

# A Tale of Two Policies: Prudential Regulation and Monetary Policy with Fragile Banks

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## Abstract

We integrate banks, modeled as in Diamond and Rajan (JoF 2000 or JPE 2001), into a standard DSGE model and use this framework to study questions regarding the role of banks in the transmission of shocks, the effects of monetary policy when banks are exposed to runs, and the interplay between monetary policy and Basel-like capital ratios. Three findings emerge among others. A monetary restriction reduces bank leverage and risk, while a productivity or asset price boom increases it. Procyclical capital ratios are highly destabilising; monetary policy can do little to neutralise this effect. Finally, the best combination policy includes mildly anticyclical capital ratios with an optimal monetary policy rule that responds to bank leverage or asset prices.

*Keywords:* capital requirements, leverage, bank runs, combination policy, market liquidity.

# 1 Introduction<sup>1</sup>

The financial crisis is producing, among other consequences, a change in perspective on the respective roles of prudential regulation and monetary policy. The pre-crisis common wisdom sounded roughly like this. Capital requirements and other prudential instruments were supposed to ensure (at least with high probability) the solvency of individual banks, with the implicit tenet that stable banks would automatically translate into a stable financial system. At the other corner, monetary policy should largely disregard financial matters and concentrate on pursuing price stability (a low and stable inflation rate) over some appropriate time horizon. The recent experience is changing this perspective in two ways. On the one hand, the traditional formal requirements for individual bank solvency (asset quality and adequate capital) are no longer seen as sufficient for systemic stability; regulators are increasingly called to adopt a *macro-prudential* perspective (Borio [9], Morris and Shin [25]). On the other, monetary policy is asked to help control systemic risks. The crisis has demonstrated that such risks can have disruptive implications for output and price stability down the road, and there is increasing evidence that monetary policy influences the degree of riskiness of the financial sector (the "risk-taking channel" of Borio and Zhu [10], to which Maddaloni and Peydró Alcalde [24] and Altunbas et. al. [1] have recently provided supporting evidence).

With this in mind, in this paper we move some steps towards studying, in an integrated framework, how bank regulation and monetary policy interact in fragile banking systems. Our first step is to propose a model that is simple enough and yet incorporates some key elements of financial fragility experienced in the recent crisis. In our model banks provide liquidity to both depositors and entrepreneurs. As in Diamond and Rajan [15], [16] they have special skills in redeploying the projects' assets in case of early liquidation. The firms' cash flow is uncertain and requires specialized entrepreneurial skills to be realized. Their relation with the banks is disciplined by two incentives: entrepreneurs may withhold their human capital, and bank can threaten to stop the project early by calling in the loan. Banks, financed with deposits and capital, are exposed to runs, with a probability that increases with their leverage<sup>2</sup>. The desired capital ratio is determined by

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<sup>1</sup>We are grateful to Kiryl Khalmetski and Marco Lo Duca for excellent research assistance.

<sup>2</sup>The argument applies not only to traditional banks issuing uninsured deposits, but to any leveraged balance sheet structure with short term funding, for example conduits financed through short maturity asset-backed commercial paper.

trading-off balance sheet risk with the ability to force higher repayment from the borrower, which increases with the share of deposits in their liability side.

Introducing these elements into the standard model provides a characterization of financial sector that is, we think, more apt to interpret the recent experience than traditional "financial accelerator" formulations<sup>3</sup>, where the transmission from the financial to the real sector takes place via the value of collateral rather than explicitly through banks. Endogenizing the banks' capital structure also provides a natural way to bring in capital requirements and study their links with monetary policy, which are our main focus. Our model allows, inter alia, to study how capital regulation, and potentially also liquidity ratios and other prudential instruments, influence economic performance, collective welfare and the optimal monetary policy.

Other papers have examined optimal monetary policy design and bank regulation, with specific reference to the pro-cyclicality of capital requirements (Blum and Hellwig [8], and Cecchetti and Li [12]). Two main elements differentiate our work. First, the previous studies take capital requirements as a given and study the optimal monetary policy response, while we consider their interaction and possible combinations. Second, in earlier studies the loan market and bank capital structure were specified exogenously or ad hoc, while we incorporate bank behavior explicitly. Gertler and Karadi [20] have recently proposed a model with micro-founded banks close in spirit to ours. But their approach to modelling the bank is different, and, more importantly, their aim is to look at the effects of unconventional monetary policies, while we explore the interplay between (conventional) monetary policy and bank regulation. Their focus is more on crisis management, ours on crisis prevention.

The rest of the paper is as follows. Section 2 describes the model. Section 3 characterizes the transmission mechanism with and without banks. Section 4 examines the sensitivity to investment risk and the performance of leaning-against-the-wind monetary policy. Section 5 discusses the role of Basel capital ratios and how they affect the transmission mechanism in our model. Sections 6 and 7 deal with optimal policy and welfare. Section 8 concludes.

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<sup>3</sup>See Bernanke, Gertler and Gilchrist [3] for a pioneering work and later formulations from Christiano, Motto and Rostagno [14] among others.

## 2 The Baseline Model

The starting point is a conventional DSGE model with nominal rigidities. To this standard structure, we add optimizing banks and subsequently, a prudential regulation in the form of capital ratios. The economy is populated by workers/depositors, capitalists/entrepreneurs and bankers. Workers are risk averse, while entrepreneurs and bankers are risk neutral. The central bank sets the nominal interest rate.

Entrepreneurs launch projects that require an initial investment; this is financed by the bank, who raises money from depositors and capitalists. Bank capital claims the residual value after deposits are paid out. As in Diamond and Rajan ([15], [16]), the bank capital structure is determined by bank managers, who act on behalf of outside investors (depositors and capitalists combined) by maximizing their return. If the return is low and the bank is not expected to be able to pay depositors in full there is a run on the bank, in which case bank capitalists get zero while depositors get the market value of the loan to the entrepreneur.

### 2.1 Households

There is a continuum of identical households who consume, save and work. Households can be either workers or bankers: in every period a fraction  $\gamma$  becomes workers and a fraction  $(1 - \gamma)$  become bankers. Workers earn wages and return them to the households; similarly bankers earn profits who return to the households. Households invest in deposits which are held with other intermediaries. To allow aggregation we assume that bankers are finitely lived: in period  $t$  there is a probability  $\theta$  that a household member becomes a banker. The last assumption is needed to avoid that bankers will accumulate enough wealth to ease up the liquidity constraints; we will return on this point later.

Households maximize the following discounted sum of utilities:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \tag{1}$$

where  $C_t$  denotes aggregate consumption and  $N_t$  denotes labour hour. As in Woodford [31]

we consider the limit of an economy as it become cashless, therefore we omit real money balances from utility. The households receive at the beginning of time  $t$  a real labour income  $\frac{W_t}{P_t} N_t$ . As households can work both in the industrial and in the banking sector, we consider labour income as inclusive of the fees that workers receive as managers of the banks. Those fees are formally determined in the next section. Households save in intermediary deposits,  $D_t$ , which pay the gross nominal return,  $R_t^D$ , one period later and in government bonds, which pay gross nominal return,  $R_t^n$ , one period later. Finally, households are the owners of both the monopolistic competitive sector and the banking sector. Because of this they are entitled to receive from the monopolistic sector nominal profits for an amount,  $\frac{\Theta_t}{P_t}$ , and from any banker who ceases activity nominal profits of an amount,  $\Pi_t$ . Hence the sequence of budget constraints in real terms reads as follows:

$$P_t C_t + D_{t+1} + B_{t+1} \leq W_t N_t + T_t + \Theta_t + R_t^D D_t + R_t^n B_t \quad (2)$$

Households choose the set of processes  $\{C_t, N_t\}_{t=0}^{\infty}$  and assets  $\{D_{t+1}, B_{t+1}\}_{t=0}^{\infty}$ , taking as given the set of processes  $\{P_t, W_t, R_t^D, R_t^n\}_{t=0}^{\infty}$  and the initial wealth  $D_0, B_0$  so as to maximize 1 subject to 2. The following optimality conditions hold:

$$\frac{W_t}{P_t} = - \frac{U_{n,t}}{U_{c,t}} \quad (3)$$

$$U_{c,t} = \beta E_t \{ R_t^D U_{c,t+1} \} \quad (4)$$

$$U_{c,t} = \beta E_t \{ R_t^n U_{c,t+1} \} \quad (5)$$

Equation 3 gives the optimal choice for labour supply. Equation 4 gives the Euler condition with respect to deposits and equation 5 gives the Euler condition with respect to government bonds. Optimality requires that the first order conditions and No-Ponzi game conditions are simultaneously satisfied.

Deposits are held by households as they provide liquidity services. For this reason they are sold at a rate of return lower than the rate of return of government bonds:

$$R_t^D = R_t^n - \zeta_t \quad (6)$$

## 2.2 Banks

There is in the economy a large number ( $L_t$ ) of investment projects, each run by an entrepreneur. The project lasts two periods and requires an initial investment. Each project's size is normalized to unity (think of one machine) and its price is  $Q_t$ . The entrepreneur has no internal funds, but receives finance from a bank. We assume a competitive banking system: bank profits are driven to zero except for a fee, determined as specified below. Likewise, banks have no internal funds but receive finance from two classes of agents: holders of demand deposits and capitalists. Total bank loans are equal to the sum of deposits ( $D_t$ ) and bank capital, ( $BK_t$ ), in the aggregate bank balance sheet written as follows:

$$Q_t L_t = D_t + BK_t \tag{7}$$

Individual depositors are served sequentially and fully as they come to the bank for withdrawal; capitalists instead are rewarded pro-quota after all depositors are served. This payoff mechanism exposes the bank to runs, that occur when the return from the project is insufficient to reimburse all depositors. The capital structure is determined by the "banker", an agent whose function is to optimize ex-ante the bank capital structure (share of demand deposits and of capital) on behalf of depositors and capitalists; the banker's task is to find the capital structure that maximizes the combined expected return of depositors and capitalists, in exchange for a fee.

Generalizing Diamond and Rajan [15], [16], we assume that the return of each project for the bank is equal to an expected value,  $R_{A,t}$ , plus a random shock with a uniform distribution with dispersion  $h$ . Therefore, the project outcome is  $R_{A,t} + x$ , where  $x$  spans across the interval  $[-h; h]$  with probability  $\frac{1}{2h}$ . We assume for the moment  $h$  to be constant across projects and time; we will relax this later.

The timing is as follows. At time  $t$ , the banker decides the optimal capital structure, expressed by the ratio of deposits to the total cost of the project,  $d_t$ , collects the funds, lends, and then the project is undertaken. At time  $t + 1$ , the project's outcome is known and payments to depositors, capitalists and the banker are made, as discussed below. A new round of projects starts.

Each project is financed by one bank. Our bank is a *relationship lender*: by lending it acquires a specialized non-sellable knowledge of the characteristics of the project. This knowledge determines

an advantage in extracting value from it before the project is concluded, relative to other agents. Let the ratio of the value for the outsider (liquidation value) to the value for the bank be  $0 < \lambda \leq 1$ . Again we assume for the moment  $\lambda$  to be constant; we will relax this later.

Consider the payoffs to each of our players. There are three cases.

