Financial Factors in Economic Fluctuations* (Preliminary)

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Abstract

We augment a standard monetary DSGE model to include financial markets, and fit the model to EA and US data. The empirical results draw attention to a new shock - a 'risk shock' to entrepreneurs - and to an important new nominal rigidity. The risk shock originates in the financial sector and accounts for a significant portion of business cycle fluctuations. We do a detailed study of the role of this shock in the boom-bust of the late 1990s and early 2000s. The new nominal friction corresponds to the fact that lending contracts are typically denominated in nominal terms. Consistent with Fisher (1933), we show that the distributional consequences of this nominal rigidity play an important role in the propagation of shocks.

*This paper expresses the views of the authors and not necessarily those of the European Central Bank.

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1 Introduction

We introduce financial frictions and financial shocks into an otherwise standard monetary equilibrium model. We estimate this model using standard Bayesian methods using data for the Euro Area (EA) and for the United States (US). The introduction of financial frictions and shocks substantially alters inference about the impulses and propagation mechanisms driving aggregate fluctuations.

Our financial frictions combine the costly state verification framework of Bernanke, Gertler and Gilchrist (1999) (BGG) with the model of banking and of inside money in Chari, Christiano and Eichenbaum (1995) (CCE). We stress five findings.

(i) Shocks motivated by the BGG financial frictions account for a substantial portion of economic fluctuations in the EA and in the US.

(ii) Most of the economic effects of BGG financial shocks occur as agents respond to advance information ('news') about the future realization of those shocks.[1]

(iii) The assumption that interest rates on loans are non-state contingent in nominal terms improves model fit and has an important impact on the way shocks propagate through the economy.[2]

(iv) The model features associated with CCE which allow us to capture M1, M3, bank reserves and currency are less important as a source of shocks and propagation than are those associated with BGG. Still, the model features motivated by CCE do improve our model's out of sample forecasting performance for inflation, output, and investment in the EA.

(v) The frictions we introduce into the standard model substantially expand the range of policy questions that model can address. Yet, these additional features do not come at a cost of reducing the standard model's out of sample forecasting performance. Indeed, on some dimensions the financial frictions actually lead to an improvement in performance.

[1] Actually, BGG do not include any financial market shocks in their model. As explained below, we work with the financial market shocks suggested in Christiano, Motto and Rostagno (2003, 2007).

[2] We follow Christiano, Motto and Rostagno (2003, 2007) in assuming that nominal rates of interest are nominally non-state contingent. This is not the specification adopted in BGG.

We now briefly expand on these observations.

Our model is a variant of the model with financial frictions in Christiano, Motto and Rostagno (2003, 2007). On the liability side of the financial sector ('banks') balance sheets of our model there are financial claims which pay interest and which provide varying degrees of transactions services. Transactions services are produced using capital, labor and bank reserves using the neoclassical approach to banking described in CCE. On the asset side of the balance sheet there are loans for firm working capital requirements as well as for longer-term investment projects. The latter are assumed to be characterized by asymmetric information problems, building on the model described in BGG.

We first review the frictions motivated by BGG.[3] A class of households called 'entrepreneurs' have a particular ability to manage capital. Entrepreneurs acquire capital through a combination of their own resources and bank loans, and they rent the capital to goods-producing firms in a competitive market. Entrepreneurial loans are risky to banks because entrepreneurs experience idiosyncratic shocks which, if sufficiently severe, prevent them from repaying their loan. The magnitude of the idiosyncratic risk shock is determined by its standard deviation, and we suppose that this standard deviation is the realization of a stochastic process. We refer to this shock as a 'risk' shock.[4]

The realization of the idiosyncratic shock is observed by the entrepreneur, but not by the bank. To mitigate problems stemming from the asymmetric information, entrepreneurs and banks adopt a standard debt contract. A property of the equilibrium contract is that entrepreneurs are constrained in the amount of loans they can receive by the amount of net worth that they have. We adopt the BGG model assumption that each period a fraction of entrepreneurs 'die' and are replaced with entrepreneurs with a low level of net worth. We suppose that this fraction is the realization of a stochastic process and we call a 'wealth' shock. If an adverse wealth shock occurs, so that a larger fraction of entrepreneurs die and are replaced by low net worth entrepreneurs, then in effect the net worth of all entrepreneurs has been reduced.[5] This reduces the ability of entrepreneurs as a group to finance capital

[3]The asymmetric information approach we build on here was pioneered by Townsend (1979, 1988) and by Gale and Hellwig (1985). Other work includes, for example, Bernanke and Gertler (1989), Covas and den Haan (2007), Fuerst (1995), Carlstrom and Fuerst (1997), Christiano, Trabandt and Walentin (2009), Kiyotaki and Moore (1997), Kwark (2002), Cooley, Marimon, and Quadrini (2004), Levin, Natalucci and Zakrajsek (2004) and Hopenhayn and Werning (2008). Extensions to open-economy settings include Krugman (1999), Aghion, Bacchetta, and Banerjee (2000), Cespedes, Chang, and Velasco (2000), De Graeve (2007) and Gertler, Gilchrist, and Natalucci (2003). An analysis of the US Great Depression using financial frictions appears in Christiano, Motto and Rostagno (2003).

[4]Our risk shock resembles - in concept as well as in its empirical effects - the measures of uncertainty studied by Alexopoulos and Cohen (2009), Bloom (2009), and Bloom, Floetotto and Jaimovich (2009).

[5]To the best of our knowledge, the wealth shock was first considered in Christiano,

purchases, and thus reduces investment and output.

Turning to (i) above, the wealth and risk shocks account for a substantial portion of economic fluctuations in the EA and the US. They account for 23 percent and 19 percent of the business cycle component of output in the EA and the US, respectively,[6] and for 50 percent and 27 percent of output fluctuations, respectively, in the low frequencies (those corresponding to cycles with period 8 years and longer). The risk shock alone, with a 30 percent contribution to the variance of GDP growth, is the single most important shock driving output growth in the EA in the low frequencies. In the US, the risk shock is a close second in terms of importance, after the persistent neutral technology shock.

There are three ways to understand why our financial shocks are estimated to be an important source of economic fluctuations. First, a jump in the risk shock drives investment, consumption, hours worked, inflation, the stock market and credit in the same direction and so the risk shock can account for the procyclical nature of these variables. The risk shock also helps to account for the counter-cyclical nature of the external finance premium and of the spread between long term interest rates and short rates. Second, according to our model the external finance premium is a good proxy for the risk shock because at least 90 percent of the fluctuations in the external finance premium are due to fluctuations in the risk shock. At the same time, it is well known (see, for example, Gilchrist, Yankov and Zakrajsek, 2009) that interest rate spreads are a good business cycle leading indicator. Figure 1 displays the relevant results for the measures of output and the external finance premium used in our analysis. According to the figure, cross correlations of US hp-filtered data for both the post World War II and interwar periods indicate that increases in the external finance premium lead business cycle contractions. A shorter time series for the EA indicates the same.[7]

Third, our risk and wealth shocks derive their importance in part by displacing the marginal efficiency of investment shocks that play a prominent role in analyses of macroeconomic data based on the standard model. Standard econometric analyses of the boom of the 1990s

Motto and Rostagno (2003). It has also been studied in Jermann and Quadrini (2007), who discuss the interpretation of the wealth shock.

[6] Here, the 'business cycle component of output' refers to variance of output after it has been transformed with the log and the HP-filtered with a smoothing parameter of 1600.

[7] We found that the external finance premium does not Granger-cause output growth. We suspect this does not contradict our model's implication that risk shocks are an important driving variable for the economy, and that they dominate the external finance premium. This is because our model implies that agents receive and respond to advance information about risk shocks. Fluctuations in the external finance premium are dominated by the anticipated component of risk shocks. As a result, we expect the past observations of all variables - not just the external finance premium - to carry information about the risk shock.

For other evidence on the countercylical nature of the external finance premium, see Gertler and Lown (1999), Levin, et al (2004) and Mody and Taylor (2003).

do not use stock market data and do not incorporate financial market shocks. These analyses tend to conclude that expansionary marginal efficiency of investment shocks played an important role in the 1990s because these shocks correctly predict a surge in investment and output. However, because an expansionary marginal efficiency of investment shock is in effect a shock to the supply of capital, it also has the implication that the price of capital falls. In the context of the standard model this implies, counterfactually, that the value of the stock market falls because the price of capital in that model corresponds to the price of equity. By contrast, in our model an expansionary disturbance to one of our financial shocks represents, in effect, an outward shift in the *demand* for capital. Thus, expansionary disturbances to our financial shocks can account for the surge in output, investment *and* the stock market in the 1990s.

We now turn to result (ii), that the economy's response to financial market shocks occurs primarily as news about the future movement of these shocks arrives. A quantitative measure of the importance of news is provided by the marginal likelihood, which increases substantially when we suppose that agents receive advance information about the financial shocks. Thus, our paper represents a contribution to the growing literature on news shocks.[8] The news literature tends to find that advanced signals about the future state of technology are an important source of fluctuations. Our analysis confirms the importance of news shocks in business fluctuations, but it shifts the focus to financial shocks.

Turning to our result (iii), we follow Irving Fisher (1933) by assuming that the liabilities issued to households to finance loans to entrepreneurs are characterized by an important nominal rigidity.[9] The nominal rate of interest on these liabilities is determined at the time the loan is originated, and is not contingent upon the state of the world at the time the loan is paid off. As a result, when there is an unexpected move in the price level during the period of the loan contract, wealth is reallocated between entrepreneurs and lenders. This has aggregate effects because of the assumption that entrepreneurs have special abilities in the operation and maintenance of physical capital. The asymmetric information associated with the asset part of the financial sector's balance sheet in effect introduces two propagation mechanisms relative to the standard environment with no financial frictions. Both mechanisms operate through changes in the net worth of entrepreneurs. The classic 'accelerator effect' channel alters net worth by changes in the flow of entrepreneurial earnings and by capital gains and losses on entrepreneurial assets. This is the channel highlighted in BGG and it tends to magnify the economic effects of a shock that raises economic activity. The second propagation mechanism, the 'Fisher deflation effect' channel, refers to the movements in entrepreneurial net worth that occur when an unexpected change in the price level al-

[8]See, for example, Beaudry and Portier (2000), Christiano, Ilut, Motto and Rostagno (2008), Davis (2008), Jaimovic and Rebelo (2008) and Schmitt-Grohe and Uribe (2008).

[9]Our model does not incorporate a rationale for this nominal rigidity. For such a discussion, see Meh, Quadrini, and Terajima (2008).

ters the real value of entrepreneurial debt. The Fisher and accelerator effect mechanisms reinforce each other in the case of shocks that move the price level and output in the same direction, and they tend to cancel each other in the wake of shocks which move the price level and output in opposite directions.[10]

Turning to (iv), our model of inside money motivated by CCE incorporates various new shocks. These include a disturbance to the demand for bank excess reserves as well as shocks to households' demand for different types of liabilities of banks. Although these shocks explain much of the variance of our model's monetary aggregates (M1 and M2), and bank excess reserves, they account for very little of the variance in standard aggregate macroeconomic variables. The intuition for this, presumably, lies in the fact that monetary policy in our model is governed by an interest rate rule. Not only do the shocks motivated by CCE not have a big impact on fluctuations, this part of the model has very little impact on the way shocks propagate through the economy. This finding is broadly consistent with the widespread conjecture among researchers, that money demand can safely be ignored if one is primarily interested in questions not directly related to money. Of course, our model is useful for policy questions that pertain to money and excess reserves. From this perspective, it is good news that incorporating inside money in the model does not lead to a deterioration in out of sample forecasting. Indeed, on some dimensions this measure of model fit improves with the inclusion of inside money.

We now turn to (v). Smets and Wouters (2003,2007) established a dramatic result when they showed that a standard monetary general equilibrium model with a suitable set of shocks could outperform reduced form statistical models in terms of out-of-sample forecasting. This took quantitative equilibrium models from the status of 'toy' models to the status of serious models for use in quantitative policy analysis. Our introduction of additional features and the inevitable additional free parameters would in principle be expected to lead to a reduction in forecasting performance. Presumably, one would be willing to accept such a reduction as the price to pay for a model that can address an expanded array of policy questions. Happily, there is no such price to be paid. We find that the model features we introduce improve out-of-sample forecasting performance.

For our econometric work, we augment the standard real and nominal macroeconomic data set with a stock market index, a measure of the external finance premium, the stock of credit, of M1, of M3, the spread between the short rate and the 10-year bond rate. We consider the two financial market shocks already discussed, the risk and wealth shocks. In addition to the financial shocks, we consider several other sources of uncertainty in the estimation. These include a shock to the productivity of the technology for converting investment goods into new capital ('marginal efficiency of investment shock'), permanent

[10] This point was stressed in Christiano, Motto and Rostagno (2003). See also Iacoviello (2005).

and temporary productivity shocks to the technology for producing goods, as well as shocks to banks' technology for converting factors of production and bank reserves into inside money. In addition, we include shocks to households' preferences for consumption and liquidity, a price mark-up shock and two shocks to monetary policy.

To help diagnose the fit of our model (labeled "CMR"), we also estimate two smaller-scale variants of our model on a reduced set of data and using a restricted set of shocks. What we call the "simple model" corresponds to the structure proposed in Christiano, Eichenbaum and Evans (2005) (CEE), which largely abstracts from financial frictions. Our version of the CEE model incorporates the various shocks analyzed in Smets and Wouters (2003, 2007). What we call the "financial accelerator" specification adds the financial contract to the simple model , but does not consider the banking technology for producing inside money that appears in CMR. We report out-of-sample root mean squared forecast errors (RMSEs) for fourteen variables that are defined in CMR and, whenever applicable, we report the same metric computed on the basis of the simple model and the financial accelerator model.

The plan of the paper is as follows. The next two sections describe the model and the estimation results. After that, we discuss the economic interpretation of our results. Technical details and some additional results appear in Christiano, Motto and Rostagno (2009). The paper ends with a brief conclusion.

2 The Model

This section provides a brief overview of the model. Because a description of the model appears in Christiano, Motto and Rostagno (2007), we limit our description to what is required for us to indicate what are the basic shocks and propagation mechanisms.

The model is composed of households, firms, capital producers, entrepreneurs and banks. At the beginning of the period, households supply labor and entrepreneurs supply capital to homogeneous factor markets. In addition, households divide their high-powered money into currency and bank deposits. Currency pays no interest, and is held for the transactions services it generates. All transactions services are modeled by placing the associated monetary asset in the utility function. Bank deposits pay interest and also generate transactions services. Banks use household deposits to loan firms the funds they need to pay their wage bills and capital rental costs. Firms and banks use labor and capital to produce output and transactions services, respectively.

The output produced by firms is converted into consumption goods, investment goods and goods used up in capital utilization. Capital producers combine investment goods with used capital purchased from entrepreneurs to produce new capital. This new capital is then purchased by entrepreneurs. Entrepreneurs make these purchases using their own resources, as well as bank loans. Banks obtain the funds to lend to entrepreneurs by issuing time deposit liabilities to households.

In this section we focus on agents' objectives and constraints. The conditions that characterize the equilibrium are displayed in the appendix.

2.1 Goods Production

Final output, Y_t, is produced by a perfectly competitive, representative firm using the technology

$$Y_t = \left[\int_0^1 Y_{jt}^{\frac{1}{\lambda_{f,t}}} dj \right]^{\lambda_{f,t}}, \ 1 \leq \lambda_{f,t} < \infty, \tag{1}$$

where Y_{jt} denotes the time-t input of intermediate good j and $\lambda_{f,t}$ is a shock, $j \in (0,1)$. The time series representations of $\lambda_{f,t}$ and all other stochastic processes in the model will be discussed below. Let P_t and P_{jt} denote the time-t price of Y_t and $Y_{j,t}$ respectively. The firm chooses Y_{jt} and Y_t to maximize profits, taking prices as given.

We assume that ongoing technological advances in the production of investment goods makes the cost of producing one unit of equipment, measured in terms of consumption units, decline at the rate $\left(\Upsilon^t \mu_{\Upsilon,t}\right)$, where $\Upsilon > 1$ is the trend rate of investment-specific technical change, and $\mu_{\Upsilon,t}$ is a stationary stochastic process which we refer to as the price of investment shock. Because firms that produce consumption and investment goods using final output are assumed to be perfectly competitive, the date t equilibrium price of consumption and investment goods are P_t and $P_t / \left(\mu_{\Upsilon,t}\Upsilon^t\right)$, respectively.

The j^{th} intermediate output used in (1) is produced by a monopolist using the following production function:

$$Y_{jt} = \begin{cases} \epsilon_t K_{jt}^{\alpha} \left(z_t l_{jt}\right)^{1-\alpha} - \Phi z_t^* & \text{if } \epsilon_t K_{jt}^{\alpha} \left(z_t l_{jt}\right)^{1-\alpha} > \Phi z_t^* \\ 0, & \text{otherwise} \end{cases}, \ 0 < \alpha < 1, \tag{2}$$

where K_{jt} and l_{jt} denote the services of capital and homogeneous labor, the non-negative scalar, Φ, parameterizes fixed costs of production, ϵ_t is a stationary shock to technology and z_t represents the persistent component of technology, with the following time series representation:

$$z_t = \mu_{z,t} z_{t-1} \tag{3}$$

In (3), $\mu_{z,t}$ is a stochastic process. Due to capital embodied technological progress, the growth rate of output is determined by the following condition:

$$z_t^* = z_t \Upsilon^{\left(\frac{\alpha}{1-\alpha} t\right)}, \ \Upsilon > 1, \tag{4}$$

which also motivates our choice concerning the structure of the firm's fixed costs in (3), Φz_t^*, and ensures that the non-stochastic steady state of the economy exhibits balanced growth path.

