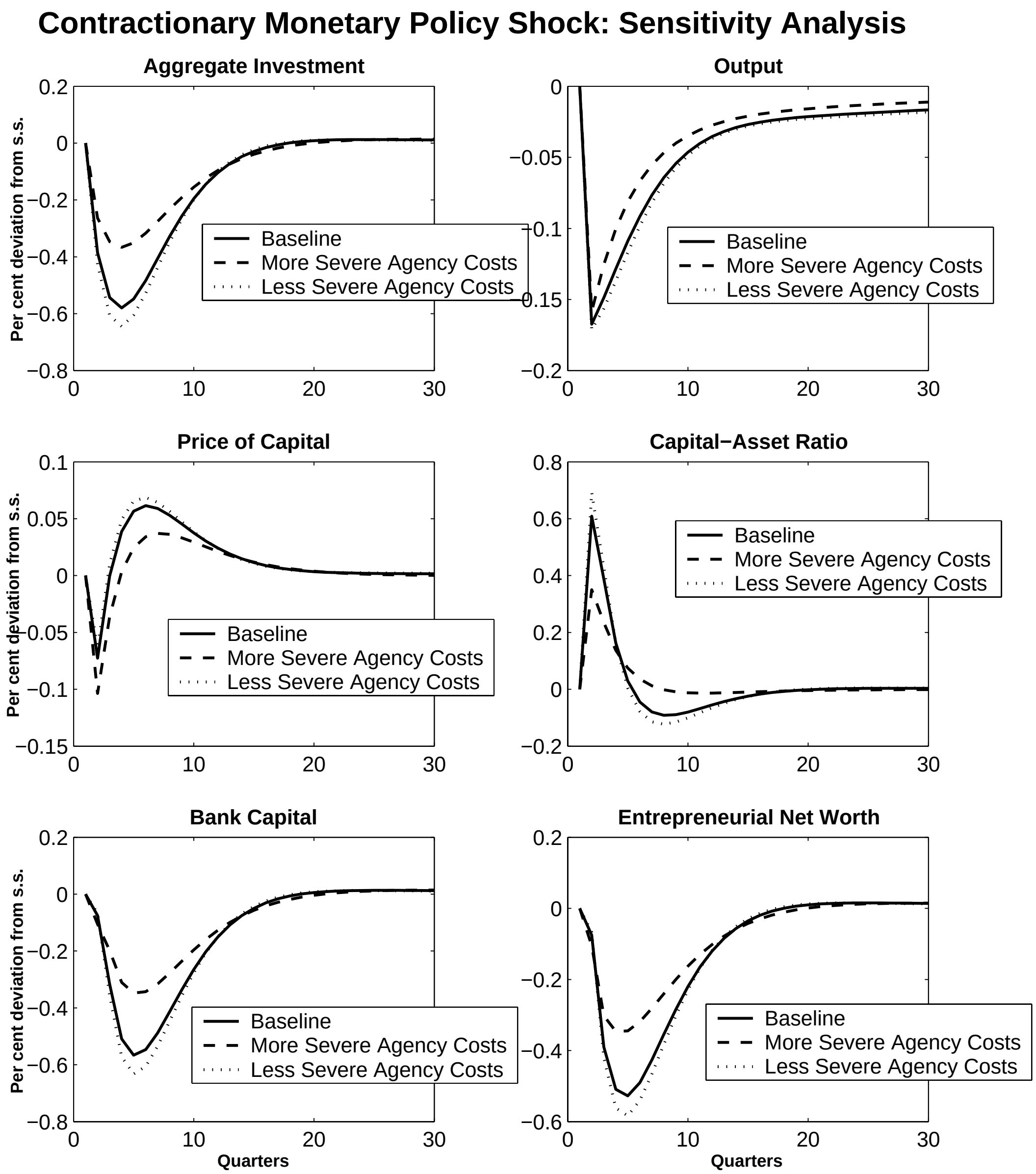


Figure 7. Contractionary Monetary Policy Shock: Sensitivity Analysis



Appendix A: Insurance within Risk-Averse Households in the Extended Model

Following Andolfatto (1996) and Cooley and Quadrini (1999), we assume the existence of an (actuarially fair) insurance market that allows households to eliminate the idiosyncratic risk inherent in financial contracts. Specifically, a household can purchase y_t real units of insurance at the price j_t. These units are paid to the household in the event that it receives a zero return from its bank deposits. The budget constraint (3) can be rewritten as follows:

$$\frac{M_{t+1}}{P_t}+q_t k_{t+1}^h+j_t y_t=\frac{M_t^c}{P_t}-c_t^h+s_t\frac{r_t^d}{\alpha^g}\left(\frac{M_t-M_t^c+X_t}{P_t}\right)+w_t^h h_t+\left(r_t^k+q_t(1-\delta)\right)k_t^h+(1-s_t)y_t, \tag{A.1}$$

where s_t is an indicator function that takes a value of 1 if the bank deposits are repaid (and insurance payments are not necessary) and a value of 0 if deposits have a zero return and insurance payments are made. Note that we have written the constraint in a manner that removes any dependence in the choices made by households over the value of s_t; we assume that this is their optimal response.

The first-order condition for the choice of y_t is as follows:

$$j_t=E_t[1-s_t]=1-\alpha^g, \tag{A.2}$$

which repeats the statement that the insurance market is actuarially fair. That feature, as well as the strict concavity of the utility function in consumption, implies that households will seek to remove any risk to their financial income flows. This would require financial revenues (including net insurance revenues) when deposits bring no returns to equal revenues when deposits pay their promised returns (net of insurance premiums). We thus have:

$$y_t-j_t y_t=\frac{r_t^d}{\alpha^g}\left(\frac{M_t-M_t^c+X_t}{P_t}\right)-j_t y_t, \tag{A.3}$$

which simplifies to $y_t=\frac{r_t^d}{\alpha^g}\left(\frac{M_t-M_t^c+X_t}{P_t}\right)$.

Inserting this result back into (A.1) makes clear that the budget constraint is similar to the one in a representative-agent economy with no idiosyncratic risk to household deposits:

$$\frac{M_{t+1}}{P_t}+q_t k_{t+1}^h=\frac{M_t^c}{P_t}-c_t^h+r_t^d\left(\frac{M_t-M_t^c+X_t}{P_t}\right)+w_t^h h_t+\left(r_t^k+q_t(1-\delta)\right)k_t^h. \tag{A.4}$$

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