*Case A:* the outcome of the project is too low to pay depositors. This happens if  $R_{A,t} + x < R_t^n d_t$ , where  $R_t^n$  is the (gross) riskless interest rate. Since depositors are served sequentially, as soon as they realize that payoff from the project is insufficient they run to the bank and force the liquidation of the project. Payoffs in case of run are distributed as follows. Capitalists receive the leftover after depositors are served, so they get zero in this case. Depositors alone (without bank) would get only a fraction  $\lambda(R_{A,t} + x)$  of the project's outcome; the remainder  $(1 - \lambda)(R_{A,t} + x_{j,t})$  is split between depositors and the bank depending on bargaining power. Following Diamond and Rajan [15] and [16] we assume this return is split in half (other assumptions are possible without qualitative changes in the results). Therefore, depositors end up with

$$\frac{(1 + \lambda)(R_{A,t} + x_{j,t})}{2} \quad (8)$$

and the bank with <sup>4</sup>

$$\frac{(1 - \lambda)(R_{A,t} + x_{j,t})}{2} \quad (9)$$

*Case B:* the project outcome is high enough to allow depositors to be served if the project's value is extracted by the bank, but not otherwise. This happens if  $\lambda(R_{A,t} + x_{j,t}) < R_t^n d_t \leq (R_{A,t} + x_{j,t})$ . In this case, the capitalists alone cannot avoid the run, but capitalists with the bank can. So depositors are paid in full,  $R_t^n d_t$ , and the remainder is split in half between the banker and the capitalists, each getting  $\frac{R_{A,t} + x_{j,t} - R_t^n d_t}{2}$ . Total payment to "outsiders" (meaning depositors plus capital) is  $\frac{R_{A,t} + x_{j,t} + R_t^n d_t}{2}$ .

*Case C:* the project's outcome is high enough to allow all depositors to be served, with or without the bank's participation. This happens if  $R_t^n d_t \leq \lambda(R_{A,t} + x_{j,t})$ . Depositors get  $R_t^n d_t$ . However, unlike on Case B, now the capitalists could decide to liquidate the project alone (without

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<sup>4</sup>Note that we have assumed that bank runs are not destructive *per se*, i.e. liquidation by depositors is equivalent to liquidation by the capitalists. The model could easily be extended to include a specific additional cost from bank runs.

the bank) and pay the depositors in full, getting  $\lambda(R_{A,t} + x_{j,t}) - R_t^n d_t$ ; this is thus a lower threshold for him. The banker can extract  $(R_{A,t} + x_{j,t}) - R_t^n d_t$ , and again we assume that the capitalists and the bank split in half the difference between this amount and the minimum return to capital. Therefore, the bank gets:

$$\frac{\{[(R_{A,t} + x_{j,t}) - R_t^n d_t] - [\lambda(R_{A,t} + x_{j,t}) - R_t^n d_t]\}}{2} = \frac{(1 - \lambda)(1 + x_{j,t})}{2}$$

less than the capitalists. Total payment to "outsiders" is:

$$\frac{(1 + \lambda)(R_{A,t} + x_{j,t})}{2} \quad (10)$$

We can now write the expected value of total payments to outsiders as follows:

$$\begin{aligned} & \frac{1}{2h} \int_{-h}^{R_t^n d_t - R_{A,t}} \frac{(1 + \lambda)(R_{A,t} + x_{j,t})}{2} dx_{j,t} + \frac{1}{2h} \int_{R_t^n d_t - R_{A,t}}^{\frac{R_t^n d_t}{\lambda} - R_{A,t}} \frac{(R_{A,t} + x_{j,t}) + R_t^n d_t}{2} dx_{j,t} + \quad (11) \\ & + \frac{1}{2h} \int_{\frac{R_t^n d_t}{\lambda} - R_{A,t}}^h \frac{(1 + \lambda)(R_{A,t} + x_{j,t})}{2} dx_{j,t} \end{aligned}$$

The three terms express the payoffs to outsiders in the three cases described above, in the respective order. Let us look at this expression closely. The realization  $x_{j,t}$  obviously ranges between  $-h$  and  $h$ . However, the value of gross deposits  $R_t^n d_t$  is also bounded, between  $R_{A,t} - h$  and  $\lambda(R_{A,t} + h)$ . Since  $R_{A,t} - h$  can be positive, why shouldn't  $R_t^n d_t$  ever fall below  $R_{A,t} - h$ ? Suppose it does. In this case a run can never take place, so a marginal increase in  $d_t$  actually raises the return to outsiders with certainty, by an amount equal to  $\frac{(1 + \lambda)(R_{A,t} + x_{j,t})}{2}$ ; so  $R_t^n d_t < R_{A,t} - h$  cannot be an equilibrium. Suppose now  $R_t^n d_t > R_{A,t} - h$ . In this range a run is certain, so the total return to outsiders (the depositors, in this case) cannot increase with  $d_t$ . So values of  $R_t^n d_t > R_{A,t} - h$  need not be considered. Think now of  $R_t^n d_t$  with a value falling in the interval  $[\lambda(R_{A,t} + h); (R_{A,t} + h)]$ . We observe that, in this case, the third integral in the equation vanishes as its interval collapses to zero. Hence in this case the expression to be maximized collapses to:

$$\frac{1}{2h} \int_{-h}^{R_t^n d_t - R_{A,t}} \frac{(1 + \lambda)(R_{A,t} + x_{j,t})}{2} dx_{j,t} + \frac{1}{2h} \int_{R_t^n d_t - R_{A,t}}^h \frac{(R_{A,t} + x_{j,t}) + R_t^n d_t}{2} dx_{j,t} \quad (12)$$

The bank then needs to maximize the first expression for  $R_t^n d_t$  falling in the interval  $[R_{A,t} - h; \lambda(R_{A,t} + h)]$ , and the second for  $R_t^n d_t$  falling in the interval  $[\lambda(R_{A,t} + h); R_{A,t} + h]$ .

It is straightforward to show that the first derivative of the first expression vanishes for  $d_t = 0$ , and the second derivative is positive; hence the function is rising for all values comprised in  $[R_{A,t} - h; \beta(R_{A,t} + h)]$ . The second expression is equal to:

$$\frac{(1 + \beta)}{8h} [R_t^{n2} d_t^2 - (1 - h)] + \frac{1}{8h} [(R_{A,t} + h + R_t^n d_t)^2 - 4R_t^{n2} d_t^2] \quad (13)$$

Its first derivative solved for  $d_t$  gives the following expression:

$$d_t = \frac{1}{R_t^n} \frac{R_{A,t} + h}{2 - \lambda}. \quad (14)$$

Since the second derivative is negative, this is the optimal value of  $d_t$ . Gross deposits,  $R_t^n d_t$ , depend on  $h$ ,  $\lambda$  and  $R_{A,t}$ . An increase in  $h$ , the dispersion of the project outcome, increases  $d_t$ , leading to a more leveraged and risky bank. An increase of  $\lambda$  also increases  $d_t$ .  $\lambda$ , the discount at which the project is liquidated in the market without the help of the bank, can be interpreted as a measure of the the liquidity of the project, or the complement to unity of the value of the bank's insider knowledge; the higher is  $\lambda$ , the more easily the project can be liquidated without loss and the lower is the bank's role as a relationship lender. When  $\lambda$  is unity this role vanishes. For given  $h$  and  $\lambda$ ,  $R_t^n d_t$  rises with  $R_{A,t}$ .

In the aggregate, the amount invested in every period is  $Q_t L_t$ . The total amount of deposits in the economy is

$$D_t = \frac{Q_t L_t}{R_t^n} \frac{R_{A,t} + h}{2 - \lambda} \quad (15)$$

and the bank's optimal capital is:

$$BK_t = (1 - \frac{1}{R_t^n} \frac{R_{A,t} + h}{2 - \lambda}) Q_t L_t \quad (16)$$

Since firms get financed by the intermediary for an amount:

$$Q_t L_t = Q_t K_t \quad (17)$$

The above expressions show that following a contractionary monetary policy the optimal amount of capital increases. The effect of cyclical up or downswings on the capital structure is more complex, as it depends on several counterbalancing factors, as the subsequent empirical results will show.

### 2.2.1 Accumulation of bank capital

Equation 16 is a demand for bank capital for any given level of investment,  $Q_t L_{t+1}$  and interest rate structure  $(R_t^n, R_{A,t})$ , derived from the banker's desired capital structure. As to the supply, we assume that bank capital accumulates in the form of undistributed dividends. After remunerating depositors and paying the competitive fee to the banker, a return accrues to the bank capitalist as retained earning (including any reinvested dividends). Bank capital accumulates from retained earnings as follows:

$$BK_{t+1} = \theta[BK_t + RITCAP_{t+1}] \quad (18)$$

The parameter  $\theta$  is a decay rate, inclusive of both the bank survival rate (Gertler and Karadi [20]) and bank capital depreciation.  $RITCAP_{t+1}$ , the residual gross return to the capitalist, can be calculated from equation 12 as follows:

$$RITCAP_{t+1} = \frac{1}{2h} \int_{R_{t+1}^n d_{t+1} - R_{A,t+1}}^h \frac{(R_{A,t+1} + x_{j,t+1}) - R_{t+1}^n d_{t+1}}{2} dx_{j,t} = \frac{(R_{A,t+1} + h - R_{t+1}^n d_{t+1})^2}{8h} \quad (19)$$

Note that this expression considers only the "safe " regime (no run), because if a run occurs the capitalist receives no return. Putting all these results together, the accumulation of bank capital is:

$$BK_{t+1} = \theta[BK_t + \frac{(R_{A,t+1} + h - \frac{R_{A,t+1} + h}{2-\lambda})^2}{8h} Q_{t+1} K_{t+1}] \quad (20)$$

### 2.2.2 A measure of bank fragility

A natural measure of bank riskiness is the probability of a run occurring. This can be written as:

$$Br_t = \frac{1}{2h} \int_{-h}^{R_t^n d_t - R_{A,t}} dx = \frac{1}{2} \left( 1 - \frac{R_{A,t} - R_t^n d_t}{h} \right) = \frac{1}{2} \left( 1 - \frac{R_{A,t} - \frac{R_{A,t} + h}{2-\lambda}}{h} \right) \quad (21)$$

Projects for which a bank run is expected (probability at least equal to one half) are not undertaken. Projects where a run is impossible (probability zero) are never optimal. Hence, a small degree of risk taking is always optimal for our bank, and its amount depends on parameter values. Note that  $Br_t$  ranges between 0 and 1 for admissible parameter values; for combinations of very low  $h$  and very high  $\lambda$ ,  $Br_t$  tends to fall below zero, but then deposits endogenously rise and  $R_{A,t}$  adjusts accordingly, maintaining  $Br_t$  above zero.