Firms are competitive in factor markets, where they confront a nominal rental rate, $P\tilde{r}_t^k$, on capital services and a nominal wage rate, W_t, on labor services. Each firm must finance a fraction, $\psi_{k,t}$, of its rental cost of capital, $P_t\tilde{r}_t^k K_t$, and a fraction, $\psi_{l,t}$, of its wage bill, $W_t l_{jt}$, in advance at a gross interest rate, R_t. As a result, the real marginal cost of producing one unit of Y_{jt} is:

$$s_t = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{\left(\tilde{r}_t^k\left[1+\psi_{k,t}R_t\right]\right)^{\alpha}\left(\frac{W_t}{P_t}\left[1+\psi_{l,t}R_t\right]\right)^{1-\alpha}}{\epsilon_t z_t^{1-\alpha}} \tag{5}$$

As, in equilibrium, real marginal costs must be equal to the cost of renting one unit of capital divided by the marginal productivity of capital, the rental rate satisfies the following condition:

$$\tilde{r}_t^k = \frac{\alpha}{1-\alpha}\left(\frac{l_{jt}}{K_{jt}}\right)\frac{\left(\frac{W_t}{P_t}\left[1+\psi_{l,t}R_t\right]\right)}{\left[1+\psi_{k,t}R_t\right]} \tag{6}$$

The homogeneous labor employed by firms in (2) and the differentiated labor supplied by individual households are related as follows:

$$l_t = \left[\int_0^1 (h_{t,i})^{\frac{1}{\lambda_w}}\, di\right]^{\lambda_w},\ 1 \leq \lambda_w. \tag{7}$$

Below, we discuss how $h_{t,i}$ is determined.

We adopt a variant of Calvo sticky prices. In each period, t, a fraction of intermediate-goods firms, $1-\xi_p$, can reoptimize their price. If the i^{th} firm in period t cannot reoptimize, then it sets price according to:

$$P_{it} = \tilde{\pi}_t P_{i,t-1},$$

where

$$\tilde{\pi}_t = \left(\pi_t^{target}\right)^{\iota}\left(\pi_{t-1}\right)^{1-\iota}. \tag{8}$$

Here, $\pi_{t-1} = P_{t-1}/P_{t-2}$ and π_t^{target} is the target inflation rate in the monetary authority's monetary policy rule, which is discussed below. The i^{th} firm that can optimize its price at time t chooses $P_{i,t} = \tilde{P}_t$ to maximize discounted profits over future histories in which it cannot reoptimize.

2.2 Capital Producers

We suppose there is a single, representative, competitive capital producer. At the end of period t, the capital producer purchases newly produced equipment – at a currency unit price of $P_t\left(\Upsilon^t\mu_{\Upsilon,t}\right)^{-1}$ – and the undepreciated physical capital, x, that has been used in the period t production cycle. The capital producer uses these inputs to produce new installed capital, x', employing the following production technology:

$$x' = x + F(I_t, I_{t-1}, \zeta_{i,t}) = x + \left(1 - S(\zeta_{i,t}\, I_t/I_{t-1})\right) I_t. \tag{9}$$

The technology to transform new equipment into capital input ready for production, $F(I_t, I_{t-1}, \zeta_{i,t})$, involves installation and adjustment costs, $S(\zeta_{i,t}\, I_t/I_{t-1})$, which increase in the rate of investment growth.Also, $\zeta_{i,t}$ is a shock to the marginal efficiency of investment: a positive $\zeta_{i,t}$ disturbance raises installation costs, and detracts from the efficiency of the process by which new investment is turned into productive capital. We adopt the following specification for S:

$$S(\cdot) = \exp\left[A\left(x - \frac{I}{I_{-1}}\right)\right] + \exp\left[-A\left(x - \frac{I}{I_{-1}}\right)\right] - 2,$$

where

$$A = \left(\frac{1}{2}S''\right)^2.$$

Here, I/I_{-1} denotes the steady state growth rate of investment and S'' is a parameter whose value is the second derivative of S, evaluated in steady state. Note that S and its first derivative are both zero in nonstochastic steady state, $S = S' = 0$, and $S'' > 0$. Given our linearization-based estimation strategy, which we discuss in section 3, the only feature of S about which we can draw inference from data is S''. Since the marginal rate of transformation from previously installed capital (after it has depreciated by $1 - \delta$) to new capital is unity, the price of new and used capital are the same, and we denote it by $Q_{\bar{K}',t}$. The firm's time-t profits are:

$$\Pi_t^k = Q_{\bar{K}',t}\left[x + \left(1 - S(\zeta_{i,t}\, I_t/I_{t-1})\right) I_t\right] - Q_{\bar{K}',t}x - \frac{P_t}{\Upsilon^t \mu_{\Upsilon,t}} I_t. \tag{10}$$

The capital producer solves:

$$\max_{\{I_{t+j}, x_{t+j}\}} E_t \left\{ \sum_{j=0}^{\infty} \beta^j \lambda_{t+j} \Pi_{t+j}^k \right\}, \tag{11}$$

where E_t is the expectation conditional on the time-t information set, which includes all time-t shocks. Also, λ_t is the multiplier on the household's budget constraint. Let $\bar{K}_{t+j}$ denote the beginning-of-period $t + j$ physical stock of capital in the economy, and let δ denote the depreciation rate. From the capital producer's problem it is evident that any value of x_{t+j} whatsoever is profit maximizing. Thus, setting $x_{t+j} = (1 - \delta)\bar{K}_{t+j}$ is consistent with profit maximization and market clearing.

Making this substitution in (10) and solving the dynamic decision problem in (11) leads to the following optimality condition linking the price of installed capital, $Q_{\bar{K}',t}$, to the price of investment goods, $\frac{P_t}{\Upsilon^t \mu_{\Upsilon,t}}$:

$$E_t \left[\lambda_t Q_{\bar{K},t} F_{1,t} - \lambda_t \frac{P_t}{\Upsilon^t \mu_{\Upsilon,t}} + \beta \lambda_{t+1} Q_{\bar{K},t+1} F_{2,t+1} \right] = 0, \tag{12}$$

where $F_{i,t}$ is the derivative of the transformation technology, $F(I_t, I_{t-1}, \zeta_{i,t})$, with respect to its argument, i. The aggregate stock of physical capital evolves as follows

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + F(I_t, I_{t-1}, \zeta_{i,t}) = (1-\delta)\bar{K}_t + \left(1 - S(\zeta_{i,t}\, I_t/I_{t-1})\right) I_t. \tag{13}$$

2.3 Entrepreneurs

There is a large number of entrepreneurs. An entrepreneur's state at the end of period t is its level of net worth, N_{t+1}. The entrepreneur combines its net worth with a bank loan to purchase new, installed physical capital, $\bar{K}_{t+1}$, from the capital producer. The entrepreneur then experiences an idiosyncratic productivity shock, ω. The purchased capital, $\bar{K}_{t+1}$, is transformed into $\bar{K}_{t+1}\omega$, where ω is a lognormally distributed random variable across all entrepreneurs with a cumulative distribution function denoted by $F_t(\omega)$. The assumption about ω implies that entrepreneurial investments in capital are risky. Moreover, the mean and variance of $\log \omega$ are μ and σ_t^2, respectively, where σ_t is a realization of a stochastic process which we discuss below. The parameter, μ, is set so that $E\omega = 1$ when σ_t takes on its steady state value. The time variation in σ_t – which we refer to below as the 'risk shock' – captures the notion that the riskiness of entrepreneurs varies over time. The random variable, ω, is observed by the entrepreneur, but can only be observed by the bank if it pays a monitoring cost.

After observing the period $t+1$ shocks, the entrepreneur determines the utilization rate of capital, u_{t+1}, and then rents capital services in competitive markets. The rental rate of a unit of capital services, in currency units, is denoted $\tilde{r}_{t+1}^k P_{t+1}$. In choosing the capital utilization rate, each entrepreneur takes into account the "user cost" function:

$$P_{t+1}\Upsilon^{-(t+1)} \tau_{t+1}^{oil} a(u_{t+1})\omega \bar{K}_{t+1}, \tag{14}$$

Here, τ_{t+1}^{oil} is a shock which we identify with the real price of oil. According to our specification, more oil is consumed as capital is used more intensely. We adopt the following functional form for the costs of capital utilization:

$$a(u_{t+1}) = 0.5 b \sigma_a \left(u_{t+1}\right)^2 + b(1-\sigma_a)u_{t+1} + b((\sigma_a/2) - 1),$$

where b is selected to ensure that $u = 1$ in steady state and $\sigma_a \geq 0$ is a parameter that controls the degree of convexity of costs. After determining the utilization rate of capital and earning rent (net of utilization costs), the entrepreneur sells the undepreciated fraction, $1-\delta$, of its capital at price $Q_{\bar{K},t+1}$ to the capital producer. Total receipts in period $t+1$, in currency units, received by an entrepreneur with idiosyncratic productivity, ω, is:

$$\left\{ \left[u_{t+1}\tilde{r}^k_{t+1} - \Upsilon^{-(t+1)}\tau^{oil}_{t+1}a(u_{t+1}) \right] P_{t+1} + (1-\delta)Q_{\bar{K},t+1} \right\} \omega \bar{K}_{t+1}.$$

We find it convenient to express the latter as follows:

$$\left(1 + R^k_{t+1}\right) Q_{\bar{K},t}\omega\bar{K}_{t+1},$$

where $1 + R^k_{t+1}$ is the average rate of return on capital across entrepreneurs:

$$1 + R^k_{t+1} \equiv \frac{\left[u_{t+1}\tilde{r}^k_{t+1} - \Upsilon^{-(t+1)}\tau^{oil}_{t+1}a(u_{t+1}) \right] P_{t+1} + (1-\delta)Q_{\bar{K},t+1}}{Q_{\bar{K},t}}. \tag{15}$$

Entrepreneurs with ω above an endogenously determined cutoff, $\bar{\omega}_{t+1}$, pay gross interest, Z_{t+1}, on their bank loan. The cutoff is defined by the following expression:

$$\bar{\omega}_{t+1}\left(1 + R^k_{t+1}\right) Q_{\bar{K},t}\bar{K}_{t+1} = Z_{t+1}B_t, \tag{16}$$

where $B_t = Q_{\bar{K},t}\bar{K}_{t+1} - N_{t+1}$ is the loan extended by the bank. Entrepreneurs with $\omega < \bar{\omega}_{t+1}$ cannot fully repay their bank loan. Bankrupt entrepreneurs are monitored and then must turn over the value of their activity to the bank. The interest rate, Z_{t+1}, and loan amount to entrepreneurs are determined as in a standard debt contract. In particular, the loan amount and interest rate maximize the entrepreneur's expected state (i.e., their net worth) at the end of the loan contract, subject to a zero profit condition on the bank.

The funds loaned by banks to entrepreneurs in period t are obtained by banks from households. The bank zero profit condition states that the repayment received by households from banks in each state of period $t+1$ must equal the amount received in that state from entrepreneurs:[11]

$$\left[1 - F_t\left(\bar{\omega}_{t+1}\right)\right] Z_{t+1}B_{t+1} + (1-\mu)\int_0^{\bar{\omega}_{t+1}} \omega dF_t\left(\omega\right)\left(1 + R^k_{t+1}\right) Q_{\bar{K},t}\bar{K}_{t+1} = \left(1 + R^e_{t+1}\right) B_{t+1}.$$

[11] In our specification, banks do not participate in state-contingent markets. In separate calculations, we show that if banks have access to state-contingent markets, so that they have a single zero-profit condition, rather one that applies to each period $t+1$ state of nature separately, the results are largely unaffected. In these calculations, we restricted the entrepreneur's interest rate, Z_{t+1}, to be uncontingent on the period $t+1$ state of nature.

The object on the right of the equality is the quantity of funds the bank must pay to households. We suppose that banks can secure these funds by issuing time deposits that are remunerated at a nominal rate of interest, R_{t+1}^{e} This interest rate is contingent on all shocks realized in period t, but is not contingent on the $t+1$ aggregate shocks. The first part of the quantity on the left is the number of non-bankrupt entrepreneurs, $1-F_t\left(\bar{\omega}_{t+1}\right)$, times the interest and principal payments paid by each one. The second term corresponds to the funds received by banks from bankrupt entrepreneurs, net of monitoring costs. Multiplying this expression by $N_{t+1}/\left(1+R_{t+1}^{e}\right)$ and taking into account the definition of $\bar{\omega}_{t+1}$, we obtain:

$$\frac{\left[\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})\right]\left(1+R_{t+1}^{k}\right)\left(\varrho_t+1\right)}{1+R_{t+1}^{e}}=\varrho_t, \tag{17}$$

where

$$\begin{aligned}
\Gamma_t(\bar{\omega}_{t+1}) &\equiv \bar{\omega}_{t+1}\left[1-F_t(\bar{\omega}_{t+1})\right]+G_t(\bar{\omega}_{t+1}) \\
G_t(\bar{\omega}_{t+1}) &\equiv \int_0^{\bar{\omega}_{t+1}} \omega dF_t(\omega) \\
\varrho_t &\equiv \frac{B_{t+1}}{N_{t+1}}.
\end{aligned}$$

Here, $\Gamma_t(\bar{\omega}_{t+1})$ is the share of entrepreneurial earnings, $\left(1+R_{t+1}^{k}\right)Q_{\bar{K},t}\bar{K}_{t+1}$, received by the bank before monitoring costs. The object, $\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})$, is this share net of monitoring costs. Also, $1-\Gamma_t(\bar{\omega}_{t+1})$ denotes the share of gross entrepreneurial earnings retained by entrepreneurs. The standard debt contract has two parameters, a debt to equity ratio, ϱ_t, and an entrepreneurial interest rate, Z_{t+1} (or, equivalently, $\bar{\omega}_{t+1}$). The two parameters are chosen to maximize the end-of-contract level of net worth for the entrepreneur subject to the bank's zero profit condition:

$$\begin{aligned}
&\max_{\varrho_t,\{\bar{\omega}_{t+1}\}} E_t\Bigg\{\frac{\left[1-\Gamma_t(\bar{\omega}_{t+1})\right]\left(1+R_{t+1}^{k}\right)\left(\varrho_t+1\right)}{1+R_{t+1}^{e}} \\
&+\eta_{t+1}\left(\frac{\left[\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})\right]\left(1+R_{t+1}^{k}\right)\left(\varrho_t+1\right)}{1+R_{t+1}^{e}}-\varrho_t\right)\Bigg\},
\end{aligned}$$

where η_{t+1} represents the Lagrange multiplier, which is a function of the period $t+1$ state of nature. The first order conditions of the problem are the zero profit condition, (17), and the first order necessary condition associated with the optimization problem. After substituting out the expression for the multiplier and rearranging, the above condition reduces to:

$$
\begin{aligned}
& E_t\{[1-\Gamma_t(\bar{\omega}_{t+1})]\frac{1+R^k_{t+1}}{1+R^e_{t+1}} \qquad (18)\\
& + \frac{1-F_t(\bar{\omega}_{t+1})}{1-F_t(\bar{\omega}_{t+1})-\mu\bar{\omega}_{t+1}F_t'(\bar{\omega}_{t+1})}\left[\frac{1+R^k_{t+1}}{1+R^e_{t+1}}\left(\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})\right)-1\right]\} \;=\; 0.
\end{aligned}
$$

As proved in BGG, condition (18) implicitly defines a key relationship in the entrepreneurial sector, linking the price of capital to the expected return on capital relative to the risk-free rate, net worth and the stock of capital that is demanded at that price:

$$
Q_{\bar{K}',t} = \psi\left(\frac{E_t\left(1+R^k_{t+1}\right)}{1+R^e_{t+1}}\right)\frac{N_{t+1}}{\bar{K}_{t+1}}, \tag{19}
$$

where $\frac{E_t\left(1+R^k_{t+1}\right)}{1+R^e_{t+1}} \geq 1$ (because otherwise entrepreneurs would not borrow in the first place) and, as shown by BGG, $\psi(1)=1$ and $\psi'(\bullet)>0$.

To gain insight into the properties of the standard debt contract, we consider (16), (17) and (18), taking as given R^k_{t+1} and R^e_{t+1}.[12] We loosely refer to (17) as the 'supply' of credit by banks. Because (18) involves optimizing entrepreneurial welfare, we refer to that relation as the 'demand' for credit. Note that all entrepreneurs, regardless of their level of N_{t+1}, receive the same ϱ_t and $\bar{\omega}_{t+1}$, and, hence Z_{t+1}. Also, (18) determines the level of the demand curve by determining a particular value for $\bar{\omega}_{t+1}$. The slope of the demand curve in (Z_{t+1}, ϱ_t) space is determined by the trade-off between Z_{t+1} and ϱ_t that is implied by (16).

To understand how the standard debt contract works, consider Figure 2. The positively sloped curves display the trade-off between the external finance premium, $Z_{t+1}-\left(1+R^e_{t+1}\right)$, and ϱ_t implied by the supply of credit curve. The negatively sloped curve corresponds to the demand for credit. In each case, the curve is drawn under the assumption of no aggregate uncertainty, so the expectation in (18) can be ignored. The solid lines in Figure 2 correspond to a baseline specification of the model, while the starred lines indicate the response of the curves to a perturbation in a parameter. The curves are drawn using the parameter values estimated for the EA economy, and discussed below. Steady state values for of the variables were used in drawing the baseline curves.

The upper left panel displays the response of the standard debt contract a 10 percent jump in σ, the estimated standard deviation of the idiosyncratic shock to entrepreneurs. Both demand and supply shift left under the shock. The external finance premium in the new debt contract jumps 20 basis points from 218 to 239, at an annual rate. The debt to

[12] For an analysis of how a slightly different formulation of our environment responds to a technology shock, see Covas and den Haan (2007).

net worth ratio drops from 0.918 to 0.80. Thus, for an entrepreneur with a given level of net worth, loans drop by 13 percent with a 10 percent jump in idiosyncratic uncertainty and the external finance premium jumps by 20 basis point. The response of the external finance premium is relatively small because both demand and supply shift in the same direction in response to the shock.