### 2.3 Producers

Each intermediate good firm  $i$  has monopolistic power in the production of its own variety and therefore has leverage in setting the price. In so doing it faces a quadratic cost equal to  $\frac{\vartheta}{2}(\frac{P_t(i)}{P_{t-1}(i)} - \pi)^2$ , where  $\pi$  is the *steady state* inflation rate and where the parameter  $\vartheta$  measures the degree of nominal price rigidity. The higher  $\vartheta$  the more sluggish is the adjustment of nominal prices. In the particular case of  $\vartheta = 0$ , prices are flexible. Each firm assembles labour (supplied by the workers) and (finished) entrepreneurial capital to operate a constant return to scale production function for the variety  $i$  of the intermediate good:

$$Y_t(i) = A_t F(N_t(i), K_t(i)) \quad (22)$$

The firm finances its capital in each period by obtaining funds from the intermediary. Hence:

$$Q_t L_t = Q_t K_t \quad (23)$$

Each monopolistic firm chooses a sequence  $\{K_t(i), L_t(i), P_t(i)\}$ , taking nominal wage rates  $W_t$  and the rental rate of capital  $Z_t$ , as given, in order to maximize expected discounted nominal profits:

$$E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_{0,t} [P_t(i) Y_t(i) - (W_t N_t(i) + Z_t K_t(i) - \frac{\vartheta}{2} (\frac{P_t(i)}{P_{t-1}(i)} - \pi)^2 P_t)] \right\} \quad (24)$$

subject to the constraint  $A_t F_t(\bullet) \leq Y_t(i)$  and to 22, where  $\Lambda_{0,t}$  is the households' stochastic discount factor.

Let's denote by  $\{mc_t\}_{t=0}^{\infty}$  the sequence of Lagrange multipliers on the above demand constraint, and by  $\tilde{p}_t \equiv \frac{P_t(i)}{P_t}$  the relative price variety  $i$ . The first order conditions of the above problem read:

$$\frac{W_t}{P_t(i)} = mc_t A_t F_{n,t} \quad (25)$$

$$\frac{Z_t}{P_t(i)} = mc_t A_t F_{k,t} \quad (26)$$

$$\begin{aligned} 0 = & Y_t \tilde{p}_t^{-\varepsilon} ((1 - \varepsilon) + \varepsilon mc_t - \vartheta (\pi_t \frac{\tilde{p}_t}{\tilde{p}_{t-1}} - \pi) \frac{\pi_t}{\tilde{p}_{t-1}} + \\ & + \vartheta (\pi_{t+1} \frac{p_{t+1}}{p_t} - \pi) \pi_{t+1} \frac{\tilde{p}_{t+1}}{\tilde{p}_t^2} \end{aligned} \quad (27)$$

where  $F_{n,t}^h$  is the marginal product of households' labour and  $\pi_t = \frac{P_t}{P_{t-1}}$  is the gross aggregate inflation rate. Notice that all firms employ an identical capital/labour ratio in equilibrium. The Lagrange multiplier  $mc_t$  plays the role of the *real* marginal cost of production. In a symmetric equilibrium it must hold that  $\tilde{p}_t = 1$ . This allows to rewrite the 27 in the following form:

$$\begin{aligned} U_{c,t}(\pi_t - \pi)\pi_t = & \beta E_t \{ U_{c,t+1}(\pi_{t+1} - \pi)\pi_{t+1} \} + \\ & + U_{c,t} A_t F_t(\bullet) \frac{\varepsilon}{\vartheta} (mc_t - \frac{\varepsilon - 1}{\varepsilon}) \end{aligned} \quad (28)$$

The above equation has the form of a (non-linear) forward looking New-Keynesian Phillips curve, in which deviations of the real marginal cost from its desired steady state value are the driving force of inflation.<sup>5</sup>

### 2.3.1 Unfinished-Capital Producers

A competitive sector of capital producers combine investment (expressed in the same composite as the final good, hence with price  $P_t$ ) and existing (depreciated) capital stock to produce unfinished capital goods. This activity entails physical adjustment costs. The corresponding CRS production function is  $\phi(\frac{I_t}{K_t})K_t$ , so that capital accumulation obeys:

$$K_{t+1} = (1 - \delta)K_t + \phi(\frac{I_t}{K_t})K_t \quad (29)$$

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<sup>5</sup>Woodford [31].

where  $\phi(\bullet)$  is increasing and convex.

Define  $Q_t$  as the re-sell price of the capital good. Capital producers maximize profits  $Q_t\phi(\frac{I_t}{K_t})K_t - P_t I_t$ , implying the following first order condition:

$$Q_t\phi'(\frac{I_t}{K_t}) = P_t \quad (30)$$

Finally, we need to determine the expected return of capital. The *nominal income* from holding one unit of finished capital is composed of the rental rate plus the re-sell price of capital (net of depreciation and physical adjustment costs):

$$Y_t^k \equiv Z_t + Q_t((1 - \delta) - \phi'(\frac{I_t}{K_t})\frac{I_t}{K_t} + \phi(\frac{I_t}{K_t})) \quad (31)$$

The return to entrepreneurs from holding a unit of capital between  $t$  and  $t + 1$  is equalized in equilibrium to the real return that entrepreneurs rebate to banks for their loan services,  $R_{A,t+1}$ :

$$\frac{R_{A,t+1}}{\pi_{t+1}} \equiv \frac{Y_{t+1}^k}{Q_t} \quad (32)$$

## 2.4 Goods Market Clearing

Equilibrium in the final good market requires that the production of the final good be allocated to total private consumption by households and entrepreneurs, investment, public spending, and to resource costs that originate from the adjustment of prices:

$$Y_t = C_t + I_t + G_t + \frac{\vartheta}{2}(\pi_t - \pi)^2 \quad (33)$$

In the above equation,  $G_t$  is government consumption of the final good which evolves exogenously and is assumed to be financed by means of lump sum taxes.

Finally we assume that market for loans clears:

$$Q_t L_t = D_t + BK_t \quad (34)$$

## 2.5 Monetary Policy

We assume that monetary policy is conducted by means of an interest rate reaction function of this form:

$$\ln\left(\frac{1+R_t^n}{1+R^n}\right) = (1-\phi_r)\left(\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_y \ln\left(\frac{Y_t}{y}\right) + \phi_q \ln\left(\frac{Q_t}{Q}\right) + \phi_{br} \ln\left(\frac{Br_t}{Br}\right)\right) + \phi_r \ln\left(\frac{1+R_{t-1}^n}{1+R^n}\right) \quad (35)$$

All variables are deviations from the target or steady state. The steady state value of (net) inflation is set to zero. Our approach will consist in finding the policy specifications  $\{\phi_\pi, \phi_y, \phi_q, \phi_{br}, \phi_r\}$  that maximizes household welfare, relative to an optimum within a class of alternative simple Taylor-type rules<sup>6</sup> We solve the model by computing a second order approximation of the policy functions around the non-stochastic steady state.

## 2.6 Parameter values

*Preferences and production.* The time unit is quarter. We employ a period utility function for households  $U(C_t, N_t) = \log(C_t) + \nu \log(1 - N_t)$ , with parameter  $\nu$  set equal to 3 and chosen in such a way to generate a steady-state level of households' employment  $N \approx 0.3$ . We assume that the annualized steady-state inflation rate is 4%, close to the historical average for the U.S.. We set the discount factor  $\beta = 0.99$ , so that the annual real interest rate is equal to 4%. We assume that the production function for the intermediate goods has the Cobb-Douglas form  $F(\bullet) = K_t^\alpha (N_t)^{1-\alpha}$ , with  $\alpha = 0.3$ . The quarterly aggregate capital depreciation rate  $\delta$  is 0.025, the elasticity of substitution between varieties  $\theta$ . The adjustment cost parameter is set so that the volatility of investment is larger than the volatility of output, consistently with empirical evidence: this implies an elasticity of asset prices to investment of 2.

In order to parameterize the degree of price stickiness  $\vartheta$ , we observe that by log-linearizing equation 28 we can obtain an elasticity of inflation to real marginal cost (normalized by the steady-state level of output)<sup>7</sup> that takes the form  $\frac{\varepsilon-1}{\vartheta}$ . This allows a direct comparison with empirical studies on the New-Keynesian Phillips curve such as Galí and Gertler [19] and Sbordone [27] using Calvo-Yun approach. In those studies, the slope coefficient of the log-linear Phillips curve can be

<sup>6</sup>See for instance Kim and Kim 2003, Kollmann [22], [23] Schmitt-Grohe and Uribe [28], [29], [30], Faia and Monacelli [18], Faia [17].

<sup>7</sup>To produce a slope coefficient directly comparable to the empirical literature on the New Keynesian Phillips curve this elasticity needs to be normalized by the level of output when the price adjustment cost factor is not explicitly proportional to output, as assumed here.

expressed as  $\frac{(1-\hat{\vartheta})(1-\beta\hat{\vartheta})}{\hat{\vartheta}}$ , where  $\hat{\vartheta}$  is the probability of not resetting the price in any given period in the Calvo-Yun model. For any given values of  $\vartheta$ . For any given values of  $\varepsilon$ , which entails a choice on the steady state level of the markup, we can thus build a mapping between the frequency of price adjustment in the Calvo-Yun model  $\frac{1}{1-\hat{\vartheta}}$  and the degree of price stickiness  $\vartheta$  in the Rotemberg setup. The recent New Keynesian literature has usually considered a frequency of price adjustment of four quarters as realistic. Recently, Bils and Klenow [5] have argued that the observed frequency of price adjustment in the U.S. is higher, and in the order of the two other quarters. As a benchmark, we parameterize  $\frac{1}{1-\hat{\vartheta}} = 4$ , which implies  $\hat{\vartheta} = 0.75$ . Given  $\varepsilon = 6$ , the resulting stickiness parameter satisfies  $\vartheta = \frac{Y\hat{\vartheta}(\varepsilon-1)}{(1-\hat{\vartheta})(1-\beta\hat{\vartheta})} \approx 38$ , where  $Y$  is steady-state output.

*Bankers.* The parameters  $h$  and  $\lambda$  depend in principle not only on preferences, but also on the state of the economy. For example, as shown by Bloom et al. [7], the dispersion of corporate returns in anticyclical: cyclical slowdowns are systematically associated with a higher variance returns. The link between  $h$  and the output gap in history depends on the preferences and technologies, and can be estimated with micro data (Bloom et al. [7]). In practice we have used a fixed  $h$  throughout the paper and only done sensitivity analysis. To determine the benchmark  $h$  we have taken the average dispersion of the data constructed by Bloom et al. [7] (we are grateful to Nicholas Bloom for kindly giving us his data), which is 0.31, and multiplied this by the square root of 3, the ratio of the maximum deviation to the standard deviation of a uniform distribution. The result, 0.5, is our benchmark.

We can interpret  $\lambda$  as a ratio of two present values of the project, the first at the interest rate applied to firms' external finance, the second discounted at the bank internal finance rate (the money market rate). A rough benchmark estimate can be obtained by taking the historical ratio between the money market rate and the lending rate. In the US over the last 20 years, taking 30-year mortgage loans, this ratio has been around 3 percent. This leads to a value of  $\lambda$  around 0.6. In the empirical analyses we have chosen 0.5 and then checked the sensitivity to a higher value, 0.8. Finally we parametrize the survival rate of banks at 0.97.

*Shocks.* Total factor productivity is assumed to evolve as:

$$A_t = A_{t-1}^{\rho_\alpha} \exp(\varepsilon_t^\alpha) \tag{36}$$

where the steady-state value  $A$  is normalized to utility (which in turn implies  $\omega_m = 1$ ) and where  $\varepsilon_t^\alpha$  is an i.i.d. shock with standard deviation  $\sigma_\alpha$ . In line with the real business cycle literature (King and Rebelo [21]), we set  $\rho_\alpha = 0.95$  and  $\sigma_\alpha = 0.0056$ . Log-government consumption is assumed to evolve according to the following process:

$$\ln\left(\frac{G_t}{G}\right) = \rho_g \ln\left(\frac{G_{t-1}}{G}\right) + \varepsilon_t^g$$

where  $G$  is the steady-state share of government consumption (set in such a way that  $\frac{G}{Y} = 0.25$ ) and  $\varepsilon_t^g$  is an i.i.d. shock with standard deviation  $\sigma_g$ . We follow the empirical evidence for U.S. in Perotti [26] and set  $\sigma_g = 0.008$  and  $\rho_g = 0.9$ .

Furthermore we introduce a monetary policy as an additive shock to the interest rate set through the monetary policy rule. The monetary policy shock,  $m_t$ , is assumed to have zero persistence. Following empirical evidence for US and Europe, the standard deviations of the shocks is set to 1.0007.

### 3 Transmission Channels With and Without Banks

We look at the responses, with parameters at their benchmark values, to three shocks: a productivity (TFP) rise; a monetary restriction; a positive shock to the marginal return on capital (MRK), interpreted as a positive asset market shock. The latter is of interest particularly to compare later simulations with a leaning-against-the-wind component in the monetary policy rule.

As one would expect, the *productivity shock* (figure 1) reduces inflation and increases output on impact. Investment and Tobin's Q rise. The nominal rate and bank return on assets (ROA) decline following the fall in inflation, driven by the relatively high weight of inflation in the policy rule. Lower interest rates raise deposits and tilt the composition of the bank balance sheet towards higher leverage and risk. In the *monetary shock* (figure 2) both inflation and output drop on impact, as in standard models, with a corresponding fall in investment and Tobin's Q. ROA rises with the interest rate; their spread depends on the persistence of the shock (with interest rate smoothing, the spread tends to rise after a monetary restriction). Banks lose deposits and replace them with capital, leading to a less risky balance sheet composition; a "risk taking channel" of monetary policy operates. Figure 3 shows that in response to a positive *asset market shock* output and inflation

rise on impact; the rise in investment fuelled by the asset price boom drives up ROA above the riskless rate. Bank risk thus declines on impact, but later rises above baseline driven by the high value of the deposit ratio. All these results together suggest that the co-movements of bank risk on one side and interest rates and output on the other is not systematic, but depend on the nature of the shock. *Ceteris paribus*, higher policy-driven interest rates lead to lower bank risk, but not if there is a concurrent investment boom, for example generated by asset market exuberance. In this case banks become more risky in spite of higher rates.

To examine how banks affect the transmission, we compare two models, one with benchmark parameters, the other obtained setting  $\lambda = 1$ . A unitary  $\lambda$  means that banks lose all relationship lender advantage because they cannot extract more value than outsiders if the project is liquidated early. Under this parametrization the response of bank ROA tends to approach that of the riskless rate. In figure 4, showing the response to the TFP shock, the response from the standard model with banks is shown with a solid line, that from the model with a unitary  $\lambda$  with a dashed line. Under this shock the presence of banks amplifies the expansionary effect on output; the reason is that the decline in the bank lending rate tends to be larger on impact than that of the riskless rate, so that the premium between ROA and the interest rate declines. This result does not generalize to other shocks, however. A low  $\lambda$  may amplify or dampen depending on parameters.

## 4 Sensitivity to Key Parameters

### 4.1 Entrepreneurial risk

The parameter  $h$ , the ex-ante uncertainty of investment outcomes, is of particular interest. A higher  $h$  tends to increase the probability of a run on the bank, as one can conclude from inspecting equation 21, but also changes the response to other shocks. Figures 5 and 6 report the responses to a TFP and a monetary shock respectively, with values of  $h$  equal to 0.5, the baseline, and 0.9, a higher risk situation. Unlike in the productivity shock, under a monetary restriction the response is amplified in the high risk case; we have a bigger drop in output, investment and capital, together with a sharper fall in bank leverage. This is due to the fact that the downward effect of a given change in  $R_t^n$  on the deposit ratio is stronger when  $h$  is high (see equation 14), hence  $R_{A,t}$  rises more on impact and the transmission to investment and output is higher – this changes when

the origin of the shock is different. Interestingly, the decline in bank riskiness is *smaller* when entrepreneurial risk is higher (a high  $h$  dampens the stronger increase in  $R_{A,t}$  in equation 21). We thus conclude that the risk taking channel of monetary policy operates more strongly when the ex-ante uncertainty of projects is low. Since the empirical evidence shows that entrepreneurial risks tend to be anti-cyclical – we did not incorporate this link in our model, but see Bloom [7] – we conclude that the strength of the risk taking channel is pro-cyclical: an expansionary monetary policy when the economy is strong increases bank risk by more than the same policy when the economy is weaker.

## 4.2 Leaning against the wind

Figure 7 compares the benchmark case of no leaning-against-the-wind two alternatives, where the interest rate reacts also respectively to asset prices (Tobin’s  $Q$  here), and bank leverage (more precisely, the change in the deposit ratio, with a coefficient equal to the previous one, 0.5). These cases are of interest for two reasons. First, if one considers using monetary policy to control risks in the financial sector, reacting leaning-against-the-wind is a natural option; many in fact now say it should have been used more often in the years before the crisis. Second, our model brings evidence to the old debate between those who contended that monetary policy should target inflation in the goods’ market only (see Bernanke and Gertler [2], and Blinder and Reis [4] for a summary of the debate) and those arguing that monetary policy should react to asset prices as well (Cecchetti, Genberg, Lipsky and Whadwani [13]). Since one of the arguments in the first camp was that responding to volatile asset prices would inject volatility in the economy through the policy actions, it is interesting to look at an alternative measure, based on bank balance sheets, that should be empirically much more stable.

The figure is constructed with an asset price shock (MRK), to facilitate comparison later on. As evident in figure 7, the two strategies give broadly similar results: both succeed in stabilizing the main macroeconomic variables to some extent. But there are differences. For example, responding to the asset price has a more powerful stabilizing effect on inflation on impact, but a lesser one after a few quarters. Moreover, responding to leverage results in greater volatility in the interest rate, ROA and bank riskiness on impact (though not after a few quarters). All in all, these results (which, we recall, are obtained applying a single shock to the model) seem to favor responding to

asset prices. However, as we shall see later, using a broader set of calibrated shocks tends to tilt the balance in favor of responding to leverage – see below the section on optimal policy.

## 5 Introducing Bank Capital Requirements

Capital regulation in our model takes the form of an exogenously imposed ratio between banking capital,  $BK_t$ , and the total amount of bank loans,  $Q_tK_t$ . The regulatory ratio can be either fixed, akin to Basel I, or risk-weighted. Since output tends to be inversely related to the riskiness of banking assets (Bloom et al. [7]) one can mimic a Basel II-type regime introducing a response to output. A negative coefficient means that the capital regime is pro-cyclical (for given loans, regulatory capital decreases in an upswing); a positive one, that the policy is anticyclical. The capital requirement thus takes the form:

$$BK_t = (B_0^c + B_1^c Y_t) Q_t K_t \quad (37)$$

We compare regimes assuming that when operating the capital ratio is binding; we do not allow for endogenous switching among regimes. Formally, introducing the capital ratio implies, in addition to replacing equation 16 with 37, also modifying the accumulation of capital, equation 20, replacing optimal capital with regulatory capital as follows:

$$BK_{t+1} = \theta [BK_t + \frac{\{R_{A,t+1} + h - R_t^n [1 - (B_0^c + B_1^c Y_{t+1})]\}^2}{8h} Q_{t+1} L_{t+1}] \quad (38)$$

Figure 8 compares the optimal capital (solid line) regime with a fixed capital ratio (dashed line), while figure 9 compares three different regimes (fixed, pro-cyclical and anticyclical, the last two with coefficient 0.1 respectively negative and positive).

The first clearly illustrates that a fixed capital ratio is quite destabilizing for the economy; the impulse responses oscillate before returning to baseline. The short run effect of a productivity shock is amplified if the bank is subject to a capital ratio. After a slow start due to the gradual accumulation, bank capital builds up strongly, driven by the higher level of ROA. The output amplification result echoes that of Cecchetti and Li, but the mechanism at play is different (they assume that the supply of capital is proportional to output).

The second figure one shows that an anticyclical coefficient is successful in stabilizing the economy, eliminating the oscillatory behavior and in most cases ensuring a faster return to the steady state. Similar results are obtained with other shocks, not reported here.

## 6 Welfare Analysis and Optimal Monetary Policy

Technically speaking, we approach the optimal policy problem by assuming that the policy authorities maximize households welfare subject to the competitive equilibrium conditions and the class of monetary policy rules represented by (35) and 37. Specifically we search for parametrization of these rules that satisfy the following 3 conditions: a) they are simple and involve only observable variables, b) they guarantee uniqueness of the rational expectation equilibrium, c) they maximize the expected life-time utility of the representative agent.

Some observations on the computation of welfare are important in our context since the model features significant frictions operating both in the steady state and over the dynamic. First, we cannot safely rely on first order approximations to compare the welfare associated to monetary policy rules, because in an economy with a distorted steady state stochastic volatility affects both first and second moments. Since in a first order approximation of the model's solution the expected value of a variable coincides with its non-stochastic steady state, the effects of volatility on the variables' mean values is by construction neglected. Policy alternatives can be correctly ranked only by resorting to a higher order approximation of the policy functions<sup>8</sup>. Additionally one needs to focus on the *conditional* expected discounted utility of the representative agent. This allows to account for the transitional effects from the deterministic to the different stochastic steady states respectively implied by each alternative policy rule<sup>9</sup>. Define  $\Omega$  as the fraction of household consumption that would be needed to equate conditional welfare  $\mathcal{W}_0$  under a generic interest rate policy to the level of welfare  $\widetilde{\mathcal{W}}_0$  implied by the optimal rule. Hence  $\Omega$  should satisfy the following equation:

$$\mathcal{W}_{0,\Omega} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U((1 + \Omega)C_t) \right\} = \widetilde{\mathcal{W}}_0$$

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<sup>8</sup>See Kim and Kim (2003) for an analysis of the inaccuracy of welfare calculations based on log-linear approximations in dynamic open economies.

<sup>9</sup>See Kim and Levin (2004) for a detailed analysis on this point.

Under a given specification of utility one can solve for  $\Omega$  and obtain:

$$\Omega = \exp \left\{ \left( \widetilde{\mathcal{W}}_0 - \mathcal{W}_0 \right) (1 - \beta) \right\} - 1 \quad (39)$$

In practice there are two ways we can proceed. The first, simpler and computationally easier, is to select ex-ante a set of policy rules of interest and then rank them according to the welfare criterion. The second is to compute the optimal policy (still in a predefined class of simple rules) and possibly also see how this policy varies with other structural parameters. We use both approaches in sequence. First, in the next subsection we compare a two-handful set of simple rules that, based on experience, are of particular interest. We look at them under both bank capital regimes, without and with binding capital requirements. Then we move on to calculate optimal policies, considering again both the cases of free and constrained capital. Here in addition we distinguish the situation in which monetary policy takes prudential policy as given, from that in which they coordinate to attain the optimum via a combined policy.

## 6.1 Comparing simple rules

We compare the welfare performance of alternative monetary policy rules including three shocks, productivity, government expenditure and monetary policy calibrated as indicated earlier. Our metric for comparison is the fraction of household's consumption,  $\Omega$ , that would be needed to equate conditional welfare  $\mathcal{W}_0$  under a generic interest rate policy to the level of welfare  $\widetilde{\mathcal{W}}_0$  implied by the optimal rule. Our 10 rules are listed in Table 1.