The upper right panel displays the impact of a 50 percent jump in the monitoring cost parameter, μ. Both curves shift left in this case too. However, the demand curve shifts relatively more, so that the external finance premium actually drops 64 basis points in response to this shock. The drop in the loan amount is 13 percent, for an entrepreneur with a given level of net worth. The lower left panel in Figure 2 shows what happens when $\left(1+R^{k}\right)/\left(1+R^{e}\right)$ drops by 0.25 percent. Again, both curves shift left. The loan amount falls 10 percent for an entrepreneur with a given level of net worth, and the external finance premium jumps by 34 basis points.

After the entrepreneur has settled its debt to the bank in period $t+1$, and the entrepreneur's capital has been sold to capital producers, the entrepreneur's period $t+1$ net worth is determined. At this point, the entrepreneur exits the economy with probability $1-\gamma_{t+1}$, and survives to continue another period with probability γ_{t+1}. A fraction Θ of the total net worth owned by the entrepreneur who closes business is consumed upon exit. The probability, γ_{t+1}, is the realization of a stochastic process. Each period new entrepreneurs enter in sufficient numbers so that the population of entrepreneurs remains constant. New entrepreneurs entering in period $t+1$ receive a transfer of net worth, W_{t+1}^{e}. Because W_{t+1}^{e} is relatively small, this exit and entry process helps to ensure that entrepreneurs do not accumulate enough net worth to escape the financial frictions. Entrepreneurs that exit the economy consume a fraction of their net worth in the period that they exit, and the remaining fraction of their net worth is transferred as a lump-sum payment to households.

The law of motion for net worth averaged across entrepreneurs, $\bar{N}_{t+1}$, is as follows:

$$\bar{N}_{t+1}=\gamma_{t}\{\left(1+R_{t}^{k}\right)Q_{\bar{K}',t-1}\bar{K}_{t}-\left[1+R_{t}^{e}\ +\ \overbrace{\mu\frac{\int_{0}^{\bar{\omega}_{t}}\omega dF_{t}(\omega)\left(1+R_{t}^{k}\right)Q_{\bar{K}',t-1}\bar{K}_{t}}{Q_{\bar{K}',t-1}\bar{K}_{t}-\bar{N}_{t}}}^{\text{external finance premium}}\right] \tag{20}$$
$$\times\left(Q_{\bar{K}',t-1}\bar{K}_{t}-\bar{N}_{t}\right)\}+W_{t}^{e}.$$

The object in braces in (20) represents total receipts by entrepreneurs active in period t minus their total payments to banks. The object in square brackets represents the average payments by entrepreneurs to banks, per unit of currency borrowed. The zero profit condition of banks implies that these payments equal banks' cost of funds, $1+R_{t}^{e}$, plus costs incurred in monitoring bankrupt entrepreneurs. These monitoring costs are proportional to gross entrepreneurial revenues, and are summed over all entrepreneurs with small ω's up to the cutoff, $\bar{\omega}_t$. They are passed onto entrepreneurs in the form of an external finance premium. Note that, as $F_t(\omega)$ is time variant and subject to risk shocks, so is the premium. Note also that the value of entrepreneurs' net worth at the end of period t is perturbed by two shocks with a different time structure. Shock γ_t is realized at time t and has a contemporary impact on net worth. The risk shock that has an impact on the external finance premium paid at time t, and which detracts from entrepreneurial profits and end-of-period-t net worth, $\bar{N}_{t+1}$, is realized at the end of the previous period, σ_{t-1}.

At the end of period $t+1$, after entry and exit has occurred, all existing entrepreneurs have a specific level of net worth. The process then continues for another period.

2.4 Banking Sector

The financial intermediary is a representative, competitive bank. The bank has two functions. First, it intermediates funds between households and entrepreneurs. Second, the bank intermediates funds between households and the intermediate good firms which require working capital. The bank bundles transactions services with its deposit liabilities. These services are produced using capital, labor and bank reserves. We begin our discussion with the first intermediation activity of banks.

The total loans made by the representative bank to entrepreneurs in period t is denoted B_{t+1}. As discussed in the previous subsection, the bank's total return from its period t loans to entrepreneurs is $B_{t+1}R^e_{t+1}$, where R^e_{t+1} is not a function of the period $t+1$ shocks. The bank finances its loans by issuing two types of liabilities to households: savings deposits, D^m_{t+1}, and time deposits, T_t, with:

$$D^m_{t+1} + T_t = B_{t+1}. \tag{21}$$

Household savings deposits pay interest, R^m_{t+1}, in period $t+1$ and, as shown in section 2.5, they also generate liquidity services. Time deposits generate interest, R^T_{t+1}, in period $t+1$ but they provide no transactions services. Because there are no costs to the bank for producing T_t, we can impose the condition, $R^e_{t+1} = R^T_{t+1}$ in all dates and states. Since we assume R^e_{t+1} is not contingent on period $t+1$ shocks, it follows that R^T_{t+1} also has this property. We also suppose that R^m_{t+1} is not contingent on period t information. As discussed in the introduction, the lack of state contingency in R^e_{t+1}, R^T_{t+1} and R^m_{t+1} captures a nominal rigidity that is standard in loan contracts. To document the role of this nominal rigidity, we also consider a version of our model in which the real return, $\left(1+R^e_{t+1}\right)/\pi_{t+1}$, is not contingent on the realization of period t shocks. Below, we explain why we assume the bank finances its loans to entrepreneurs by issuing two liabilities to households rather than, say, just one.

As mentioned already, banks make working capital loans, S^w_t, to intermediate goods producers and to other banks:

$$S_t^w = \psi_l W_t l_t + \psi_k P_t \tilde{r}_t^k K_t. \tag{22}$$

Recall that ψ_l and ψ_k are the fraction of the wage and capital rental bills, respectively, that must be financed in advance. The funds for working capital loans are obtained by issuing demand deposit liabilities to households, which we denote by D_t^h. These liabilities are issued in exchange for receiving A_t units of high-powered money from the households, so that

$$D_t^h = A_t. \tag{23}$$

Working capital loans are made in the form of demand deposits, D_t^f, to firms, so that

$$D_t^f = S_t^w. \tag{24}$$

Total demand deposits, D_t, are:

$$D_t = D_t^h + D_t^f. \tag{25}$$

Demand deposits pay interest, R_t^a. We suppose that the interest on demand deposits that are created when firms and banks receive working capital loans are paid to the recipient of the loans. Firms and banks hold these demand deposits until the wage bill is paid in a settlement period that occurs after the goods market closes. We denote the interest rate that firms pay on working capital loans by $R_t + R_t^a$. Since firms receive interest, R_t^a, on deposits, net interest on working capital loans is R_t.

The bank has a technology for converting homogeneous labor, l_t^b, capital services, K_t^b, and excess reserves, E_t^r, into transactions services:

$$\frac{D_t + \varsigma D_t^m}{P_t} = x_t^b \left(\left(K_t^b\right)^\alpha \left(z_t l_t^b\right)^{1-\alpha} \right)^{\xi_t} \left(\frac{E_t^r}{P_t} \right)^{1-\xi_t} \tag{26}$$

Here ς is a positive scalar and $0 < \alpha < 1$. Also, x_t^b is a technology shock that is specific to the banking sector and $\xi_t \in (0,1)$ is a stochastic process that governs the relative usefulness of excess reserves, E_t^r. We include excess reserves as an input to the production of demand deposit services as a reduced form way to capture the precautionary motive of a bank concerned about the possibility of unexpected withdrawals. Excess reserves are defined as follows:

$$E_t^r = A_t - \tau D_t, \tag{27}$$

where τ denotes required reserves.

At the end of the goods market, the bank settles claims for transactions that occurred in the goods market and that arose from its activities in the previous period's entrepreneurial loan and time deposit market. The bank's sources of funds at this time are: interest and principal on working capital loans, $(1+R_t+R_t^a)S_t^w$, interest and principal on entrepreneurial loans extended in the previous period, $(1+R_t^e)B_t$, the reserves it receives from households at the start of the period, A_t, and newly created time and savings deposits, $T_t + D_{t+1}^m$. The bank's uses of funds includes new loans, B_{t+1}, extended to entrepreneurs, principal and interest payments on demand deposits, $(1+R_t^a)D_t$, interest and principal on saving deposits, $(1+R_t^m)D_t^m$, principal and interest on time deposits, $\left(1+R_t^T\right)T_{t-1}$, and gross expenses on labor and capital services. Thus, the bank's net source of funds at the end of the period, Π_t^b, is:

$$\Pi_t^b = (1+R_t+R_t^a)S_t^w + (1+R_t^e)\,B_t + A_t + T_t + D_{t+1}^m - B_{t+1} - (1+R_t^a)D_t \\ - (1+R_t^m)D_t^m - \left(1+R_t^T\right)T_{t-1} - \left[(1+\psi_k R_t)\,P_t\tilde{r}_t^k K_t^b\right] - \left[(1+\psi_l R_t)\,W_t l_t^b\right].$$

In solving its problem, the bank takes rates of return and factor prices as given. In addition, B_{t+1} is determined by the considerations spelled out in the previous subsection, and so here $\{B_{t+1}\}$ is also taken as given. At date t, the bank takes D_t^m, T_{t-1} as given, and chooses S_t^w, D_{t+1}^m, T_t, A_t, K_t^b, l_t^b, E_t^r. The constraints are (21), (**??**), (23), (24), (25), (26) and (27). The equilibrium conditions associated with the bank problem are derived in the Appendix.

The table reported below reproduces a snapshot of the bank's balance sheet at the beginning of period t. It highlights two aspects of our banking sector. The first is that the bank creates inside money by operating a fractional reserve system. While broad money on the liability side of the balance sheet includes demand deposits held by households and firms, D_t^h and and D_t^f, and savings deposits issued in the previous period to households, D_{t+1}^m, the bank's reserves of base money, A_t, which appear on the asset side of the balance sheet, back only a fraction $A_t/(A_t+D_t^f+D_t^m)$ of those liabilities. The remaining portion of the bank's monetary liabilities is backed by the book value of the working capital loans to intermediate-good firms (S_t^w) and by the loans to entrepreneurs. The second aspect worth noting is that our model has implications for various monetary aggregates. Beside currency, M_t, which – as explained in the next section – is held in households' portfolio, the model defines M_1 (currency plus demand deposits, D_t); M_3 (M_1 plus savings deposits, D_t^m), and bank excess reserves, $A_t - \tau D_t$. M_1, M_3 and reserves are used in our estimation exercise.

Infra-Period Assets	**Infra-Period Liabilities**
- *Reserves*	- *Household demand deposits*
A_t	$D_t^h = A_t$
- *Short-term Working Capital Loans*	- *Firm demand deposits*
S_t^w	$D_t^f = S_t^w$
Inter-temporal Assets	**Inter-temporal Liabilities**
B_t	D_t^m
	T_{t-1}

(28)

2.5 Households

There is a continuum of households, indexed by $j \in (0,1)$. Households consume, save and supply a differentiated labor input. They set their wages using the variant of the Calvo (1983) frictions proposed by Erceg, Henderson and Levin (2000).

The preferences of the j^{th} household are given by:

$$E_t^j \sum_{l=0}^{\infty} \beta^l \zeta_{c,t+l} \{ u(C_{t+l} - bC_{t+l-1}) - \psi_L \frac{h_{j,t+l}^{1+\sigma_L}}{1+\sigma_L} - H\left(\frac{\frac{M_{t+l}}{P_{t+l}}}{\frac{M_{t+l-1}}{P_{t+l-1}}} \right) \tag{29}$$
$$- \upsilon \frac{\left[\left(\frac{(1+\tau^c)P_{t+l}C_{t+l}}{M_{t+l}} \right)^{(1-\chi_{t+l})\theta} \left(\frac{(1+\tau^c)P_{t+l}C_{t+l}}{D_{t+l}^h} \right)^{(1-\chi_{t+l})(1-\theta)} \left(\frac{(1+\tau^c)P_{t+l}C_{t+l}}{D_{t+l}^m b} \right)^{\chi_{t+l}} \right]^{1-\sigma_q}}{1-\sigma_q} \},$$

where E_t^j is the expectation operator, conditional on aggregate and household j idiosyncratic information up to, and including, time t; C_t denotes time t consumption; h_{jt} denotes time t hours worked; τ^c is a tax on consumption; $\zeta_{c,t}$ is an exogenous shock to time t preferences; and χ_t is a shock to the demand for savings deposits relative to other forms of money. To help ensure balanced growth, we specify that u is the natural logarithm. When $b > 0$, (29) allows for internal habit formation in consumption preferences. The term in square brackets captures the notion that currency, M_t, savings deposits, D_t^m, and household demand deposits, D_t^h, contribute to utility by providing transactions services. The value of those services are an increasing function of the level of consumption expenditures (inclusive of consumption tax, τ^c). The function, H, represents a cost of adjusting (real) currency holdings. The function H is convex, and achieves its global minimum when real currency growth is at its steady state value.

We now discuss the household's period t uses and sources of funds. The household begins the period holding the monetary base, M_t^b. It divides this between currency, M_t, and deposits at the bank, A_t subject to:

$$M_t^b - (M_t + A_t) \geq 0. \tag{30}$$

In exchange for A_t, the household receives a demand deposit, D_t^h, from the bank. Thus, $D_t^h = A_t$. Demand deposits pay R_t^a and also offer transactions services.

The period t money injection is X_t. This is transferred to the household, so that by the end of the period the household is in possession of $M_t + X_t$ units of currency. We assume that the household's period t currency transactions services are a function of M_t only, and not X_t, because X_t arrives 'too late' to be useful in current period transactions. We make a similar assumption about demand deposits. At some point later in the period, the household is in possession of not just D_t^h, but also the deposits that it receives from wage payments.

We assume that the household only enjoys transactions services on D_t^h, and that the other deposits come in 'too late' to generate transactions services for the household.

The household also can acquire savings and time deposits, D_{t+1}^m and T_t, respectively. These can be acquired at the end of the period t goods market and pay rates of return, $1+R_{t+1}^m$ and $1+R_{t+1}^T$ at the end of period $t+1$. The household can use its funds to pay for consumption goods, $(1+\tau^c)\, P_t C_t$ and to acquire high powered money, M_{t+1}^b, for use in the following period.

Sources of funds include after-tax wage payments, $\left(1-\tau^l\right) W_{j,t} h_{j,t}$, where $W_{j,t}$ is the household's wage rate; profits, Π, from producers of capital, banks and intermediate good firms; and $A_{j,t}$. The latter is the net payoff on the state contingent securities that the household purchases to insulate itself from uncertainty associated with being able to reoptimize its wage rate. In addition, households receive lump-sum transfers, $1-\Theta$, corresponding to the net worth of the $1-\gamma_t$ entrepreneurs who exit the economy the current period. Also, the household pays a lump-sum tax, W_t^e, to finance the transfer payments made to the γ_t entrepreneurs that survive and to the $1-\gamma_t$ newly entering entrepreneurs. Finally, the household pays other lump-sum taxes, $Lump_t$. These observations are summarized in the following asset accumulation equation:

$$\begin{aligned}
&(1+R_t^a)\left(M_t^b-M_t\right)+X_t-T_t-D_{t+1}^m \\
&-(1+\tau^c)\,P_tC_t+(1-\Theta)\,(1-\gamma_t)\,V_t-W_t^e+Lump_t \\
&-B_{t+40}^{long}+\sigma_t^{long}(1+\left[1-\tau_t^D\right]R_t^{long})B_t^{long}+\left(1+R_t^T\right)T_{t-1}+(1+R_t^m)\,D_t^m \\
&+\left(1-\tau^l\right)W_{j,t}h_{j,t}+M_t+\Pi_t+A_{j,t}\geq M_{t+1}^b>0.
\end{aligned} \tag{31}$$

Equation (31) also allows the household to purchase a 10-year bond, B_{t+40}^{long}, which pays R_t^{long} at maturity. Because households are identical in terms of their portfolios, equilibrium requires that $\aleph_t$ are in zero net supply. We nevertheless find it useful to introduce B_t^{long} as a way to diagnose model fit. The mean value of $\sigma_t^{\aleph}$ is fixed at unity. If the estimation strategy finds that the variance of σ_t^{long} is zero, we infer that the model has no difficulty in accounting for the term spread. Formally, we treat σ_t^{long} as a tax on the return to B_t^{long}, whose proceeds are returned to the household in $Lump_t$. The household knows the value of R_t^{long} at date, $t-40$, when B_t^{long} is purchased. The household becomes aware of σ_t^{long} at the date when the bond matures.

The j^{th} household faces the following demand for its labor:

$$h_{j,t}=\left(\frac{W_{j,t}}{W_t}\right)^{\frac{\lambda_w}{1-\lambda_w}} l_t,\ 1\leq\lambda_w, \tag{32}$$

where l_t is the quantity of homogeneous labor employed by goods-producing intermediate good firms and banks, W_t is the wage rate of homogeneous labor, and $W_{j,t}$ is the j^{th} household's wage. Homogeneous labor is thought of as being provided by competitive labor contractors who use the production function, (7). The j^{th} household is the monopoly supplier of differentiated labor of type $h_{j,t}$. In a given period the j^{th} household can optimize its wage rate, $W_{j,t}$, with probability, $1-\xi_w$. With probability ξ_w it cannot reoptimize, in which case it sets its wage rate as follows:

$$W_{j,t} = \tilde{\pi}_{w,t} \left(\mu_{z^*}\right)^{1-\vartheta} \left(\mu_{z^*,t}\right)^{\vartheta} W_{j,t-1},$$

where $0 \leq \vartheta \leq 1$ and

$$\tilde{\pi}_{w,t} \equiv \left(\pi_t^{target}\right)^{\iota_w} \left(\pi_{t-1}\right)^{1-\iota_w}, \ 0 < \iota_w < 1. \tag{33}$$

Here, π_t^{target} is the target inflation rate of the monetary authority.