<b>Table 1. Simple Rules</b>					
<b>Rule</b>	<b>Description</b>				
<i>Parameter</i>	$\phi_\pi$	$\phi_y$	$\phi_q$	$\phi_{br}$	$\phi_r$
<i>Flexible inflation target</i>	1.5	0.5	0	0	0
<i>Flexible i. t. with interest rate smoothing</i>	1.5	0.5	0	0	0.6
<i>Aggressive i. t. with interest rate smoothing</i>	2.5	0.5	0	0	0.6
<i>Pure inflation target with smoothing</i>	1.5	0	0	0	0.6
<i>Aggressive output target with smoothing</i>	1.5	1.0	0	0	0.6
<i>Aggressive interest rate smoothing</i>	1.5	0.5	0	0	0.9
<i>Flexible i.t. with l.a.w. on asset price, smoothing</i>	1.5	0.5	0.5	0	0.6
<i>Flexible i.t. with l.a.w. on leverage, smoothing</i>	1.5	0.5	0	0.5	0.6
<i>Flexible i.t. with l.a.w. on asset price</i>	1.5	0.5	0.5	0	0
<i>Flexible i.t. with l.a.w. on leverage</i>	1.5	0.5	0	0.5	0

Table 2 shows results for the case in which the bank capital is set optimally as in equation 16. The table shows results for different values of entrepreneurial risk,  $h$ , and market liquidity,  $\lambda$ . Note that the "best rule", our benchmark for comparing the welfare loss implied by the others, is different across columns, so that numbers in the table can be compared only within and not across columns.

<b>Table 2. Welfare results, optimal bank capital</b>				
$h, \lambda$	0.5, 0.5	0.5, 0.8	0.8, 0.5	0.8, 0.8
<b>Rule</b>	<b>Welfare loss, <math>\Omega</math></b>			
<i>Flexible inflation target</i>	0.0224	0.0350	0.0240	0.0388
<i>Flexible i. t. with interest rate smoothing</i>	0.4524	0.6481	0.5085	0.6564
<i>Aggressive i. t. with interest rate smoothing</i>	0.1211	0.2137	0.1457	0.2246
<i>Pure inflation target with smoothing</i>	0.8538	0.6683	<i>ind.</i>	0.6786
<i>Aggressive output target with smoothing</i>	0.4547	0.4681	0.4602	0.4421
<i>Aggressive interest rate smoothing</i>	8.6769	10.856	9.1876	<i>ind.</i>
<i>Flexible i.t. with l.a.w. on asset price, smoothing</i>	0.4162	0.4703	0.4432	0.4348
<i>Flexible i.t. with l.a.w. on leverage, smoothing</i>	0.4522	0.5513	0.4835	0.4970
<i>Flexible i.t. with l.a.w. on asset price</i>	0	0	0	0
<i>Flexible i.t. with l.a.w. on leverage</i>	0.0230	0.0253	0.0212	0.0221

Note:  $\Omega$  is the fraction of consumption required to equate welfare under any given policy rule to the one under the optimal policy (see equation (39)).

We can identify three groups of rules according to performance: the very bad ones, the bad and the good ones. The only "very bad" is aggressive interest rate smoothing, whose welfare loss reaches an astronomical level. Excluding this one, the "bad" performers are all the class incorporating interest rate smoothing (flexible IT with and without leaning-against-the-wind, pure – and to some extent also aggressive – IT and aggressive output targeting). The small club of good ones includes only flexible IT, with and without leaning-against-the-wind. For all parametrizations of  $h$  and  $\lambda$ , the winner is... flexible IT with a response to the asset price. The other two are close seconds, within a 2-4 percent consumption loss depending on parameter values. One wonders if this ranking would change if we introduced some volatility in the asset price, following the argument of Bernanke and Gertler [2]; we haven't tried this yet.

Table 3 shows results for the case in which the bank capital is constrained by regulation as in equation 37. We label this the *Basel regime*, and within this regime we consider both a simple rule with fixed capital ratio, and two risk-weighted approaches, one pro-cyclical as Basel II and

the other anti-cyclical. Unlike in the earlier table, we have constructed the numbers so that the "best rule" serving as benchmark is common to the whole table, so comparison is possible across alternative Basel regimes.

<b>Table 3. Welfare results, Basel capital regimes</b>			
<i>Fixed, anticyclical, procyclical</i>	$B_1^c = 0$	$B_1^c = 0.1$	$B_1^c = -0.1$
<b>Rule</b>	<b>Welfare loss, <math>\Omega</math></b>		
<i>Flexible inflation target</i>	0.0866	0.0920	0.9090
<i>Flexible i. t. with interest rate smoothing</i>	0.4050	0.4434	5.6314
<i>Aggressive i. t. with interest rate smoothing</i>	0.1079	0.1326	3.3264
<i>Pure inflation target with smoothing</i>	0.4266	0.4946	333.30
<i>Aggressive output target with smoothing</i>	0.5293	0.5426	2.6235
<i>Aggressive interest rate smoothing</i>	13.749	12.842	479.41
<i>Flexible i.t. with l.a.w. on asset price, smoothing</i>	0.3005	0.3319	3.4150
<i>Flexible i.t. with l.a.w. on leverage, smoothing</i>	0.4050	0.3673	3.4573
<i>Flexible i.t. with l.a.w. on asset price</i>	0.0361	0.0512	0.4746
<i>Flexible i.t. with l.a.w. on leverage</i>	0.0866	0	0.7820

Again, aggressive interest rate smoothing performs very badly. And again, all rules with smoothing (flexible IT with and without leaning-against-the-wind, pure and – to some extent also aggressive – IT and aggressive output targeting) are quite bad also, all in the range of 30 to 50 percent loss except for aggressive IT with smoothing, close to 10 percent. A key result from this table is that pro-cyclical Basel performs very badly for all monetary policy rules; see the last column. The best chance monetary policy has under pro-cyclical Basel is to go for flexible IT without smoothing and respond to the asset price, but even in this case the consumption loss is very high, 47 percent. On this point we are less optimistic than Cecchetti and Li [12], who suggest that monetary policy may effectively correct for the perverse cyclical impact of Basel II. For real improvement we need to look elsewhere, in the region that combines flexible IT without smoothing and fixed or anticyclical Basel. The very best rule, among the 10 we consider, is one where monetary policy reacts to bank leverage and the capital ratio moves with output in an anticyclical way. The rules where monetary policy reacts to asset prices, and capital ratios are fixed or anticyclical, are not too far back. At more distance we find the "classic" flexible IT without leaning-against-the-wind, still with an anticyclical or fixed capital ratio.

## 6.2 Optimal monetary policy

To enhance our assessment of the optimal monetary policy rule we search over a grid of parameters the welfare-maximizing simple rule within the class 35. Computation of conditional welfare is done by considering the three main shocks: productivity, government expenditure and interest rate parametrized as described in the calibration section. The search grid is specified as follows:  $\phi_\pi \in \{1.5 - 3.5\}$ ,  $\phi_y \in \{0.5 - 1\}$ ,  $\phi_q \in \{0 - 1\}$ ,  $\phi_r = \{0; 0.3; 0.9\}$ . The choice of the search grid is motivated by two considerations: a. to consider empirically plausible values for the operational rules, b. to avoid indeterminacy regions, which in our model occur for too aggressive values of the response to output and asset prices. We search within the model in which the allocation of bank capital is chosen optimally. The values that identify the optimal policy rules are as follows:  $\phi_\pi = 3.5$ ,  $\phi_y = 0.5$ ,  $\phi_q = 1$ ;  $\phi_r = 0$ . Figure 10 shows the welfare costs of deviating from the optimal policy for different values of the response to inflation and asset price. Three results emerge. First, optimality requires a rather active policy rule that includes both a positive response to output and asset prices. The lean-against-the-wind policy seems a rather robust prescription from our model, in contrast with the result obtained from financial accelerator-type models (Bernanke and Gertler [2]; Faia and Monacelli [18]). Second, the optimal response to inflation remain aggressive. Since the model induces amplification of the main macro variables, including inflation, under our combination of shocks, it does not come as a surprise that it calls for aggressive inflation stabilization. Finally, the model prescribes no response to past interest rates. Our banking model induces a quite persistent dynamics for most variables; in this context, further persistence from the policy is unwarranted.

## 7 Conclusions

Since the crisis started, the landscape of economic policy has changed considerably. Some well established paradigms have collapsed right at the time of their maximum triumph. One of the casualties concerns the interaction between bank regulation and monetary policy. The old consensus, according to which the two policies should be conducted in isolation, each pursuing its own goal using separate sets of instruments, is increasingly challenged. After years of glimpsing at each other from the distance, monetary policy and prudential regulation – though still unmarried – are moving in together. This opens up new research horizons, highly relevant at a time in which central banks

on both sides of the Atlantic are acquiring new responsibilities in the area of systemic stability.

We have tried to move a step forward by constructing a new macro-model that integrates banks in a meaningful way and using it to analyze the role of banks in transmitting shocks to the economy, the effect of monetary policy when banks are fragile, and the way monetary policy and bank capital regulation can be conducted as a coherent whole. Our conclusions at this stage are summarized in the front page, and need not repeating here.

While our model brings into the picture a key source of risk in modern financial system, namely leverage (and implicitly, also the maturity mismatch between bank assets and liabilities), there are also others that for simplicity we have left out from our highly abstract construct. One that we regard as of special importance is the degree of interconnections of the banking system. Thanks to work by Morris, Shin and Brunnermeier among others (see e.g. [25], [11]), we now understand better that a system where leveraged financial institutions lend to each other and may suddenly withdraw funding under stress is, other things equal, more unstable than one in which, as in our model, banks lend only to entrepreneurs. Introducing bank inter-linkages and heterogeneity in macro models is, we believe, the most urgent challenge in this line of research.

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Figure 1: Impulse response to a positive productivity shock

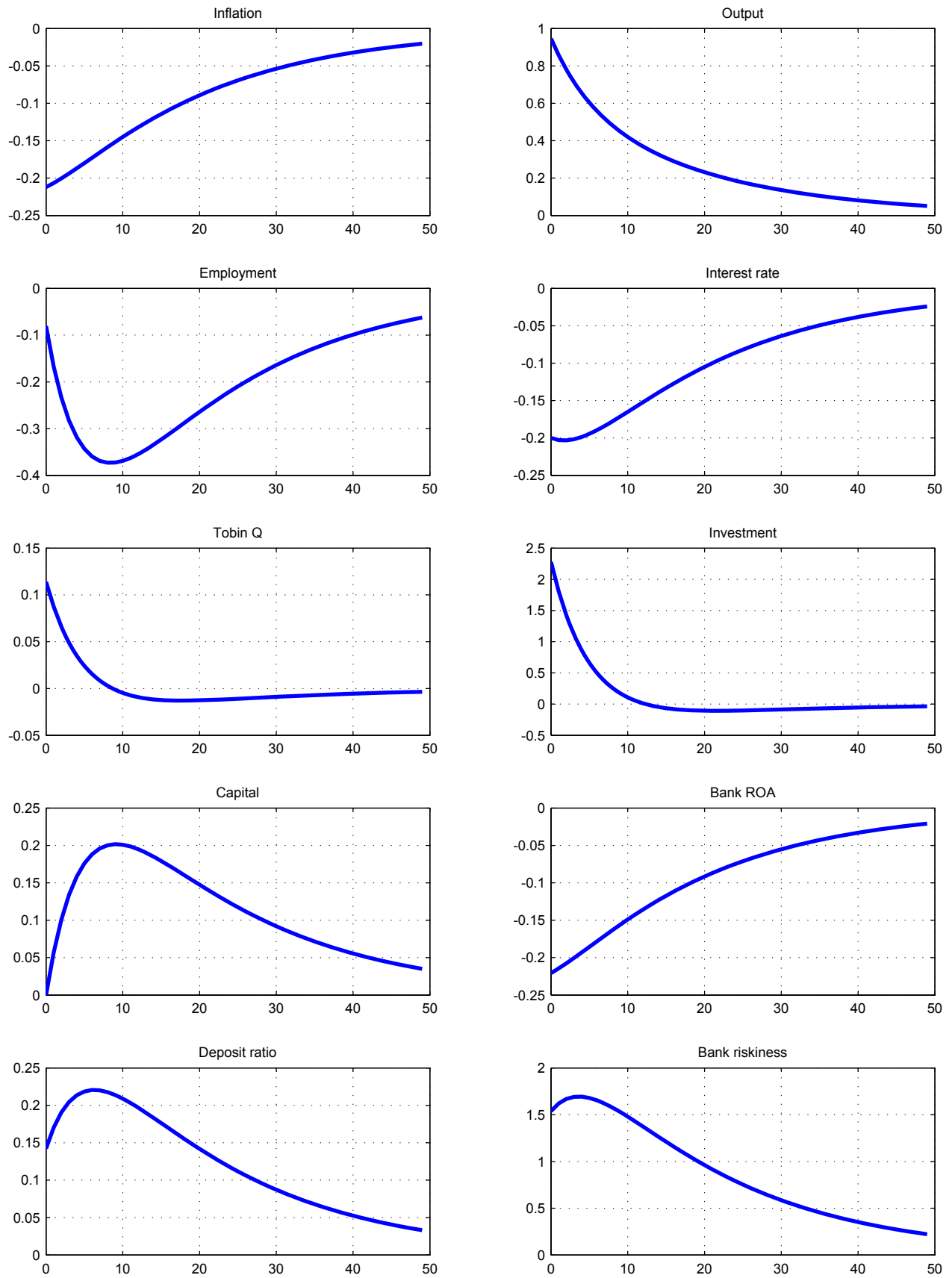


Figure 2: Impulse response to a positive interest rate shock

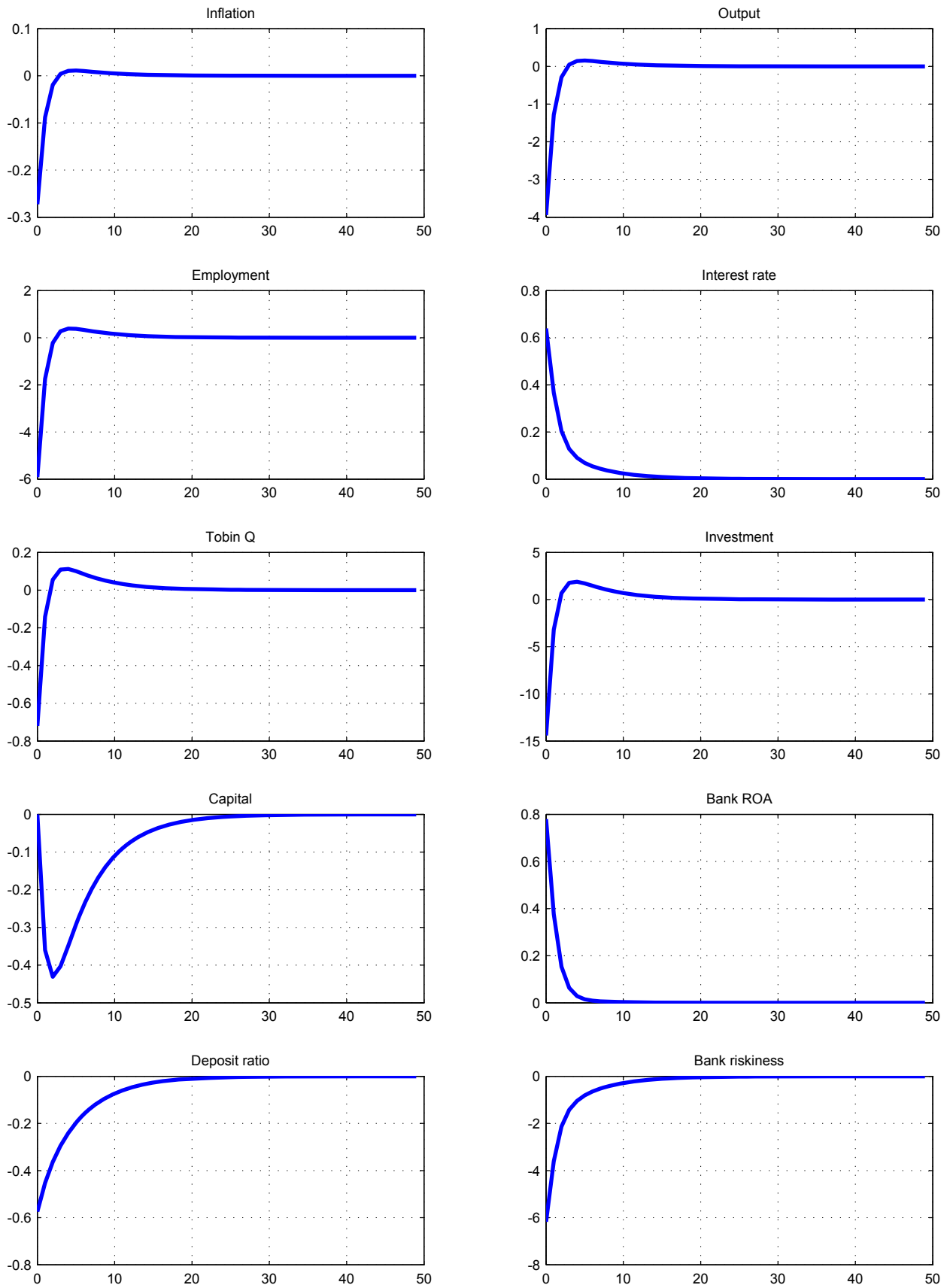


Figure 3: Impulse response to a positive shock in the marginal return on capital

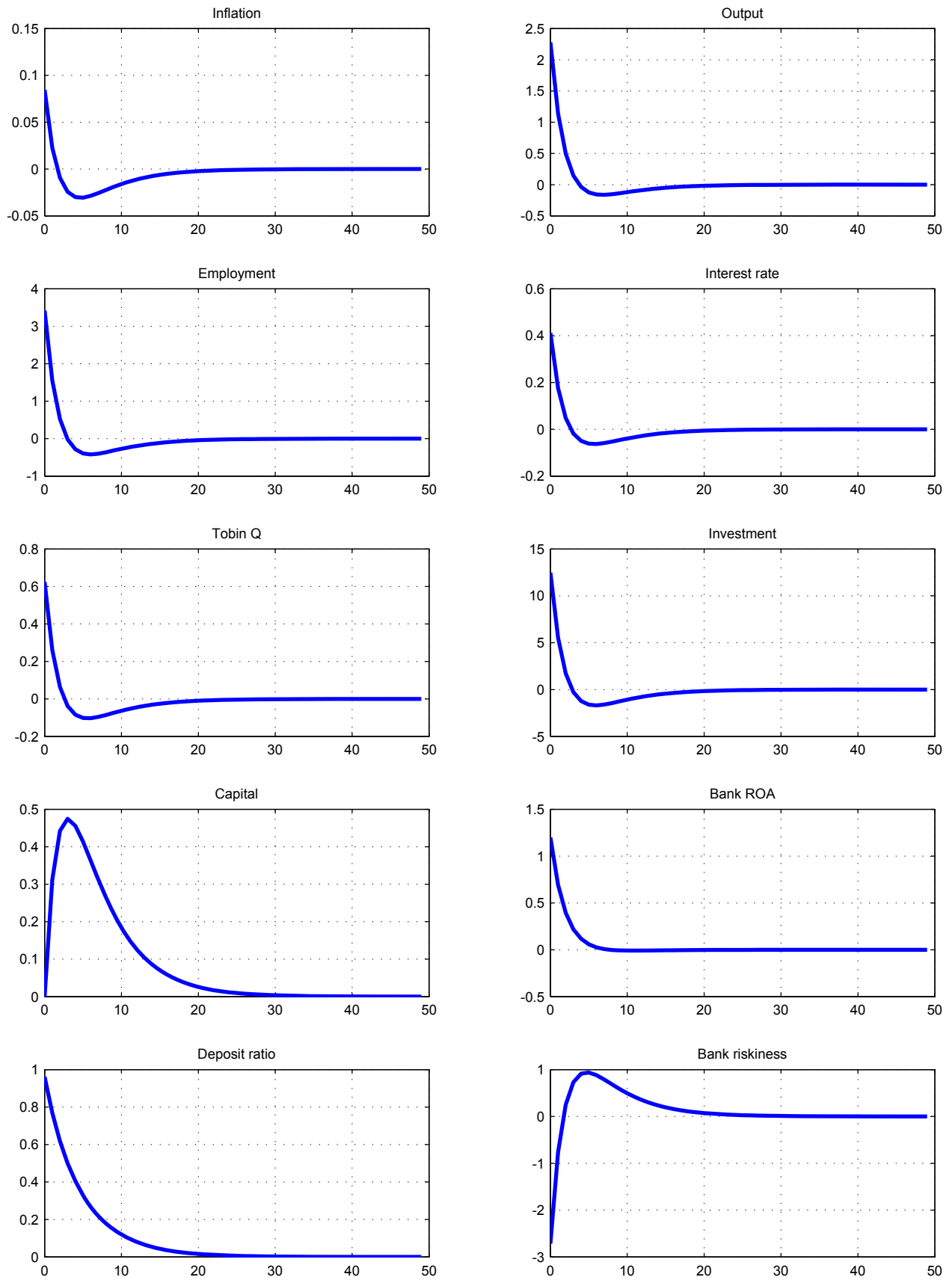


Figure 4: Alternative values of lambda (positive productivity shock)