The household's problem is to maximize (29) subject to the various non-negativity constraints, the demand for labor, the Calvo wage-setting frictions, and (31). The equilibrium conditions associated with the household problem are derived in the appendix.

2.6 Resource Constraint

We now develop the aggregate resource constraint for this economy. Clearing in the market for final goods implies:

$$\mu \int_0^{\bar{\omega}_t} \omega dF(\omega) \left(1+R_t^k\right) \frac{Q_{\bar{K}',t-1}\bar{K}_t}{P_t} + \frac{\tau_t^{oil} a(u_t)}{\Upsilon^t} \bar{K}_t + \frac{\Theta(1-\gamma_t)V_t}{P_t} + G_t + C_t + \left(\frac{1}{\Upsilon^t \mu_{\Upsilon,t}}\right) I_t \leq Y_t. \tag{34}$$

The first object in (34) represents final output used up in bank monitoring. The second term captures capital utilization costs.[13] The third term corresponds to the consumption of the $1-\gamma_t$ entrepreneurs who exit the economy in period t. We model government consumption, G_t, as in Christiano and Eichenbaum (1992):

$$G_t = z_t^* g_t,$$

where g_t is a stationary stochastic process. This way of modeling G_t helps to ensure that the model has a balanced growth path. The last term on the left of the equality in the goods clearing condition is the amount of final goods used up in producing I_t investment goods. In the appendix, we develop a scaled version of the resource constraint. In addition, we follow

[13] Here, we use the fact that an entrepreneur's rate of utilization, u_t, is independent of the draw of ω. In addition, we use the fact that the integral of ω across entrepreneurs is unity.

the strategy of Yun (1996), in deriving the relationship between Y_t and aggregate capital and aggregate labor supply by households.

We measure real gross domestic product (GDP) in the model as follows:

$$GDP_t = G_t + C_t + q_{I,t} I_t, \; q_{I,t} \equiv \frac{1}{\Upsilon^t \mu_{\Upsilon,t}}.$$

2.7 Monetary Policy

The richness of the monetary sector in our model permits a versatile representation of monetary policy. Versatility here means two things. First, we can sort through various specifications of a generalized Taylor rule, when the model is operated under a monetary policy rule that uses a short-term interest rate as its instrument and operating target. For example, the set of reaction variables which the central bank is supposed to respond to in changing its policy stance can be expanded to include broad monetary aggregates and financial quantities. Second, and alternatively, we can simulate the model under the assumption that the central bank uses a narrow monetary aggregate – rather than a short-term interest rate – for policy settings. For example, as in Christiano, Motto and Rostagno (2003), the central bank can try to adjust injections and withdrawals of cash so as to hit a flexible growth target for base money that takes into account and accommodates shocks to liquidity demand. A money-base rule corrected for deviations of inflation from target and output from trend, as in McCallum (1988), is also possible.

In the baseline estimation and model evaluation exercise that is presented below we use a generalized version of the Taylor rule. Under this rule, the monetary policy operating target is R^e_{t+1} (or, equivalently, R^T_{t+1}, the interest rate paid by the bank on time deposits) as in the expression below:

$$\begin{aligned}\hat{R}^e_{t+1} &= \rho_i \hat{R}^e_t + (1-\rho_i)\alpha_\pi \frac{\pi}{R^e}\left[E_t\left(\hat{\pi}_{t+1}\right) - \hat{\pi}^{target}_t\right] + (1-\rho_i)\frac{\alpha_y}{4R^e}\log\left(\frac{GDP_t}{\mu_{z^*} GDP_{t-1}}\right) \\ &+ (1-\rho_i)\alpha_{d\pi}\frac{\pi}{R^e}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + (1-\rho_i)\frac{\alpha_b}{4R^e}\log\left(\frac{B_{t+1}}{\mu_{z^*} B_t}\right)\frac{1}{400R^e}\varepsilon_t,\end{aligned} \quad (35)$$

where variables with a $\hat{}$ are percent deviations from their steady state values[14] and the inflation objective, π^{target}_t, has the time series representation described in the next section. The expression in (35) is a *generalized* Taylor rule because, unlike in Taylor's original formulation,

[14]If we have a variable, x_t, whose steady state is x, then $\hat{x}_t \equiv \frac{x_t - x}{x} \simeq \log \frac{x_t}{x}$ denotes the percent deviation of x_t from its steady state value. It follows that $x\hat{x}_t$ is the actual deviation from steady state. When x_t is a variable such as the rate of interest, then $400x\hat{x}_t$ expresses x_t as a deviation from steady state, in annualized, percent terms.

the policy instrument is postulated to be changed in response to total credit with a positive coefficient α_b – a simplified way to capture some of the features of the euro area monetary policy strategy – and, following Smets and Wouters (2003), to the change in inflation. We set α_b to zero in the model for the US. Finally, ε_t in (35) denotes the monetary policy shock.

In the last part of the paper we show the results of a model simulation on US data in which the policy rule is of a McCallum (1988) type. This latter exercise is motivated by the observation that starting in the autumn of 2008, the Feral Open Market Committee in the US has reacted to the exacerbation of the financial crisis by placing stronger emphasis on quantitative measures of the monetary policy stance. This policy has produced a sharp increase in the dollar volume of the Federal Reserve System's operations and a surge in banks' holdings of central bank reserves. With the target for the federal funds rate reduced to a narrow range between 0% and 0.25%, monetary policy cannot be described by the baseline generalized Taylor rule over the period beyond the end of our estimation sample.

The quantitative rule that we use in the simulation exercise at the end of the paper is of the following form:

$$\hat{x}_t = \pi_t^* - \alpha_\pi(\hat{\pi}_t - \pi_t^*) - \alpha_{\Delta y}\left(\hat{y}_t - \hat{y}_{t-1} + \hat{\mu}_{z,t}\right) - \alpha_{\Delta\pi}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + \varepsilon_t. \tag{36}$$

As the low of motion for base money, $M_{t+1}^b = M_t^b(1+x_t)$, defines the quantitative money-base injection, x_t, the rule presented above prescribes that the path of such injections, in deviation from their value in steady state, $\hat{x}_t$, be calibrated to respond to deviations of inflation from the central bank's inflation objective, output growth and inflation growth. The last terms, ε_t, stands for the unsystematic deviations of the observed monetary injections from the rule.

2.8 Model Solution

Our economy evolves along a stochastic growth path. The short-term nominal interest rates, the long-term interest rate, inflation and hours worked are stationary. Consumption, real wages, output, real net worth, real monetary aggregates and real credit grow at the rate determined by z_t^*. Capital and investment grow faster, due to increasing efficiency in the investment production sector, at a rate determined by $z_t^*\Upsilon^t$, with $\Upsilon > 1$. Therefore, the solution involves the following steps. First, we rewrite the model in terms of stationary variables by detrending each variable using its specific trend growth rate, z_t^* or $z_t^*\Upsilon^t$. Note that, due to the declining relative costs of production in the investment producing sector, detrending for the relative price of capital, $\frac{Q_{\bar{K}',t}}{P_t}$, and for the real rate of return on a unit of capital services, $\tilde{r}_t^k$, involves the following transformations: $q_t = \frac{Q_{\bar{K},t}}{\Upsilon^{-t}P_t}$ and $r_t^k = \Upsilon^t\tilde{r}_t^k$, respectively. Second, we find the non-stochastic steady state for the detrended system following the procedure described in Christiano, Motto and Rostagno (2003) and construct a log-linear approximation around it. Finally, we solve the resulting linear system of rational expectations equations using the approach proposed by Christiano (2002).

2.9 Fundamental Shocks

The model we estimate using the US data includes the following 16 shocks:

$$\left(\begin{array}{cccccccccccccccc} \hat{x}_t^b & \hat{\mu}_{\Upsilon,t} & \hat{\chi}_t & \hat{g}_t & \hat{\mu}_{z^*,t} & \hat{\gamma}_t & \hat{\epsilon}_t & \varepsilon_t & \hat{\sigma}_t & \hat{\zeta}_{c,t} & \hat{\zeta}_{i,t} & \hat{\tau}_t^{oil} & \hat{\lambda}_{f,t} & \hat{\sigma}_{long,t} & \hat{\xi}_t & \hat{\pi}_t^{target} \end{array}\right), \quad (37)$$

where a hat over a variable means (??). Note that, due to capital embodied technical progress, shocks to the growth rate of output, $\mu_{z^*,t}$, are linked to shocks to the persistent component of technology, $\mu_{z,t}$, through the following expression:

$$\mu_{z^*,t} \equiv \mu_{z,t} + \frac{\alpha}{1-\alpha}.$$

The target shock, $\hat{\pi}_t^{target}$, is assumed to have the following time series representation:

$$\hat{\pi}_t^{target} = \rho_\pi \hat{\pi}_{t-1}^{target} + \varepsilon_t^{target}, \quad E\left(\varepsilon_t^{target}\right)^2 = \sigma_\pi.$$

We calibrate the autoregressive parameter, ρ_π, and the standard deviation of the shock, σ_π, at 0.965 and 0.00035 respectively, in order to accommodate the downward inflation trend in the early 1980s. We do not include $\hat{\xi}_t$ in the analysis of the EA because bank reserves data are unavailable for the full sample.

With one exception, each of the variables in our analysis has a conventional univariate first order autoregressive representation with two parameters. The exception is the monetary policy shock, ε_t, which we assume is *iid*.

While we suppose that the financial wealth shock and the risk shock, $\hat{\gamma}_t$ and $\hat{\sigma}_t$, have a first order autoregressive representation, we assume that agents acquire advance information, or revise beliefs, about the realization of the univariate innovations. For example, we suppose that $\hat{\sigma}_t$ evolves as follows:

$$\begin{aligned} \hat{\sigma}_t &= \rho_\sigma \hat{\sigma}_{t-1} + u_t^\sigma, \ u_t \,\tilde{}\, iid \\ u_t^\sigma &= \xi_{\sigma,t}^0 + \xi_{\sigma,t-1}^1 + \xi_{\sigma,t-2}^2 + \ldots + \xi_{\sigma,t-p}^p. \end{aligned} \quad (38)$$

Here, $\xi_{\sigma,t-i}^i$ is observed by agents at $t-i$. We refer to $\xi_{\sigma,t-i}^i$ as the period $t-i$ 'news' or 'signal' about u_t. The vector, $\left\{\xi_{\sigma,t}^0, \xi_{\sigma,t-1}^1, \ldots, \xi_{\sigma,t-p}^p\right\}$, has a diagonal covariance matrix and is *iid* over time. In addition, we assume

$$\sigma_i^2 = Var\left(\xi_{t-i}^i\right), \ i = 0, \ldots, p.$$

In practice, we restrict $\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_p^2$. A similar representation applies to $\hat{\gamma}_t$.

2.10 Variants of the baseline model

For model validation purposes we consider and evaluate empirically three variants of our baseline model. Two nested, reduced-scale versions of our model are derived from the baseline specification by deactivating, in turn, the two financial frictions that are the main focus of this paper: households' demand for money and the supply of inside money by banks, and the financial contract of the entrepreneur. The third model variation corresponds to our baseline specification except that the 'Fisher effect' channel is deactivated, as in BGG.

2.10.1 The Financial Accelerator model

We refer to the specification without money and banks as the *Financial Accelerator model*, as this set-up preserves the costly state verification mechanism and the entrepreneurial financial accelerator contract that are embodied in the baseline. The financial accelerator model is extracted from the baseline specification by: (1) eliminating the conditions that pertain to the bank (section 2.4); (2) setting the weight attached to liquidity services in households' utility (29), υ, the function for adjusting households' real currency holdings, H, and all monetary variables, M_j^b, M_j, A_j, D_j^m, $j = t-1, t, t+1, ...$, in the household's budget constraint to zero; (3) setting the fraction of capital services and labor services that firms need to finance in advance by working capital loans, $\psi_k = \psi_l = 0$.

2.10.2 The Simple Model

The second, reduced-scale version of our model is what we refer to as the *Simple Model*. It does not include money, the banking sector *and* the entrepreneurial sector, and is a variant – with small adjustments – of the model proposed by Christiano, Eichenbaum and Evans (2005) in its money-less version analyzed by Smets and Wouters (2003, 2007). To obtain the simple model we start from the financial accelerator model and: (1) we drop the entrepreneurial sector (section 2.3); (2) we set the monetary policy reaction coefficient attached to credit growth in (35), α_b, to zero; (3) we introduce a capital stock accumulation decision in the household's intertemporal optimization problem. The latter modification implies that the nominal return on capital defined in (15) in the simple model satisfies the standard equality condition:

$$1 + R_{t+1}^e = 1 + R_{t+1}^k = \frac{r^k(\bar{K}_{,t+1}, \tau_{t+1}^{oil}) + (1-\delta)E_t Q_{\bar{K},t+1}}{Q_{\bar{K},t}}. \tag{39}$$

where $r^k(\bar{K}_{,t+1}, \tau_{t+1}^{oil})$ stands for the the nominal rental rate of a unit of capital services net of utilization costs.

2.10.3 The No-Fisher-Effect Model

We have stressed how surprise movements in the price level induce wealth reallocations between entrepreneurs and households, and how this has real effects. To quantify these effects, we modify the baseline model so that the return to households, R^e_{t+1}, is state-non contingent in real terms. This version of the model with *No Fisher Effect* retains all the channels of transmission that are embodied in our baseline specification but with the following transformation for R^e_{t+1},

$$\widetilde{R}^e_{t+1} = \frac{1 + R^e_{t+1}}{\pi_{t+1}},$$

replacing R^e_{t+1} in the model's state.

3 Estimation and Fit

We apply a Bayesian version of the maximum likelihood strategy used in Christiano, Motto and Rostagno (2003). The strategy is designed to accommodate the fact that the computation of the model's steady state is time intensive. We divide the model parameters into two sets. The first set contains the parameters that control the steady state. The values of some of these parameters, such as α and δ, are simply taken from the literature. The values of the other parameters that control the steady state are set so that the model reproduces key sample averages in the data. We report the numerical values of the steady state parameters in Table 1 and we document the degree to which the steady state implications of our model match the corresponding sample averages for selected *great ratios*, for equity to debt ratios, inflation, money and credit velocities and various rates of return in Tables 2 and 3, for the EA and US empirical models, respectively. We discuss the calibration and the fit of the steady state in detail in Appendix A.

The second set of parameters is estimated using the Bayesian procedures discussed in An and Schorfheide (2005), Schorfheide (2000) and Smets and Wouters (2003). The parameters estimated here include the ones that characterize monetary policy, wage and price frictions, the shock processes, capital utilization, σ_a, and investment adjustment costs. We now turn to the estimation procedure.

3.1 Parameters Governing Dynamics

We adopt a standard state observer set-up in assuming that measured data correspond to a subset of the endogenous variables defined in the model plus a measurement error. We treat the following 16 variables as observed processes to estimate the model parameters that do not influence steady state:

$$X_t = \begin{pmatrix} \Delta \log \left(\frac{\text{per capita stock market index}_t}{P_t} \right) \\ GDP \text{ deflator inflation}_t \\ \log \left(\text{per capita hours}_t \right) \\ \Delta \log \left(\frac{\text{per capita credit}_t}{P_t} \right) \\ \Delta \log \left(\text{per capita GDP}_t \right) \\ \Delta \log \left(\frac{\text{Hourly compensation}_t}{P_t} \right) \\ \Delta \log \left(\text{per capita investment}_t \right) \\ \Delta \log \left(\frac{\text{per capita } M1_t}{P_t} \right) \\ \Delta \log \left(\frac{\text{per capita } M3_t}{P_t} \right) \\ \Delta \log \left(\text{per capita consumption}_t \right) \\ \text{External Finance Premium}_t \\ R_t^{long} - R_t^e \\ R_t^e \\ \Delta \log (P_{It}) \\ \Delta \log (\text{real oil price}_t) \\ \Delta \log (\frac{\text{per capita Bank Reserves}_t}{P_t}) \end{pmatrix}, \tag{40}$$

where R_t^e is the 3-month interbank interest rate for the EA and the Federal Funds rate for the US, $R_t^{long} - R_t^e$ is the spread between the 10-year government bond rate and R_t^e, and P_{It} denotes the ratio of the investment deflator divided by the GDP deflator. We match P_{It} with $1/\left(\Upsilon^t \mu_{\Upsilon,t}\right)$ in the model. For the EA, we use only 15 variables in the estimation as observations for bank reserves before the inauguration of monetary union in 1999 are unavailable. Our measure of bank reserves for the US is total reserves held at the Federal Reserve System. The sample period used in the estimation is 1985Q1-2008Q2.[15] We use this rather short sample because of data limitations in the EA and because we want to preserve comparability between the US and the EA results. In addition, by using this sample period, we minimize the impact of various structural breaks that are said to have occurred in the early 1980s.[16] While details about our data sources are provided in Appendix B, Figures 3.a and 3.b show the time series of our data observations and the in-sample model fit. All data are quarterly and, except the short-term interbank interest rate (R_t^e), inflation and hours

[15] Our data sample begins in 1981Q1. We use the first 16 quarters as a 'training sample', so that the likelihood is evaluated using data drawn from the period 1985Q1-2008Q2.

[16] That is, a possible break in monetary policy and the 'Great Moderation', the apparent decline in macroeconomic volatility.

worked, they are first-differenced. Prior to estimation, we remove the sample mean from the data and we set the steady state of X_t in the observer equation to zero. In this way, inference about the parameters governing model dynamics is not distorted by difficulties the model has in matching the sample averages of the elements in X_t. In Figures 3.a and 3.b, the dark line denotes the data and the red-dotted line is the data simulated by the model in response to the estimated (by two-sided Kalman smoothing) economic shocks, computed at the mode of the posterior distribution of the parameters. Data and smoothed estimates exactly coincide for some variables (GDP and its components, inflation, hours, real wages, the price of investment and the price of oil), while for "financial variables" (the stock market, credit, $M1$, $M3$, the external finance premium, the spread between the long-term and the short-term interest rates, and bank reserves) it is possible to detect a positive, small vertical difference between the two lines, corresponding to the estimated measurement error. We interpret "measurement errors" mainly as stand-ins for model-specification errors. So, in the estimation we set them to zero for all variables except those that pertain to the financial sectors of our model economy. It is evident from the figures, however, that "measurement errors" play a very minor role, with the possible exception of the stock market.

The number of parameters that we estimate is 48 and 47 for the US and EA versions of the model, respectively. There is one fewer parameter in the EA version of the model because we drop the shock to the demand for bank reserves, ξ_t, and the measurement error on bank reserves, and we add the monetary policy response to credit. Finally, as the curvature parameter, H'', turned out to be zero in the US version, we dropped it from our US model. [17]

Of the parameters that we estimate, 7 relate to the price and wage setting behavior of firms and households and to elasticities regulating the cost of adjusting portfolios and investment flows:

$$\overbrace{\xi_p,\ \xi_w}^{\text{Calvo wage and price setting}},\ \overbrace{S''}^{\text{investment adjustment costs}},\ \overbrace{\iota,\ \iota_w}^{\text{weight on steady state inflation, in price and wage equations}},$$
$$\overbrace{\vartheta}^{\text{weight on permanent technology shock in wage equation}},\ \overbrace{\sigma_a}^{\text{capital utilization parameter}}.$$

Five parameters pertain to the monetary policy rule, (35):

$$\overbrace{\rho_i}^{\text{monetary policy persistence}},\ \overbrace{\alpha_\pi}^{\text{reaction to: inflation}},\ \overbrace{\alpha_y}^{\text{output change}},\ \overbrace{\alpha_{d\pi}}^{\text{inflation change}},\ \overbrace{\alpha_b}^{\text{credit change}}.$$

[17]The 48 free parameters that control the dynamics of the US model break down as follows: there are 29 shock parameters (2 for 12 of the shocks, three for the shock with the signal representation, one for the monetary policy shock and one for the financial market shock), 11 parameters that control the dynamics of the model, and 8 measurement error parameters.

Prior and posterior distributions of the parameters that do not control steady state are displayed in Figures 4.a, 4.b and 4.c. Prior and posteriors modes are also reported in Table 4, along with the 5% and 95% bounds.[18] Priors and posteriors for the *iid* "measurement errors" appear in Table 5.[19] We also estimate the three variants of our baseline model that are briefly described in section 2.10. These alternative models and the posterior modes of their parameters are reported in the Appendix (Tables A.1, A.2 and A.3) and we do not discuss them further.

In the case of the Calvo parameters, ξ_p, ξ_w, our priors (Table 4) imply that prices and wages are reoptimized on average once a year in the Euro Area, and every 1.6 quarters in the US. Our priors are fairly tight, reflecting the extensive empirical analysis of the behavior of prices in recent years and, notably, the microeconomic evidence available.[20] The posteriors on ξ_p and ξ_w for the US are shifted substantially to the right, relative to our priors (Figure 4.a). On the contrary, for the EA they are shifted to the left, relative to the priors. The posterior modes imply that prices and wages in the EA are reoptimized every 3.6 and 3.8 quarters, respectively. In the case of the US, our posteriors imply that both prices and wages are reoptimized every 3.2 quarters.[21] Our estimate of the degree of price stickiness for the US is almost identical to the baseline estimate of Smets and Wouters (2007) and considerably less than those reported by Levin, Onatski, Williams and Williams (2006) (LOWW), who find that price contracts have a duration of about 5 quarters.

Our findings for prices are in accord with recent microeconomic studies which suggest prices are more flexible in the US than in the EA. Moreover, the implication of our model for the frequency with which prices are reoptimized in the US are reasonably close to the empirical findings of Bils and Klenow (2004), Golosov and Lucas (2007) and Klenow and Kryvtsov (2004). These authors conclude that firms re-optimize prices a little more frequently than once every 2 quarters.[22] Prices in our US model are only a little less flexible than these

[18] Posterior probability intervals are computed using the Laplace approximation (for completeness, the Laplace approximation is discussed in the appendix.) Smets and Wouters (2007) report that results based on the Laplace approximation are very similar to those based on the MCMC algorithm.

[19] The priors on the measurement errors have a Weibull distribution with standard deviation equal to 10 percent of the standard deviation of the underlying variable, based on the past 10 years' observations. The Weibull distribution has a second parameter, whose value is indicated Table 5.

[20] See, for a survey of EA evidence, Altissimo, Ehrmann and Smets (2006).

[21] Smets and Wouters (2004) report that wages in the US are more sticky than they are for the EA. The 90 percent probability intervals around the posterior modes for ξ_w in the EA and US do not overlap. However, this result is based on on their full sample estimates, which corresponds to the period, 1974-2002. When Smets and Wouters (2004) work with a shorter sample, 1993-2002, then the modes of their posterior distributions imply that wages in the EA are more sticky than they are in the US.

[22] For example, in calibrating their model to the micro data, Golosov and Lucas (2003,

studies suggest.

As in LOWW, our results indicate that there is a high degree of indexation of wages to the persistent technology shock. Our results for the degree of indexation of prices to inflation differ between the US and EA. For the US we find a relatively lower degree of indexation compared to the EA.

Regarding investment adjustment costs, our priors on S'' are in line with CEE. However, the posterior distribution is shifted sharply to the right, and is much larger than the posterior modes reported in Smets and Wouters (2003, 2007). The sharp increase in the posterior mode for S'' that we observe by comparing the estimate for our baseline model with the one that we obtain by estimating our *Simple Model* indicates that the inclusion of the stock market among the data that are treated as directly observable might be responsible for the high value of S''.[23] Our estimates imply a high cost of varying capital utilization. This is consistent with the findings in Altig, Christiano, Eichenbaum and Linde (2004), who report a similar result for US data only, using a very different estimation strategy. LOWW, however, show that there is very little information in the data about the costs of varying capital utilization. This contrasts with our results, since our posterior distribution easily rules out values of σ_a that are small enough to imply substantial variation in capacity utilization. Our estimation strategy, which uses the relative price of crude oil to help identify shocks to capital utilization costs (recall (14), is the explanation for both the high estimated value of σ_a and for the fact that the data seem to be quite informative regarding this parameter.[24]

We now turn to the parameters of the monetary policy rule, (35). Our estimates suggest that the EA and US policy rules exhibit a high degree of inertia (the parameter, ρ_i), and a relatively strong long-run response to anticipated inflation (α_π), one quarter ahead. In addition, the estimated reaction function exhibits modest sensitivity to the growth rate of output (α_y) and to the recent change in inflation ($\alpha_{d\pi}$). The response to inflation appears to be stronger than in Taylor (1993), although the form of the interest rate rule used here differs somewhat from the one he proposes.[25] The estimated policy rules in LOWW and Smets and

Table 1, page 20) select parameters to ensure that firms re-optimize prices on average once every 1.5 quarters.

[23]Notice that the posterior mode for S'' is virtually the same in the baseline estimation (Table 4) and in the estimation of our *Financial Accelerator* model (Table A2), which also includes the stock market in the estimation.

[24]This interpretation is corroborated by a comparison between the estimated posterior values for σ_a in the baseline model and in the *Simple Model* and the *Financial Accelerator* model. The latter two variants, which also utilise the relative price of oil in the estimation, yield very high posterior values for σ_a (Tables A1,2), which in the case of the EA, are virtually the same as in the baseline estimation (Table 4).

[25]According to the 'Taylor rule', the nominal rate of interest responds to the current realized rate of inflation and the current realized level of output. The coefficient on realized inflation is 1.5 and the coefficient on realized output is 0.5.

Wouters (2003, 2007) are consistent with our results in that they also imply strong response of monetary policy to inflation and a high degree of inertia. Finally, the standard deviation of the monetary policy shock in the Taylor rule is 46 and 52 basis points, respectively, in the EA and US models.

In terms of the other standard deviations, it is worth noting that σ_t^{long} is estimated to have a positive variance. The 90% probability interval about the mode of the posterior distribution for the EA is fairly tight, 0.001-0.004, and above zero. The 90% probability interval for the US is larger, having the same lower bound and having upper bound 0.003-0.010. This finding is consistent with the evidence reported in the literature that term structure data do not conform well to a simple expectations hypothesis (see, for example, Rudebusch and Swanson, 2007). Other variance estimates that are of interest are those that control variables which must lie inside a particular interval or which have a particular lower bound. These include ξ_t, χ_t, γ_t and $\lambda_{f,t}$, the shock variances on these variables are also of plausible magnitude. The priors and posteriors associated with the parameters governing the dynamic processes of shocks are displayed in Figures 4.b and 4.c, and reported in Table 4.

3.2 Estimated Shocks

The similarity between raw data and model predicted data in Figures 3.a and 3.b suggests that we have a nearly exact linear decomposition of the historical data into economic shocks. The two-sided Kalman smoothed time processes for each of the economic shocks that are activated in the estimation are graphed in Figures 5.a and 5.b. We start with the inflation objective process, which is reported in the second panel on first row of Figures 5.a and 5.b. Recall from section (2.9) that the autoregressive coefficient and the standard deviation of this process have been calibrated both in the EA and US model in order to help account for the drawn-out disinflation that took place in both the EA and US over the earlier part of our sample period. Indeed, the simulated time series for the inflation objective in the two economies captures well the pronounced downward trend in realized inflation until the second half of the 1990s, and its flattening out in the following period.

Consider $\zeta_{c,t}$. Because we model $\zeta_{c,t}$ as a first order autoregression, when that variable is perturbed it creates an expectation of returning to its mean. The further $\zeta_{c,t}$ is above its mean of unity, the quicker it is expected to fall. Thus, a high value of $\zeta_{c,t}$ creates a desire to consume in the present and places upward pressure on the interest rate. Note how the estimated value of $\zeta_{c,t}$ trended down from above its mean in the EA. This behavior helps the model explain the trend down in the nominal rate of interest in the EA. In the case of the US, $\zeta_{c,t}$ also plays an important role in the dynamics of the interest rate, though not in its sample trend.

The banking reserve demand parameter, ξ_t, displays sharp spikes in the US in late 2001, corresponding to the jump in banks' desired reserves following the terrorist attack of September 11 and the temporary seizing up of the inter-bank money market that ensued. While large, this shock seems minor in retrospect, when compared to the more recent episode of market turbulence which followed the demise of the Lehman Brothers investment bank in September 2008. In the final part of this paper, we extend the data set beyond the end of our estimation sample to draw early inferences about the financial panic of the second half of 2008. We defer to that section a more detailed analysis of the reserve demand shock in times of acute financial instability.

Beside ξ_t, we isolate several shocks, $\sigma_{long,t}$, γ_t, σ_t and $\zeta_{i,t}$, for special attention in the next section. The upward trend in $\sigma_{long,t}$ indicates that the model has difficulty fully accounting for the trend fall in the long term interest rate in the EA and the US (see the down trend in R_t^e and the absence of a trend in the term premium in Figures 3.a and 3.b). Note that γ_t fluctuates in a fairly narrow range. We will see later that this shock plays only a small role in fluctuations. The σ_t and $\zeta_{i,t}$ shocks are difficult to interpret directly, and we will instead study them below from the perspective of their impact on the endogenous variables.

Tables 6.a and 6.b report the autocorrelations and contemporaneous cross-correlations of the innovations of the shocks in the case of the EA and the US, respectively. According to the model, all innovations are *iid* over time and with each other. With the exception of the autocorrelation of the monetary policy shock, some of the autocorrelations of the signals on σ_t and some positive contemporaneous correlations of the signals on σ_t, the EA data appear consistent with the assumptions of the model. In the case of the US there is in addition some evidence of autocorrelation in the inflation objective shock.

3.3 Model Fit

We perform two tests to evaluate our model's fit. We first inspect the complete correlation structure for a selection of observable variables as it is implied by the model and we compare it to the correlation structure that is visible in the data. We then run forecasts and we measure the model's out of sample performance in relation to that of other models. Recently, Del Negro, Schorfheide, Smets and Wouters (2007) implement measures of model fit built on Bayesian foundations. They show that these measures work very much like RMSE tests, and so we restrict ourselves to the latter here.[26]

Figures 6.a and 6.b report the autocorrelations and cross-correlations at up to a 12 quarter lead and lag generated by our model and by a VAR(2) for a subset of our observable variables. The data are represented by the grey lines in the panel. The model predictions are the black thick lines along with the 90 percent posterior intervals for the model implied by parameter uncertainty and small sample uncertainty. The first thing to note, along the

[26]For further discussion, see Christiano (2007).

diagonals, is that the model captures quite well the decaying autocorrelation structure of the variables reported. The second thing to point out, in terms of cross-correlations, is that the model does well for output (first row in the two Figures), except for the correlation between current output and lagged inflation. We discuss the model-implied correlations involving consumption in a later section.

An advantage of the RMSE calculations that we report is that we can use standard sampling theory to infer the statistical significance of differences in RMSE results for different models. We do this in two ways. We apply the procedure suggested in Christiano (1989) for evaluating the difference between two RMSEs. In addition, we apply a regression-based procedure that selects optimal combinations of forecasts from different models. For the most part, the two procedures provide similar results, and so we display results for the RMSE procedure in the text. Results based on the regression-based procedure are presented in the technical appendix.

RMSE results for all the variables in our analysis are reported in Figures 7.a and 7.b for the EA and US, respectively. Our first forecast is computed in 2001Q3, when we compute 1, 2, ..., 12 quarter ahead forecasts. We compute forecasts using our baseline model (labelled *Baseline* in the figures), reestimating its parameters every other quarter. We also compute RMSE's using the *Simple Model* and the *Financial Accelerator* model. In addition, we use a Bayesian Vector Autoregression (BVAR) re-estimated each quarter with standard Minnesota priors. Finally, we also compute forecasts using the no-change or random walk forecast. The grey area in Figures 7.a and 7.b represent classical 95 percent confidence intervals about the BVAR RMSEs.[27]

Consider Figure 7.a, first, and particularly the forecasts of GDP growth in the EA. Note that the baseline model significantly outperforms the *Simple Model*. The baseline model also outperforms the *Financial Accelerator* model, the BVAR and the random walk model, though not statistically significantly so. Turning to inflation, note that the baseline model appears to dominate the *Simple Model* significantly and it also dominates the random walk model. The BVAR slightly outperforms the baseline model, though not significantly so. In the case of investment growth, the baseline model dominates both its small-scale nested variants, and significantly so at the 3 quarter ahead horizon, while it does about as well as the BVAR. Turning to the spread and to the stock market, note that the baseline model

[27] To understand the confidence intervals, let $RMSE^{BVAR}$ and $RMSE^{Baseline}$ denote the RMSEs from the BVAR and baseline models, respectively, for some forecast horizon. The technical appendix shows that, for T large, $RMSE^{BVAR} - RMSE^{Baseline}\tilde{}N(0, \frac{V}{T})$, where T is the number of observations used in computing the RMSE. An asymptotically valid estimator of V, denoted $\hat{V}$, is discussed in the appendix. The grey area in Figures 4a and 4b represent $RMSE^{BVAR} \pm 1.96\sqrt{\frac{\hat{V}}{T}}$.So, if $RMSE^{Baseline}$ lies outside the grey area, then the null hypothesis that the two models produce the same RMSE is rejected at the 5% level, in favor of the alternative that one or the other model produces a lower RMSE.

outperforms the other specifications significantly. Interestingly, the evidence indicates that the stock market is far from a random walk. In the case of hours worked, the baseline model outperforms the *Financial Accelerator* at the longer horizons, but does significantly worse than the BVAR at the short horizons. In one deviation from the overall pattern, the *Simple Model* does slightly better than the baseline model at all horizons. Finally, it is somewhat disappointing that the baseline and the *Financial Accelerator* models do poorly forecasting the external finance premium ('risk premium').

Now consider the results for the US in Figure 7.b. The results are generally the same as for the EA, although all three structural models perform significantly better than the BVAR in forecasting hours worked. As in the EA, the model does poorly at forecasting the risk premium. Also, the baseline model somewhat underperforms in forecasting consumption.

Smets and Wouters (2007) also report out of sample RMSE's. Based on a different US sample (1990Q1-2004Q4), they show that in terms of short-term interest rate their model is dominated by the BVAR at horizons up to 2 years, while their model does better at longer horizons. Interestingly, this is not a general characteristic of our forecasting models. In the case of the EA, the baseline model dominates BVAR at the short horizons and exhibits roughly the same performance at the longer horizons. In the case of hours worked, the pattern does resemble the one found by Smets and Wouters: the baseline model is dominated by the BVAR at the shorter horizons, while the baseline model dominates at the longer horizons. In the case of the interest rate and credit, the baseline model is roughly as good as the BVAR at the shorter horizons and worse at long horizons. In the case of the interest rate spread, the baseline model is substantially better than the BVAR at the short horizons and worse at the long horizons.

We conclude that, all things considered, our model fits reasonably well in terms of RMSEs.

4 Key Economic Implications

To understand the economic implications of our model, we refer to Figure 1. The picture raises two sets of questions. The first one is methodological. We have assembled a complex quantitative framework in which a standard CEE-type model of the monetary business cycle interacts with a financial accelerator and a neo-classical banking system to deliver implications for asset prices, credit and insight money creation. The three main building blocks of this model – the Simple Model, the Financial Accelerator and the bank – offer various primitive sources of fluctuations and impose tight restrictions on the model's dynamics. The first question is: What shock processes and endogenous channels of propagation are necessary to reproduce the tight correlations of Figure 1 over the cycle? In particular, what model features can account for the close contemporaneous co-movement between equity and investment? What channel or shocks deliver the correct cyclical response of credit and the correct *negative* correlation between the volume and the price of credit? This negative correlation is interesting because it lies at the core of recent debates about the causes of the ongoing financial crisis. If the price of credit tends to be low when the volume of credit is high relative to output and, conversely, if it is high when credit is weak, then the financial system might contain inherently destabilizing mechanisms that magnify booms and exacerbate busts.