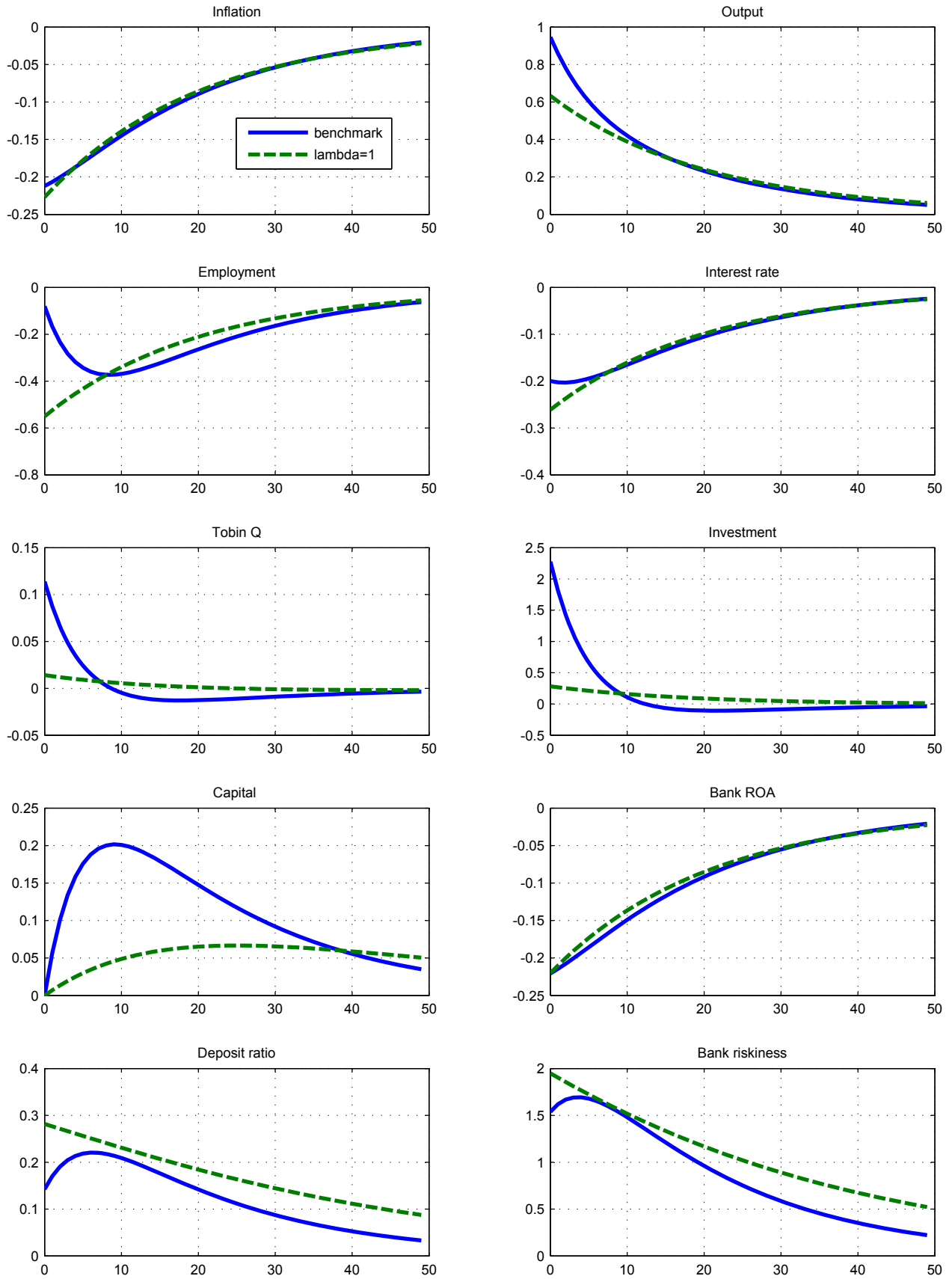


Figure 5: Alternative values of  $h$  (positive productivity shock)

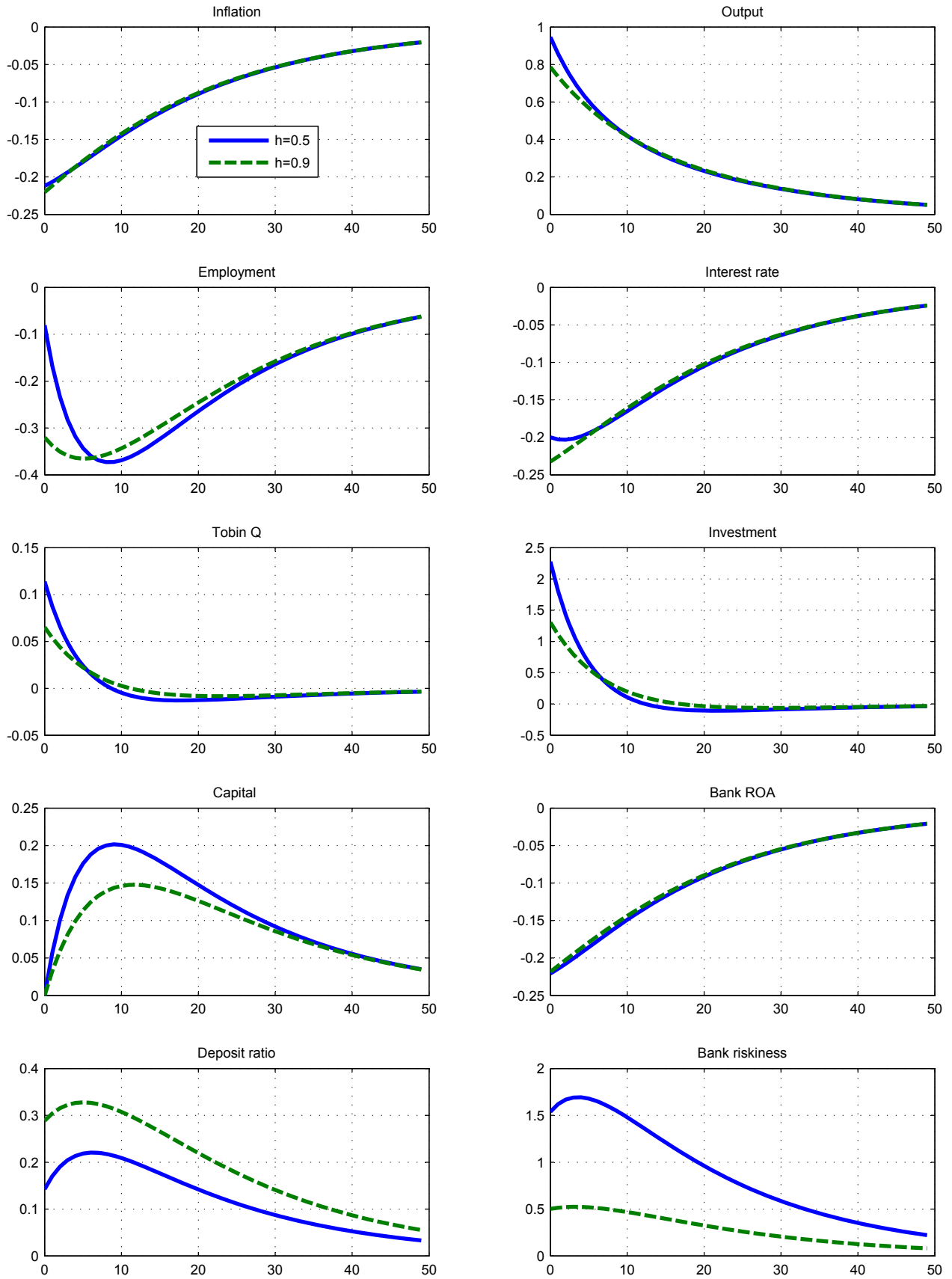


Figure 6: Alternative values of  $h$  (positive interest rate shock)

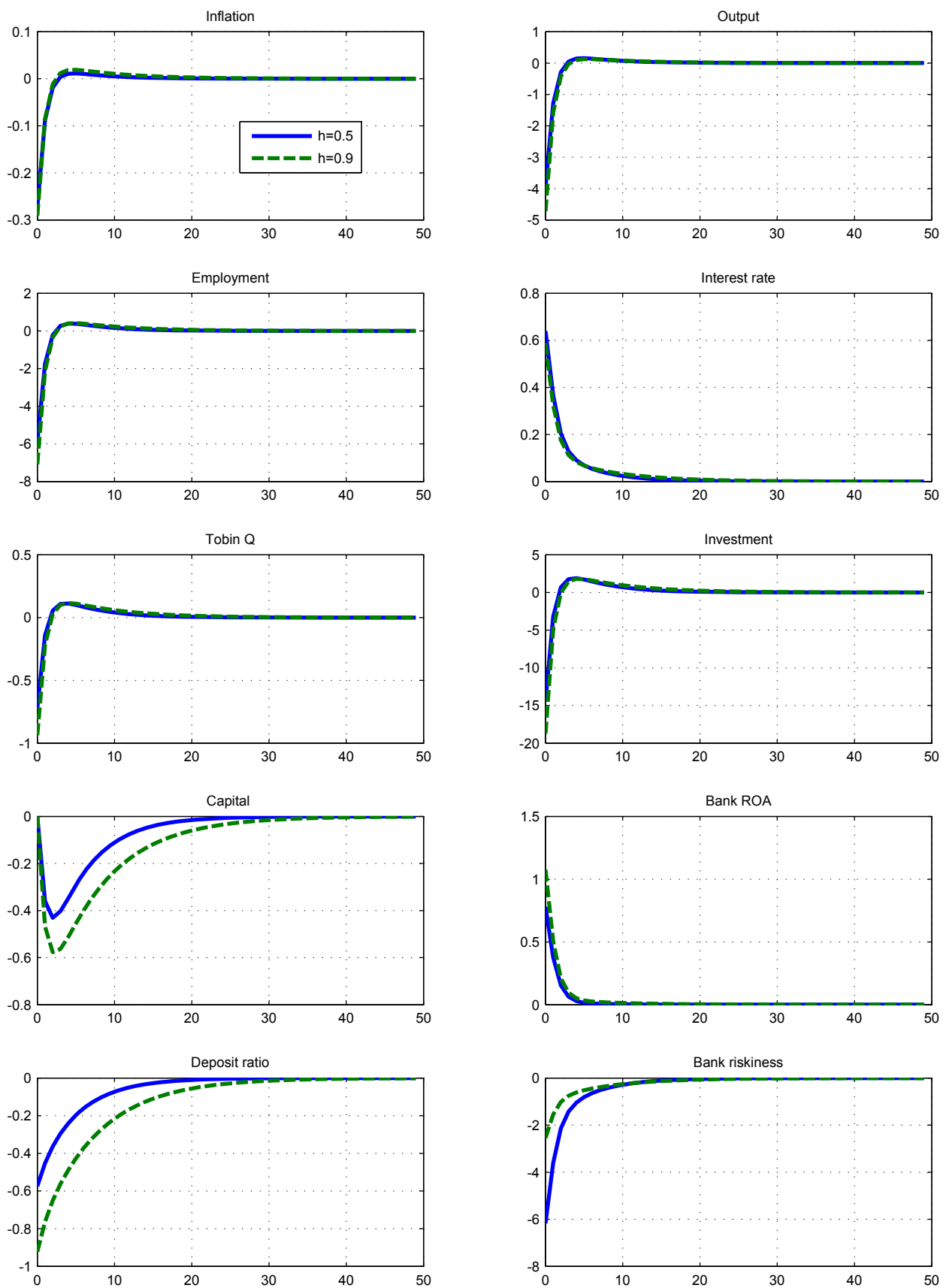


Figure 7: Leaning-against-the-wind on asset prices or leverage (positive shock on marginal return on capital)