The second type of questions that are inspired by Figure 1 is empirical. Since the model provides a reasonable fit of the data, what does the model tell us about the sources of economic fluctuations?

This section tries to answer the two questions in combination. We tackle co-movements one at a time. First, we concentrate on the synchronous pattern of the price of capital and investment. To anticipate our line, the first sub-section will argue that the financial contract is critical in our model to generate that pattern. The Simple Model – while in principle equipped with sufficient structure to account for the price of capital and capital formation – delivers counterfactual correlations. The following sub-section argues that adding observations on credit to an empirical model with a financial accelerator is nontrivial. In particular, to mimic credit's *positive* correlation with the cycle we need to introduce *news shocks*. But, what news are these about? These are predominantly revisions of beliefs in the credit market about future business risk conditions. They are *not* signals on future technology for producing goods. We are not able to support our analysis in Christiano, Ilut, Motto and Rostagno (2008), in that here we find that signals on the future state of the goods-producing technology do not help account for the dynamic configuration of asset prices and financial quantities that we want to match empirically.

The inclusion of a financial contract in the model and of the stock market and credit in the estimation shift emphasis to a new shock and a particular type of nominal rigidity. What we call the 'risk' shock turns out to be a primary driver of economic fluctuations. This shock reflects shifts in the realized riskiness of entrepreneurial projects and anticipations on how this risk will evolve in the future. To the extent that the anticipated component is relevant, this shock largely originates in the credit market, in the perceptions about borrowers' creditworthiness. The rigidity stems from the fact that the financial contract in the model is denominated in nominal terms. What we call the 'Fisher-effect' channel turns out to be an important propagator of real and monetary shocks. Again, the credit market with its frictions occupies center stage in our empirical results.

We conclude this Section with the notion that banks' decisions concerning the size and composition of the left-hand side of their balance sheet (28), where *assets* – credit – are recorded, are critical for economic performance.

4.1 Investment and the price of capital

The joint procyclicality of the price of capital (the market value of corporations, as proxied by 'equity') and capital formation is the first striking feature of Figures 1a and 1b. What are the implications of the Simple Model on this dimension? Why did we add the financial contract and what did we gain?

We start from the capital producers' optimality condition, (12), which links the price of installed capital to the price of investment goods and the volume of investment in our baseline model and in all its modifications, including the Simple Model. After scaling, and making use of $\lambda_{z,t} = \lambda_t P_t z_t^*$, we obtain:

$$q_t = \frac{\frac{1}{\mu_{\Upsilon,t}} - \frac{\beta}{\Upsilon}\frac{\lambda_{z,t+1}}{\lambda_{z,t}} F_2(\bar{k}_{t+2}, \bar{k}_{t+1}, \zeta_{i,t+1}) E_t q_{t+1}}{F_1(\bar{k}_{t+1}, \bar{k}_t, \zeta_{i,t})}. \tag{41}$$

In (41) we rely on a scaled version of (13) to replace investment at time t with capital at time $t+1$ as an argument of the installation technology, $F(I_t, I_{t-1}, \zeta_{i,t})$. Because this technology incorporates installation costs, $S(\zeta_{i,t}\, I_t/I_{t-1})$, and these costs increase in the rate of investment and are convex, (41) defines a positive schedule in a static q_t– $\bar{k}_{t+1}$ space. Figure 8 represents this space, which reduces dynamic conditions to a single time dimension for the sake of exposition. In the upper panel, the positive schedule indicates the supply of capital in the Simple Model. The same condition applies in the Baseline Model and in all of its variants. Figure 8 combines the supply of capital with a demand for capital, which in the Simple Model is derived from (39). After scaling and rearranging, (39) becomes:

$$q_t = \frac{r^k(\bar{k}_{t+1}) + (1-\delta) E_t q_{t+1}}{\Upsilon\left(1 + R^e_{t+1}\right)} \left(1 + \pi_{t+1}\right). \tag{42}$$

where $r^k(\bar{k}_{t+1})$, a decreasing function linking r^k_{t+1} to the scaled capital stock, is obtained from (6), ignoring variable utilization. Notice three elements of Figure 8. First, demand and supply are defined as functions of the capital stock, *for a given state of expectations*, $E_t q_{t+1}$. This static representation – while neither conventional nor necessary – is useful to single out the role of anticipations about future shocks in shifting the two schedules, a theme to which we revert later. Second, two investment-specific shocks shift the supply schedule, (41): $\mu_{\Upsilon,t}$, which perturbs the price at which capital producers acquire new machinery from goods producers, and $\zeta_{i,t}$, which changes the productivity of that machinery in terms of the capital on line. The presence of two shocks in (41) poses an obvious identification problem. Third, no investment-specific shock moves the demand schedule, (42), in the same space. The absence of investment shocks in (42) poses a more fundamental problem of fit. We discuss the identification and the model fit problems in what follows.

4.1.1 Investment-specific technology shocks

Why do we need $\mu_{\Upsilon,t}$ *and* $\zeta_{i,t}$ in the first place? Because we need to break the tight link between the market value of installed capital and the price of investment, which applies in standard macroeconomic models. As the price of investment is counter-cyclical – as we show below – while the stock market is strongly pro-cyclical (Figure 1), a tight link between the two prices would pose an empirical trade-off which our model, or any of its variants, would not be able to reconcile. The $\mu_{\Upsilon,t}$-$\zeta_{i,t}$ duality helps reproduce the business cycle properties of the measured price of investment *and* the stock market. We try to solve the identification problem by exploiting the fact that the price of investment goods is routinely measured by statistical offices. We therefore include the investment deflator index – relative to the GDP deflator – in our data set, and we use the mapping between the investment deflator and $\frac{P_t}{\Upsilon^t \mu_{\Upsilon,t}}$ to identify the separate contribution of $\mu_{\Upsilon,t}$ to the supply of capital.[28] This exercise is important for answering the methodological question formulated in the introduction to this section. But, we believe, it is of broader significance and relevant for the second, empirical question as well. Indeed, shocks similar to our $\mu_{\Upsilon,t}$ and $\zeta_{i,t}$ have long been studied as possible primary sources of the trade cycle. On the one hand, Fisher (2006) and Greenwood, Hercowitz and Krusell (2000) have argued for an important role of investment-specific technical advances that make investment goods progressively cheaper. On the other hand, Greenwood, Hercowitz and Huffman (1988) have rehabilitated shocks to the marginal efficiency of investment as plausible candidate impulses for the cycle and Justiniano, Primiceri and Tambalotti (2007) find that this shock is the prime driver of short-run fluctuations.

What do we find? To summarize: (1) $\mu_{\Upsilon,t}$ is an unimportant source of fluctuations of output or any of its components – including investment – in all model variants and at all frequencies; (2) $\zeta_{i,t}$ is the most important source of fluctuations of short-term and, even more starkly, long-term swings in output and investment in the Simple Model; (3) in the Baseline Model, $\zeta_{i,t}$ is a relevant source of business cycle variation for output, but its relative contribution drops sharply as we lower the frequency along the spectrum of fluctuations.

Tables 7 and 8, display our models' implications for the variance decompositions of the observable variables at business cycle frequencies and for periodic components with cycles of 33-1000 quarters, respectively, for the EA (part a) and US (part b). The statistics are derived using the mode of the posterior distributions of the shocks reported in Table 4. As

[28] As documented in the Appendix B, we use a national accounts measure for the private investment deflator. As pointed out by Gordon (1990) and Cummins and Violante (2002), the methodology employed by statistical offices to account for quality adjustments might underestimate the rate of technological progress in areas such as equipment and software. We nevertheless use the offical measures as they are available for the entire sample which we use in our empirical exercise.

is standard, we define the business cycle component of a variable as the component after logging the level of the variable, and applying the HP filter (rate of return variables are not logged).[29] Each cell in the Tables contains three statistics: the contributions of the corresponding shock to the Baseline Model, the Financial Accelerator Model and the Simple Model. From the fourth column in the Tables we see that the explanatory power of $\mu_{\Upsilon,t}$ is confined to the relative price of investment in both economies and across models. We also see that $\zeta_{i,t}$ does extremely well accounting for output, hours and, notably, investment volatility at business cycle frequencies in the Simple Model. This result lends support to the contention in Justiniano et al (2007) that shocks to the marginal efficiency of investment are – within a model specification for the US similar to our Simple Model – the key drivers of macroeconomic fluctuations. However, in line with our third result mentioned above, the primacy of this shock in explaining the cycle does not seem to be robust to the addition of an explicit financial channel and the inclusion of financial factors in the estimation. The contribution of $\zeta_{i,t}$ to GDP growth drops from slightly less than 50 percent in the Simple Model to 25 percent (EA) and 22 percent (US) in our Baseline specification at business cycle frequencies. The drop at lower frequencies is even more dramatic, and more than halves to around 15 percent in both economies.

Figures 9.a and 9.b offer a different, in-sample perspective on shock contributions to observable variables. The panels on the first row of the Figures show the two-sided smoothed processes for three shocks in the Baseline Model (first three columns) and in the Simple Model (last two columns). Because of our identification choice, the price of investment shock, $\mu_{\Upsilon,t}$, matches exactly the *inverse* of the price of investment relative to the price of output**.** So, the line in the third panel on the first row represents the time profile of the shock and the inverse of the corresponding observable variable as well. Each of the panels on the remaining rows plots the data for the stock market index, output and investment (black continuous lines) together with the model projections for these variables, conditional on the estimated sequence of one shock only (red-dotted lines). Again, the Baseline Model occupies the first three columns (corresponding to the risk shock, $\zeta_{i,t}$ and $\mu_{\Upsilon,t}$) and the Simple Model the remaining two (for $\zeta_{i,t}$ and $\mu_{\Upsilon,t}$).

The in-sample evidence confirms the unconditional variance-decomposition analysis of the role of $\mu_{\Upsilon,t}$. This shock helps fit the counter-cyclical pattern of the price of investment but – because of that – has very limited propagation in both economies and across the two models (third column, second, third and fourth rows). The reason is that this shock triggers offsetting effects on the marginal installation costs. The fall in investment prices after a positive $\mu_{\Upsilon,t}$ innovation drives marginal costs down at times in which, observationally, the price of capital and investment are rising.

What explains the remarkable difference in inferences concerning the importance of $\zeta_{i,t}$

[29] The model's implications are based on population second moments.

between our baseline model and the Simple Model? We go back to panel (a) of Figure 8 which describes the market for capital in the Simple Model, and we focus again on the lack of an investment-specific shock hitting the demand schedule in that space. The key to interpreting the contribution of $\zeta_{i,t}$ with or without a financial channel lies in the latter observation. In the Simple Model, with no financial sector, an *autonomous,* non-policy induced increase in the investment-GDP ratio of the type that we often observe during the boom phase of the cycle can be simulated only as a positive increase in the marginal efficiency of investment or, equivalently, as a negative innovation to $\zeta_{i,t}$. A negative innovation to $\zeta_{i,t}$ pushes marginal installation costs down which boost investment. But, while the shift can trigger an investment boom, it determines a counter-cyclical change in the price of capital.

To be sure, the counter-cyclicality of the price of capital relative to the marginal efficiency of investment shock, $\zeta_{i,t}$, does not necessarily represent an empirical embarrassment for the model. In fact, in selected episodes of the past, stock prices and investment did not move together. Figure 9.b identifies one such episode in the US recession of the early 1990s. Not surprisingly, both the Simple Model *and* our Baseline Model predominantly ascribe the investment and output fluctuations observed over the period 1990-1993 to swings in $\zeta_{i,t}$ (see the panels along the second column, third and fourth rows). From the panel on the second column, second row, it is apparent that the contemporaneous behavior of the stock market is such that the negative correlation introduced by $\zeta_{i,t}$ does not contradict the data. However, this sign switch in the asset price and cyclical implications of $\zeta_{i,t}$ can be seriously counter-factual in episodes of equity price boom-bust dynamics, when investment and the stock market move sharply together. Figure 1 shows that this pattern of comovement has been dominant since the second half of the 1990s. Moreover, the same pattern prevails at very low frequencies when the price of capital and the capital stock tend to be tightly positively associated. This explains why in Tables 7 and 8 the contribution of $\zeta_{i,t}$ in our baseline specification drops so dramatically moving from business-cycle to very low frequencies of fluctuations. It also explains why $\zeta_{i,t}$ retains its principal role even at low frequencies in the Simple Model, which does not make use of stock market information.

Because stock market observations impose no restrictions in the estimation of the Simple Model, the unconstrained $\zeta_{i,t}$ process becomes of overwhelming importance as a driver of investment and output fluctuations (Figures 9.a and 9.b, fourth column, third and fourth rows). However, this almost perfect fit of $\zeta_{i,t}$ is gained at the price of generating a path for the relative price of capital in the model that almost invariably contradicts the evidence. The red-dotted line reported in the panel on the second row, fourth column represents the Simple Model's predictions for the (latent) process of Tobin's q in-sample. When the data shows a generalized boom in the stock market *and* in the broader economy, the Simple Model predicts an investment-output boom and a stock market bust. The reverse is also true.

4.1.2 Shocks to the demand for capital

Complicating the Simple Model with an entrepreneurial sector and a financial contract adds investment-specific shocks to the demand for capital. This improves the asset pricing performance of the model. The financial channel of the Baseline Model – and its Financial Accelerator and No-Fisher-Effect variants – can be aggregated into a demand for capital schedule of a form that differs from (42). To obtain the new demand for capital we start from (19). After scaling, that expression becomes:

$$q_t = \psi \left(\frac{\frac{r^k_{t+1}+(1-\delta)E_t q_{t+1}}{\Upsilon q_t}\left(1+\pi_{t+1}\right)}{1+R^e_{t+1}} \right) \frac{n(\gamma_t\ ,\ \sigma_{t-1})}{\bar{k}_{t+1}}. \tag{43}$$

With $\psi(1) = 1$ and $\psi'(\cdot) > 0$, and recalling $r^k_{t+1} = r^k(\bar{k}_{t+1})$,(43) implicitly defines a negative relation, $\Psi(\cdot)$, between q_t and $\bar{k}_{t+1}$ in the static space of Figure 8.[30] $\Psi(\cdot)$ is the new demand for capital schedule which replaces (42) in our Baseline Model and in all of its modifications with a financial channel. This schedule shifts around with innovations to n_{t+1}, the value of entrepreneurs' net worth at the end of period t. According to (a scaled version of) the evolution process for net worth, (20), two shocks, the financial wealth shock, γ_t , and the risk shock, σ_{t-1}, are important sources of motion for n_{t+1}. So we can replace n_{t+1} with $n(\gamma_t\ ,\ \sigma_{t-1})$ in the above expression. This substitution shows that the demand for capital has now two shifters, the two shocks with an impact on equity. A positive innovation to γ_t helps more equity-rich entrepreneurs that were in business in the previous period to remain in business. As a consequence, the aggregate purchasing power of entrepreneurs as a group increases, which sustains the demand for capital and tends to push up its price. A negative innovation to σ_{t-1} has the same effect on aggregate equity, but the channel is through the number of bankruptcies, and the impact of the shock is delayed. If the entrepreneurial project becomes less risky, more entrepreneurs are able to pay back their loans in full and continue their activity into the next period. In addition, because of less bankruptcies in the aggregate, *all* entrepreneurs are charged a lower interest rate in the financial contract and can retain a higher share of their business profits.

In both cases, a boom in capital formation can go hand in hand with a *rise* in the price of capital. Periods in which the stock market moves in sync with investment and output are interpreted as episodes in which the *demand* for capital – not the supply – is high. Accordingly, our Baseline Model attributes the responsibility for the bulk of output and investment variation over the international boom-bust phase of the late 1990s and early 2000s to the risk shock (last two rows of Figures 9.a and 9.b, first column). In contrast,

[30] The following section will show that the slope of the relation is indeed negative in the $q_t - \bar{k}_{t+1}$ space.

positive innovations to $\zeta_{i,t}$ play a moderate role and in fact work *against* the cycle. By making installation more costly, they amplify the stock market boom, but they discourage investment and partly offset the economic fallout of the rightward shift in the demand for capital.

In sum, complicating the model with a financial contract and adding the stock market to the estimation does two things. It turns shocks to the marginal efficiency of investment from a pro-cyclical source of upturns into a counter-cyclical smoother. At the same time, it tips the weight of the evidence against a primary role of $\zeta_{i,t}$ in explaining economic fluctuations. Financial shocks, and notably the risk shock σ_t, usurp its explanatory power. The risk shock becomes a major determinant of investment and output over those phases – frequent in our sample – in which the stock market displays abnormal volatility relative to the rest of the economy.

4.2 Credit and the business cycle

The positive correspondence of credit with aggregate investment and equity and its inverse relation with the credit risk premium is another striking property of the economic time series that we document in Figure 1. Evidently, during investment/asset price booms, intermediated credit tends to rise, and its price tends to fall.[31] While the latter, inverse relation lies at the core of the BGG model, the former correlation has not received much attention in studies that use equilibrium models to interpret the cycle. In fact, the inclusion of credit *and* the stock market in such an empirical analysis turns out to be a non-trivial exercise.