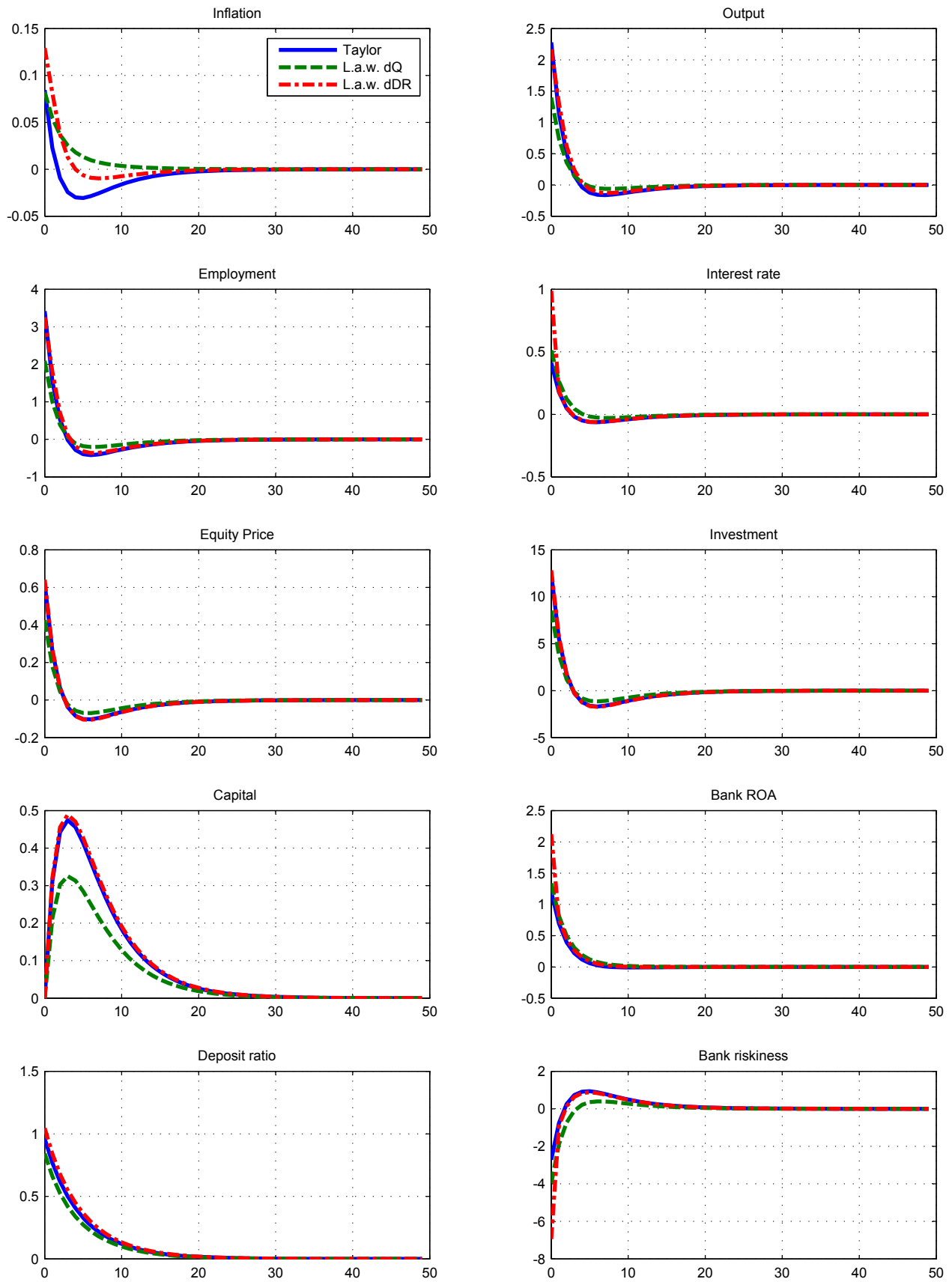


Figure 8: Unconstrained vs. fixed capital ratio (positive productivity shock)

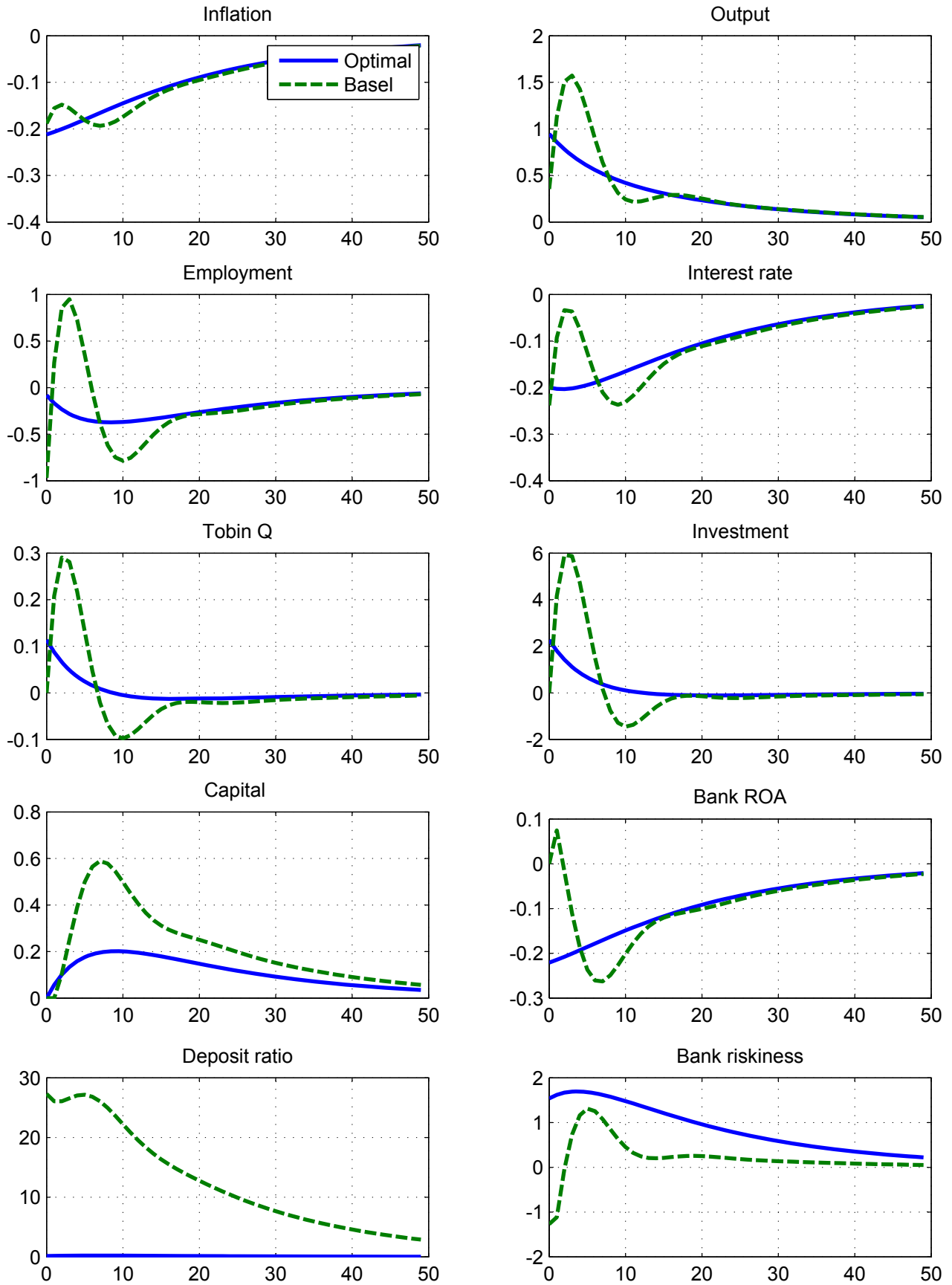


Figure 9: Comparing Basel regimes (positive productivity shocks)

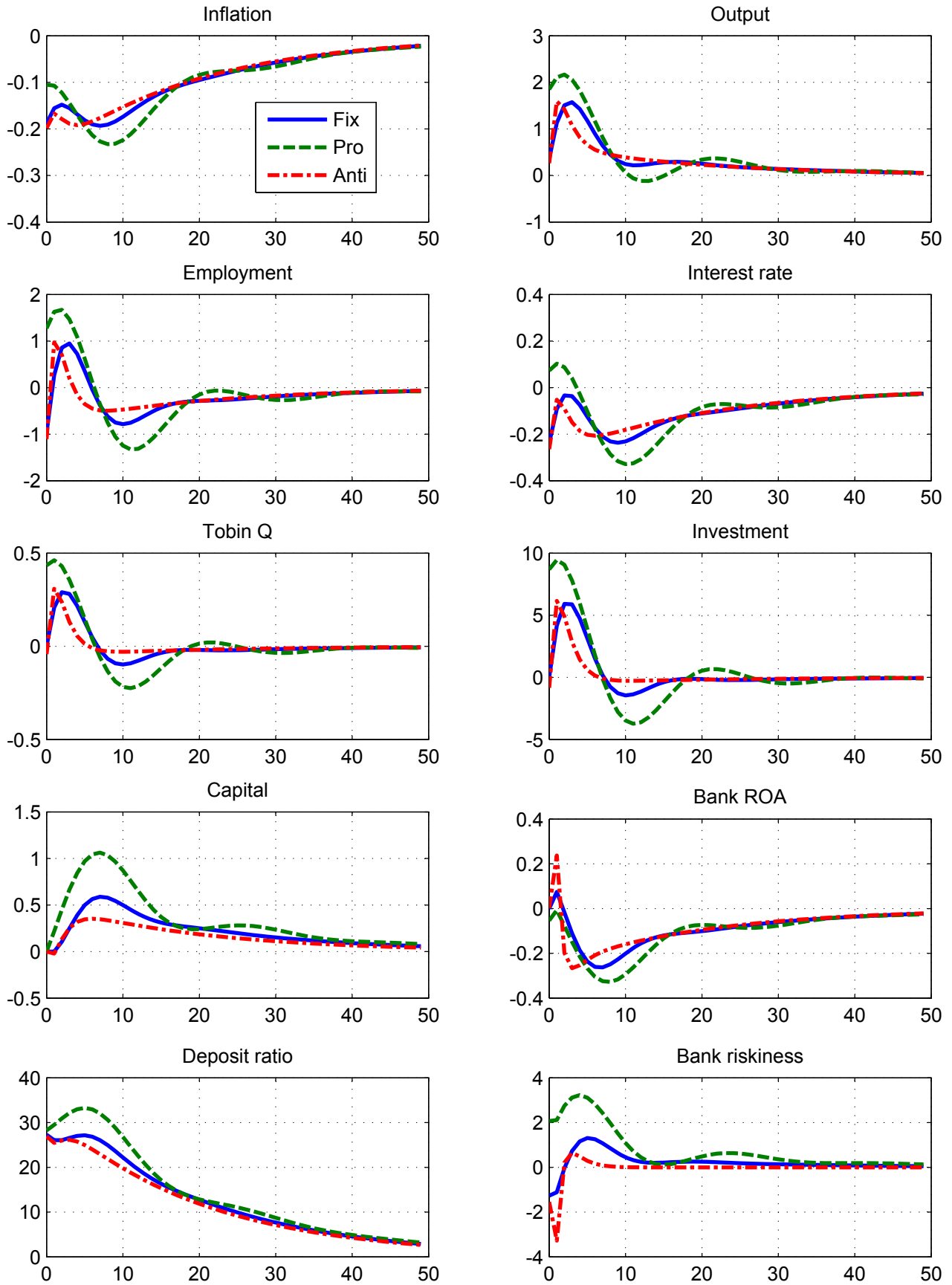


Figure 10