To study the way observations on credit can restrict the fit of the model, we first linearize the demand for capital, (43), around the model's non-stochastic steady state:

$$\hat{q}_t = -\widehat{\bar{k}}_{t+1} + \hat{n}_{t+1} + \frac{n}{\bar{k}}\psi'\left(\frac{1+R^k}{1+R^e}\right)\frac{1+R^k}{1+R^e}\left[\frac{R^k}{1+R^k}\hat{R}^k_{t+1} - \frac{R^e}{1+R^e}\hat{R}^e_{t+1}\right], \tag{44}$$

where we impose the condition that, in steady state, $\psi = \frac{\bar{k}q}{n}$ and $q = 1$. We use a scaled linearized version of (15) to eliminate $\hat{R}^k_{t+1}$ from (44), and we group together terms that have an impact on $\hat{q}_t$ which is of second-order of magnitude. We then rearrange terms to obtain:[32]

$$\hat{q}_t = -\frac{\left(1+\frac{n}{\bar{k}}\psi'\left(\frac{1+R^k}{1+R^e}\right)\frac{r^k}{1+R^e}\frac{\pi}{\Upsilon}\right)}{\Phi}\widehat{\bar{k}}_{t+1} + \frac{1}{\Phi}\hat{n}_{t+1} + \frac{\frac{n}{\bar{k}}\psi'\left(\frac{1+R^k}{1+R^e}\right)\frac{(1-\delta)}{1+R^e}}{\Phi}\frac{\pi}{\Upsilon}E_t q_{t+1} + others \tag{45}$$

[31] While present in both economies, this negative correlation between the external finance premium and the business cycle is more evident in the EA than in the US.

[32] Ignoring taxation, $\hat{R}^k_{t+1} = \frac{r^k+(1-\delta)q}{\Upsilon R^k q}\pi\left[\frac{r^k\hat{r}^k_{t+1}+(1-\delta)q\hat{q}_{t+1}}{r^k+(1-\delta)q} + \hat{\pi}_{t+1} - \hat{q}_t\right]$. Ignoring fluctuations in R_t, hours, wages and permanent shocks to technology, $\hat{r}^k_{t+1} = -\hat{\bar{k}}_{t+1}$. Substituting and rearranging yields (45) in the text.

where $\Phi = \left(1 + \frac{n}{k}\psi'\left(\frac{1+R^k}{1+R^e}\right)\frac{r^k+(1-\delta)}{1+R^e}\frac{\pi}{\Upsilon}\right) > 1$. Note that the slope of the demand schedule in the $q_t - \bar{k}_{t+1}$ space is negative and < 1 in absolute terms.

Our next step is to substitute (45) into a scaled, linearized expression for bank credit to entrepreneurs, $\left(\bar{k} - n\right)\hat{b}^E_{t+1} = \bar{k}\hat{q}_t + \bar{k}\widehat{\bar{k}}_{t+1} - n\hat{n}_{t+1}$, where $\bar{k} - n$ is the volume of such credit in steady state. While our definition of credit is broader and includes working capital loans, (22), in practice the dynamics of credit in the model is dominated by loans to entrepreneurs. So, we concentrate on the latter in the following analysis. Substituting out $\hat{q}_t$, the expression for entrepreneurial credit becomes:

$$\frac{\bar{k}-n}{\bar{k}}\hat{b}_{t+1} = \left[1 - \frac{\left(1 + \frac{n}{\bar{k}}\psi'\left(\frac{1+R^k}{1+R^e}\right)\frac{R^k}{1+R^e}\frac{r^k}{\Upsilon R^k}\pi\right)}{\Phi}\right]\widehat{\bar{k}}_{t+1} + \left[\frac{1}{\Phi} - \frac{n}{\bar{k}}\right]\hat{n}_{t+1} \tag{46}$$

$$+\frac{\frac{n}{\bar{k}}\psi'\left(\frac{1+R^k}{1+R^e}\right)\frac{(1-\delta)}{1+R^e}}{\Phi}\frac{\pi}{\Upsilon}E_t q_{t+1} + others \tag{47}$$

For $\psi'\left(\frac{1+R^k}{1+R^e}\right) \cong 0$, $\Phi = \left(1 + \frac{n}{\bar{k}}\psi'\left(\frac{1+R^k}{1+R^e}\right)\frac{R^k}{1+R^e}\frac{r^k+(1-\delta)}{\Upsilon R^k}\pi\right) \cong 1$, and the first term, in $\widehat{\bar{k}}_{t+1}$, on the right-hand side cancels out, whereas the coefficient multiplying the second term, in $\hat{n}_{t+1}$, is always positive. This implies that, if financial frictions are not very important in the economy, and entrepreneurs' expected returns relative the risk-free interest rate does not exert a great influence on their cost of borrowing, *any* shock to equity will have a positive impact on credit. Credit will always be pro-cyclical with respect to one of our financial shocks, γ_t or σ_{t-1}. However, for $\psi'(\bullet) > 0$, the first term is always positive, while the second term depends on the relevance of financial frictions and on the equity-to-capital ratio.

We conclude that if financial frictions and the ratio are sufficiently large, then credit might become counter-cyclical with respect to a financial shock. This poses an empirical trade-off. Shocks that are essential to delivering a positive comovement between the price of capital and the cycle might in fact produce a counter-factual path for credit. Hence, the inclusion of credit in the empirical exercise might subject the model to a very tough test.

4.3 News Shocks

The last statement needs to be qualified. What it means precisely is that contemporaneous, *unexpected* shocks to equity might not necessarily generate pro-cyclical credit. Indeed, under our parameterization, they tend to produce the opposite. This is confirmed by the empirical exercise documented in Figures 10.a and 10.b. Each of these Figure shows the fit when the model is estimated – on EA and US data, respectively – under the assumption that all the shocks, including γ_t or σ_{t-1}, have a standard AR(1) representation. This implies a departure from our baseline representation for γ_t or σ_{t-1}. While in the baseline estimation the financial shocks, γ_t and σ_{t-1}, have both an *expected* (signal) and an unexpected component (recall (38)), the exercise underlying Figures 10 assumes only unexpected innovations for all shocks. The first row in the Figure shows the fit of the model when estimated with both the stock market and credit included among the observable variables. The black continuous line in the panels represents the data, while the red-dotted line shows the simulated time series for the same variable in response to all the estimated economic shocks. While the fit to credit is preserved (the two lines almost coincide), the fit to the stock market deteriorates visibly if compared to the baseline estimation (Figures 3.a and 3.b, first panel). Table 9 shows the degree to which the exclusion of signals on the future value of the two shocks to equity from the estimation deteriorates the marginal likelihood of the Baseline Model. Comparing the first column (Baseline specification) with the second column (Baseline Model without signals), we conclude that the log marginal likelihood falls very significantly, by about 300 and 130, respectively, for the two economies.

The second row of Figures 10 re-estimates the model with unexpected shocks, but now dropping credit from the observation equations. While the fit of the stock market is now comparable to that obtained from the Baseline estimation, the model-implied path for credit is very different from the actual observations: the black line and the red line display a clear negative association.

Adopting a signal structure for other shocks – different from our two shocks to equity – does not help. The third column of Table 9 reports the marginal likelihood that we obtain when we re-estimate the Baseline Model without signals on the shocks hitting the demand for capital margin, but with signals on three technology shocks: $\zeta_{i,t}$, hitting the supply of capital, ϵ_t, the temporary neutral technology shock to intermediate firms' production technology, and $\mu_{z^*,t}$, the permanent labour-augmenting technology shock. Again, the log marginal data density drops noticeably, by around 70 and 120 units for the EA and the US model, respectively, relative to the Baseline estimation.

We conclude that, without allowing for advance information on shocks that hit the demand for capital, the model finds the empirical trade-off posed by the observations on the stock market *and* credit hard to reconcile.

4.3.1 The risk shock

The signal representation of the risk shock, in particular, is instrumental in reconciling this trade-off and making credit pro-cyclical. It does so through the first term on the right hand side of (46), by sustaining the demand for capital *in the future*. Given the adjustment costs to investment, anticipations of a higher desired capital stock tomorrow are actualized into a higher desired stock of capital today, which sustains the demand for capital in the present relative to available equity. This widens entrepreneurs' financing gap today in response to any positive shock to equity, and supports credit. More broadly, Figures 11.a and 11.b document how the risk shock – while helping the model match credit – also becomes a primary source of cyclical comovement among *all* real variables. The first column reports the contribution of the whole risk shock process to some selected variables. The second and the third columns disaggregate that contribution into groups of signals referring to the nearer or more distant future. For example, along the second column, the red line in a panel denotes the value that the corresponding variable would take on at any time t if, at that time, only the signals received at t and concerning the value of the risk shock at $t+1, ..t+4$ were active and all other shocks in the economy were set to zero. The third column gives the contribution of the signals referring to time $t+5, ..t+8$. The first column adds to the sum of the contributions coming from all the signals the impact of the contemporary unexpected innovation. It is apparent that the principal source of pro-cyclicality in this model economy are perceptions about the importance of investment risk at a horizon beyond one year. Interestingly, after monetary policy innovations – whose fit is surprisingly accurate – the risk shock emerges from Figures 11.a and 11.b as the second most important explanatory force behind the in-sample swings in the long-term spread.

The unconditional variance analysis of Tables 7 and 8 (part a for the EA, and part b for the US) reinforces the inference based on the time-series shock decomposition. The risk shock explains 16 percent of GDP growth business-cycle fluctuations in the EA and 19 percent in the US (add over the columns corresponding to σ_σ and to its signals).[33] The fraction of business-cycle variation in financial variables that is due to the risk shock is overwhelming. This shock accounts for over 87 and 97 percent, respectively, of the business cycle variance of the external finance premium in the EA and US. The corresponding fractions for the stock market are 64 percent and 80 percent in the two economies. In the very long run, this shock becomes the most important source of output variance in the EA, with 30 percent of output fluctuations, and the second most important shock in the US – after the persistent technology shock – with 22 percent. At these frequencies, σ_t is the most significant source of variation for real net worth growth, credit, investment, the external finance premium and the long term interest rate spread, and gives a very significant contribution to the variance of consumption, in both economies. Combined with the other shock to equity, γ_t , the risk shock at lower frequencies explains one half of output growth in the EA and 27 percent in the US.

The surprisingly large fraction of the long-term variance of the slope of the term structure of interest rates that is explained by the economic shocks, and notably the risk shock, deserves some attention. It lends support to the 'expectations hypothesis': that long rates are the

[33] The rows marked $\sigma_{\sigma^{signal}}$ in Tables 7 and 8 report the sum of the percent of variance due to information j periods in the past, $j = 1, ..., 8$.

expected value of future short rates. Since the risk shock is an important determinant of aggregate demand in this economy, and the short-term interest rate systematically responds to demand conditions, the long-run influence of the risk shock is perhaps less puzzling.[34]

The importance of the risk shock, in its characteristic news/realization structure, raises two questions. First, what are the transmission properties that make this shock such a leading source of fluctuations? Second, a market economy produces several measures of business risk. In financial markets, risk perceptions become readily measurable. How does the risk shock and the related bankruptcy indicators in the model compare with available statistics of business risk?

We try to answer the first question by studying Figures 6.c and 6.d in conjunction with Figures 6.a and 6.b, and the impulse response functions for the risk shock reported in Figures 12.a and 12.b. In Figures 6.c and 6.d we compare the cross-covariance functions for our observable variables generated by the model on the basis of all shocks (black thick lines, the same as in Figures 6.a and 6.b) and those generated by the model conditional on the risk shock only (dotted lines). The relatively good performance of the model in replicating the empirical correlation function is reported in Figures 6.a and 6.b and has been discussed before. Here, the focus is on the fraction of the cross-correlation fit that is due to the risk shock. The decomposition shows that, indeed, the risk shock helps the model reproduce important cyclical properties, such as the correlation between the first difference of current output and the current and lagged first differences of consumption and investment. Other cross-correlations that are of interest to us, given our focus on producing comovements that are consistent with Figure 1, are those between investment, the stock market, the external finance premium and credit. The risk shock is critical to explaining the model's relatively good fit to the dynamic correlations between investment growth and the values of the premium, credit growth and the growth of the stock market index at all the leads and lags considered. The exception to this general pattern of financial cross-correlations is the correlation between current credit and the lagged stock market in the EA, and the correlation between current premium and lagged credit in the US, where the risk shock seems to be responsible for the unsatisfactory performance of the model. The risk shock does not help improve the model's performance on two dimensions where the model does

[34] We capture the deviation of the data from the term structure hypothesis with the shock, σ_{long}, included in the household's budget constraint, (31). According to Table 8.a, this shock for 37 percent of the variance of the term structure in the EA. In the case of the US, the shock only accounts for 24 percent of the variance of the term structure. That is, particularly in the US the fluctuations in the slope of the term structure are accounted for primarily by the estimated economic shocks in the system operating through the expectations hypothesis. This finding, that the term structure hypothesis accounts reasonably well for the slope of the term structure, is consistent with the findings reported in Davis (2008,2008a).

relatively worse or fails. The risk shock imparts the wrong sign on the association between current output growth and past inflation at all lags, and to the association between current inflation and past output growth at shorter lags. The dynamic correlations involving current consumption growth – except with output when consumption is lagged – are also a problem for the risk shock, and for the model more generally, beyond very short lags.

The impulse responses to a risk shock that are documented in Figures 12.a and 12.b explain why this major source of business cycle variance in our model fails on the inflation-output relation. The impulse described in the picture is made of an unexpected contemporary innovation to the risk shock process at time t, and a set of eight signals received at t on the value of the shock at $t+1$, $t+2, \ldots$ $t+8$. No other signals or unexpected innovation occur thereafter. As is evident from the pictures, the risk shock acts as a prototypical demand-side shock under both the EA and the US parameterization. After positive innovations to risk, output, inflation, consumption, investment, real net worth, loans and hours – the last variable, in the EA, after a very short-lived counter-cyclical spike – all move in the same direction. The external finance premium moves counter-cyclically, as expected. The strong positive comovement between output and inflation that the risk shock produces is counterfactual in the data, where current output growth is negatively correlated with contemporary and lagged inflation at all lags, and current inflation is negatively correlated with lagged output growth at short lags. This property of the data seems to suggest the prevalence of supply-side shocks over the sample or, alternatively, a different – and possibly stronger – monetary policy response to cyclical conditions in the economy than is implicit in the estimated policy rule of the model.

The reaction in investment is proportional to that in output but stronger by a factor of four. Importantly, consumption displays the expected positive correlation with output and investment, although its response is muted in the EA on impact. This diffusion property of the risk shock is very interesting. It contradicts the notion that investment shocks are incompatible with a simultaneous change in consumption and work effort in the same direction. Furthermore, it does so in a parameterized model in which capital utilization is close to fixed (recall the high estimated value of σ_a in our Baseline Model).[35] The signals about *future* risk innovations combined with investment adjustment costs help generate a shift in the current demand for capital together with an opposite shift in the marginal utility of future income. This limits the scope for an intertemporal substitution in consumption and leisure, which makes it possible for these two variables to comove.

[35] The first to note the impossibility for investment-specific shocks to deliver a procyclical consumption in a real business cycle model were Barro and King (1984). Greenwood et al. (1988) studied the role of variable capital utilisation in delivering the right response in labour. Justiniano et al. (2007) use many more nominal and real frictions in a monetary business framework similar to our Simple Model. However, their models still generate the "wrong" reaction of consumption to an investment-specific shock.

How does our measures of risk compare to extra-model evidence on entrepreneurial risk? Figure 15 provides some evidence that is helpful to validate the estimated risk shock and those objects in the model from which the risk shock is derived. The first three panels in Figure 15 refer to the US, the last panel to the EA. The first panel in the Figure plots the time series of entrepreneurs' default probability, $\int_0^{\bar{\omega}_t} \omega dF_t(\omega)$, generated by the US model estimation against the actual charge-off rate on business loans at all US commercial banks, as published by the US Federal Reserve Board. As the risk shock is defined as the standard deviation of entrepreneurs' idiosyncratic productivity factor, ω, the default probability and the risk shock are tightly associated in the model. The second panel plots the model-implied default probabilities against the expected default probabilities of non financial corporations, as estimated by Moody's. The third panel shows the year-on-year growth rates of the model-implied default probabilities together with business bank filings. The fourth picture plots a 3-month moving average of our risk shock process together with a 3-month moving average of the cross-sectional variance of sales growth in the US, which we borrow from Bloom, Floetotto and Jaimovich (2009). Finally, the last picture compares the year-on-year growth rate of bankruptcies in the EA with the same year-on-year growth rate as implied by our EA model.

As is apparent from all panels, with the possible exception of the third one, extra-model measures of business risk and the related objects in the model are generally highly correlated. We interpret this evidence as supportive of the measure of economic risk that we generate in our estimation.

4.4 The Fisher Effect

While the risk shock is an important source of motion, the Fisher effect is a critical channel of propagation in our model. Here, the No-Fisher Effect version of our model in which the interest payments received by households are non-state contingent in real terms, rather than in nominal terms, is useful to quantify the importance of nominal rigidities in the financial contract. The log marginal likelihood comparison favors the Baseline specification with the Fisher effect against this latter alternative. Table 9 shows that the posterior odds favor the Fisher effect specification overwhelmingly.

The quantitative importance of the Fisher effect is also documented using the model's impulse response functions. In the case of shocks, such as the risk shock (Figure 12.a and 12.b) or a shock to monetary policy (Figures 13.a and 13.b), that drive output and the price level in the same direction, the response of output is bigger in the Baseline Model than it is when we shut down the Fisher effect. However, in the case of shocks that drive output and the price level in opposite directions, such as a temporary shock to the intermediate goods production function (Figures 14.a and 14.b), the response of output is smaller than it is when we shut down the Fisher effect. In some cases, these effects are quantitatively large.

We first focus on the differences in the propagation of a monetary policy shock, ε_t, in (35) with and without the Fisher effect. In addition to showing the responses implied by our Baseline Model and its No-Fisher-Effect variant, we also display the responses implied by our Simple Model and the Financial Accelerator model. All the alternative models that are reported in the impulse response pictures are calibrated with the parameters that have been estimated using that particular model specification. The size of the monetary policy shock is the same in each model and drives up the short term interest rate by about 40 basis points both in the EA and the US.

In the Baseline Model, the internal propagation of the model is strong in that the effects on output, employment and other variables continue well after the roughly 2 years it takes for the effects on the interest rate to die out. Output, investment, consumption and hours worked display an inverted 'U' shape. The maximal response of EA (US) investment is roughly three times (similar) as big, in percent terms, as the response of output, and peaks almost two years after the shock. The fall in investment drives down the price of capital (not shown), and the implied capital losses contribute to a fall in entrepreneurial net worth. The drop in net worth is roughly twice as big as the drop in the price of capital, presumably because net worth is also reduced by the fall in income earned by entrepreneurs. These effects contribute to a rise in the external finance premium paid by entrepreneurs and reinforce the drop in investment.

Now consider the role of the Fisher debt-deflation channel. To understand the latter, recall that the nominal payments owed by banks in period $t+1$ because of loans they make to entrepreneurs in period t are not contingent on the realization of period $t+1$ shocks. Because the payments made by banks are financed by receipts obtained from entrepreneurs, the nominal rigidity in debt contracts gives rise to a Fisher debt-deflation effect in the baseline model. A surprise rise in the price level increases the real value of the transfer made from entrepreneurs to households. Other things the same, this cuts into entrepreneurs' net worth and inhibits their ability to borrow for the purpose of buying capital. The latter effect acts as a further drag on economic activity. Indeed, from Figures 13.a and 13.b it is evident that the monetary policy shock generates a fall in the price level, which results in a transfer of resources from entrepreneurs to households. The consequence is that the debt-deflation channel reinforces the fall in output that occurs in the wake of a contractionary monetary policy shock. This effect is quantitatively large, with the baseline responses in output, investment, consumption and employment all lying well below what they are in the version of the model without the debt-deflation channel. We conclude that the Fisher debt-deflation channel is a substantial part of the mechanism whereby financial frictions alter the propagation of monetary policy shocks in our model.

The temporary, neutral technology shock, ϵ_t, interacts with the Fisher effect in the opposite direction. Figures 14.a and 14.b show the corresponding impulse responses. To understand the role of the debt-deflation channel, note that the technology shock produces a fall in the price level, and so ϵ_t triggers a transfer of resources from entrepreneurs to households. Note that when the channel is removed, the response of output is substantially greater. Also, the response of investment nearly doubles and the response of net worth nearly triples. Clearly, the Fisher debt-deflation channel is very important in determining the propagation of technology shocks as well.

5 Are Liquidity Shocks Important?

The analysis above leaves us with one loose end: what is the role of banks' liquidity creation? We have seen that banks' decisions over credit extension and the specification of the credit contract are critical. Two financial shocks, γ_t or σ_{t-1}, and notably the latter, are important determinants of banks' credit decisions and, indirectly, of investment and output fluctuations. But, what is the role of banks' decisions concerning the right-hand side of their balance sheets: how *to finance* credit?

We adopt two perspectives on this issue. First, we briefly look at the unconditional variance decomposition of macroeconomic variables and the contribution from liquidity shocks. Tables 7 and 8 (parts a and b) show that money demand shocks emerging from the banking sectors – and from households alike – have virtually no impact on any of the usual quantity variables. See the rows corresponding to σ_{x^b} – the banking technology shock, σ_χ – the money demand shock, and σ_ξ – the shock to banks' demand for reserves. Not surprisingly, these shocks do have a large impact on $M1$ and $M3$.

Our second perspective on the question stated at the beginning of this Section is the historical decomposition of growth in terms of our economic shocks.

5.1 Seven Broad Categories of Shocks

To simplify the exposition, we organize our shocks into seven broad categories. The goods 'Technology' category is composed of the technology shocks affecting the production of the final output good, Y_t. The 'Financial Factors' category is composed of shocks that affect the demand for and supply of capital. On the demand side, we include all the financial shocks that affect the entrepreneurs: the risk shock, σ_t, and the financial wealth shock, γ_t. On the supply side, we include the shocks that affect the producers of capital: the marginal efficiency of investment shock, ζ_{it}, and the shock to the price of investment goods, $\mu_{\Upsilon,t}$. The 'Demand' category includes the shock to government consumption, as well as to the preference for current utility. The shocks related to monetary policy are separated into a pure Taylor rule innovation, ε_t, and the inflation objective process. Finally, the 'Money Demand and Banking' category includes our three liquidity shocks: the two shocks perturbing households' demand for and banks' provision of inside money, and the shock affecting bank reserves.[36] The seven groups of shocks are summarized as follows:

$$
\begin{array}{rl}
\text{Goods Technology:} & \epsilon_t,\ \mu^*_{z,t} \\
\text{Markups:} & \lambda_{ft}, \tau^{oil}_t \\
\text{Financial Factors:} & \mu_{\Upsilon,t},\ \zeta_{i,t}\ ,\ \gamma_t,\ \sigma_t \\
\text{Demand:} & \zeta_{c,t},\ g_t \\
\text{Money Demand and Banking:} & \chi_t,\ x^b_t,\ \xi_t \\
\text{Monetary Policy:} & \varepsilon_t, \\
\text{Monetary Policy objective}\ : & \pi^*_t
\end{array}
$$

Figures 17.a and 17.b, for the EA and the US, respectively, present the historical disaggregation of the year-on-year demeaned GDP growth in terms of the contribution from each of the seven groups of shocks. In each case, the dark line indicates the actual data, and the bars associated with each observation indicate the contribution of each category of shocks. In each period, the sum of the length of the bars (with the length of bars below the mean line being negative) equals the actual data in the dark line.

In order to build confidence in the analysis, we first provide some general considerations regarding the interpretation of selected historical episodes. We then proceed to a discussion of the role of liquidity shocks specifically.

5.1.1 The early 1990s

Consider the model's analysis of the causes of the recession in the early 1990s in the EA and the US. The recession looks very different on the two sides of the Atlantic. In the EA the downturn was mainly associated with monetary policy restrictions (see the drag exerted by the red bars on output over the period). This is consistent with a conventional interpretation of this episode. Under this interpretation, the initial economic weakness was caused by the high interest rates associated with the 1990 reunification of Germany. Under this interpretation, the further collapse in output in 1992 was due to the breakdown of the exchange rate mechanism and the associated financial crises in several European countries. Our demand shocks, as well as the capital producer and entrepreneur shocks may be our model's reduced form way of capturing this financial instability.

In the US, the shocks to capital formation (grey bars) were the main forces. Our model's interpretation of the role of financial factors in the 1990 recession is consistent with the consensus view of Federal Reserve staff economists, as characterized in Reifschneider, Stockton

[36] As the shock to the term structure, $\sigma_{long,t}$, is recursive in the model we do not consider it in the following analysis.

and Wilcox (1997). According to these three authors, balance sheet problems in firms held back aggregate demand.[37] A deterioration in balance sheets in the model reduces the amount that entrepreneurs can borrow for the purpose of financing investment. Entrepreneurs and capital producer shocks also play a substantial role in the strong growth of the late 1990s, and to some extent also in the collapse with the 2001 recession. Again, σ_t and γ_t play an important role here.

5.1.2 The late 1990s

Now, consider the boom-bust period from 1995 to 2004. Whereas monetary policy shocks were the main expansionary influence in the EA, in the US financial factors were the main drivers in the boom phase. Our model is consistent with a popular analysis of the period for both economies. For what concerns the EA, interest rates in many traditionally high-interest rate countries fell in 1997 as a consequence of market anticipations that they would join Monetary Union. The idea is that these interest rate reductions acted as a potent monetary stimulus to the respective economies and more broadly to the EA as a whole. This analysis of the role of expansionary monetary policy in the 1990s boom is one that is shared by our model. Towards the end of the 1990s boom, demand shocks (green bars) and markup shocks (blue bars) take over as the forces driving the expansion. In the US, by contrast, the early part of the boom was entirely attributable to capital deepening shocks (the grey bars) which boosted output through their influence on productivity.

The beginning of the bust in 2000, instead, looks similar in the two economies, except for the role played by technology shocks. The downturn is associated with a sudden reversal of the positive capital producer and entrepreneur shocks in the US, reinforced by substantial negative demand shocks. In the EA the negative drag exerted by the financial shocks is similar qualitatively and even stronger in magnitude than in the US. Technology shocks (the yellow bars) have the usual pro-cyclical sign in the EA, while they soon become counter-cyclical and help support the economy in the US. This latter pattern is atypical and may well reflect a relatively greater ability in the US economy to find ways to obtain more output from factors of production in difficult times. The pattern is consistent with one identified in Field (2003). He observed that between 1929 and 1936, a period that includes the worst years of the US Great Depression, US business investment in research and development surged.

[37] Quoting from the paper, '...the [Board] staff gave weight to the possibility that credit constraints and balance sheet problems were holding back aggregate demand [in the 1990 recession]. The micro-level research on the role of bank credit, the anecdotal reports of credit availability difficulties, and survey evidence gathered from the banks themselves suggested that these influences could not be dismissed. Certainly, judging from public pronouncements, many Fed policymakers also were of the view that these influences were exerting a significant drag on activity.'

Mills (1934) makes a similar observation about the US Great Depression. After reporting that output per hour in industrial activity rose 11 percent in 1930 over 1929 and another 4 percent in 1931 over 1930, he concludes (p. 8): 'These figures are in accordance with our expectations. Depression brings a tightening up of efficiency and a systematic attempt to eliminate resources and waste. Industrial productivity almost invariably increases during such a period of economic strain.'

5.1.3 The 2007-2008 Financial Crisis and the Liquidity Shocks

In some respects, in the US, the onset and the early phases of the ongoing financial crisis resemble the recession of the early 1990s. Note the sharp reversal of the contribution from financial shocks, now partly alleviated by the built-in stabilizer role of the response in productivity. However, the role of the liquidity shocks (orange bars) is very different.

In general, this latter factor is relatively unimportant in explaining developments in output growth, although more relevant in the US than in the EA. Also, the sign of these shocks seems highly correlated with the sign of the impact of the unsystematic part of monetary policy. Obviously, while the model possesses an intrinsic money multiplier which connects policy-induced innovations in narrow money aggregates with the broader aggregates $M1$ and $M3$ that are used in the estimation, this intrinsic mechanism seems to be insufficient to account for the comovement between narrow and broad money creation in the data. However, at the start of the crisis, in the third quarter of 2007, this tight connection disappears and liquidity shocks becomes a non-negligible independent cyclical influence. Their impact is originally positive, as inside money creation remains strong in the face of a rapidly decelerating economy. But the impact of the formidable increase in banks' demand for liquidity which followed the collapse of Lehman Brothers in September 2008 – outside of the estimation sample – has the potential of inverting the sign of the contribution of the liquidity shock category to economic activity.

In order to detect whether such a sign switch might have occurred, and to measure the impact of the liquidity shock in most recent phase of the crisis we extend our US data sample by two quarters through the end of 2008. As the FOMC responded to the exacerbation of the financial crisis in September by shifting to a policy of targeting the size of the Federal Reserve System's overall balance sheet – the so-called 'credit easing' policy – we simulate the US model over the last two quarters of 2008 using the quantitative, McCallum-style rule in (36), rather than our baseline generalized Taylor rule, as a description of monetary policy. The parameters of the new rule are found by re-estimating our Baseline Model over the entire sample on the basis of the quantitative rule as if the FOMC had used such a rule throughout our estimation period.

The results of the simulation of the Baseline Model on the basis of the new policy specification are shown at right-most corner of Figure 17.b. We notice two things that conform well with our conjecture. First, the power of traction of the liquidity shock category on the general economic conditions has strengthened formidably. Second, the sign of the impact has indeed switched and has become strongly negative.

We conclude that liquidity shocks looks very different *in times of crisis.* As these are rare events, conventional statistical measures of relevance condemn liquidity shocks to being unimportant sources of fluctuations for the economy at large. However, when these rare event materialize, shocks that originate in banks' technology for transforming cash reserves into insight money can become responsible for major swings in output and economic conditions.

6 Concluding Remarks

The events of the past two years make it clear that, to be useful, quantitative equilibrium models must be expanded to make it possible to address a broader range of policy questions. One important question that has been asked recently is, how should monetary policy respond to increases in interest rate spreads? To answer this question requires a model that includes an interest rate spread. This paper presents one such model, one that assumes that these spreads are driven almost entirely by changes in bankruptcy risk. This model can be used to evaluate John Taylor's proposal that a central bank should respond to a one percent increase in the interest rate spread by reducing its policy rate by one percent. We have pursued this policy experiment elsewhere.

Of course, interest rate spreads could also be driven by changes in the value of liquidity as modeled, for example, in Kiyotaki and Moore (2008). It would be of interest to pursue an exercise like ours, using a model environment that also allows for the role of liquidity in determining interest rate spreads.[38] An important challenge to be confronted by this work is that for a shock to interest rate spreads to be important empirically, it must make consumption and investment procyclical. This is a challenge because there is a sense in which shocks that drive interest rate spreads are shocks to intertemporal Euler equations. Other things the same, one expects such shocks to drive consumption and investment in opposite directions. But, of course other things are not the same. The risk shock that is so important in our analysis implies that consumption and investment are procyclical. Although we have not yet investigated the reasons for this carefully, we suspect that it reflects the price and wage frictions in our environment. These frictions have the consequence of making the

[38] Such an estimation exercise is being pursued by del Negro, Eggertsson and Ferrero. To some extent, liquidity considerations already appear in our model in the form of shocks to household preferences for different types of bank liabilities. However, the primary effect of these shocks is on the spread between the return on different objects on the liability side of the bank balance sheet, and not between the return on bank liabilities and assets. The latter spread corresponds more closely to the sort of spreads that are of concern to policymakers.

markup countercyclical. Thus, a contraction caused by a jump in risk simultaneously makes the economy less competitive by raising the markup and the latter has a contractionary effect on consumption.

Recent events raise a much broader set of policy questions than simply how the monetary authority should respond to interest rate spreads. There is concern about the riskiness of banks, and policymakers want to know whether it is desirable to in effect 'bail out' banks by purchasing their assets at possibly above-market prices. The environment considered here cannot be used to ask such questions. However, a natural extension of the environment that allows for risky banks does make it possible to ask these questions. Work along these dimensions is now well underway.[39]

[39] See Dib (2009), Hirakata, Sudo and Ueda (2009) and Zeng, (2009).

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7 Appendix A: Steady State Parameters

Values of parameters that control the nonstochastic part of our model economies are displayed in Table 1. The left and right columns report results for the EA and US, respectively.

The values of the parameters that control the financial frictions (e.g., γ, μ, $F(\bar{\omega})$ and $Var(\log \omega)$) were primarily determined by our desire to match the external financial premium, $Z - R^e$, the equity to debt ratio and the rate of return on capital. The value of the quarterly survival rate of entrepreneurs, γ, that we use for both the EA and US models is fairly similar to the 97.28 percent value used in BGG. The value of μ used for the EA model is similar to the value of 0.12 used in BGG. The value of μ in our US model is a little larger, though still well within the range of $0.20 - 0.36$ that Carlstrom and Fuerst (1997) defend as empirically relevant. The value of $F(\bar{\omega})$ that we use for our US model is slightly higher than the 0.75 quarterly percent value used in BGG, or the 0.974 percent value used in Fisher (1999). The value of $F(\bar{\omega})$ used in our EA model exceeds the corresponding empirical estimates by a more substantial margin. Smaller values of $F(\bar{\omega})$ caused the model to understate the equity to debt ratio, the external finance premium and credit velocity. The interval defined by the values of $Var(\log \omega)$ in our EA and US models contains in its interior, the value of 0.28 used by BGG and the value of 0.4 estimated by Levin, Natalucci and Zakrajsek (2004) on US data.

Several additional features of the parameter values in Table 1 are worth emphasizing. During the calibration, we imposed $\psi_k = \psi_l$, i.e., that the fraction of capital rental and labor costs that must be financed in advance are equal. Note, however, that these fractions are much higher in the EA than in the US. This result reflects our finding (see below) that velocity measures in the EA are smaller than their counterparts in the US.

Consider the tax rates in Panel E of Table 1. We obtained the labor tax rate for the EA by first finding the labor tax rate data for each of the 12 EA countries from the OECD in 2002.[40] We then computed a weighted average of the tax rates, based on each country's share in EA GDP. The result, 45 percent, is reported in Table 1. The tax rate on capital is taken from Eurostat and corresponds to the EA implicit tax rate on capital over the period 1995-2001.

We now turn to the US tax rates. We compute effective tax rates by extending the data compiled by Mendoza, Razin and Tesar (1994) to 2001. The differences in tax rates between the EA and the US are notable. The relatively high tax on consumption in the EA reflects the value-added tax in the EA. The relatively high tax on capital income in the US has been noted elsewhere. For example, Mendoza et al. find that in 1988 the tax rate on capital income was 40 percent in the US, 24 percent in Germany, 25 percent in France and 27 percent in Italy. The value for the US tax rate on capital income that we use is similar

[40]See 'Taxing Wages', OECD Statistics, Organisation for Economic Co-operation and Development, 2004.

to Mulligan (2002)'s estimate, who finds that the US capital income tax rate was about 35 percent over the period 1987-1997. McGrattan and Prescott (2004) also report a value for the US capital tax rate similar to ours. According to them, the corporate income tax rate was 35 percent over the period 1990-2001.[41] Regarding the labor tax rate, our estimates imply a lower value for the US than the EA. This pattern is consistent with the findings of Prescott (2003), whose estimates of the labor tax rate in Germany, France and Italy are higher than for the US.

Consistent with the analysis of Prescott (2002), our model parameters imply that the wedge formed from the ratio of the marginal product of labor to the marginal household cost of labor is greater in the EA than in the US. This wedge is, approximately,

$$\frac{1+\tau_c}{1-\tau_w}\lambda_w\lambda_f.$$

Our model parameters imply that this wedge is 2.75 in the EA and 1.74 in the US.

Steady state properties of the EA and US versions of our model are provided in Tables 2 and 3. Details of our data sources are provided in the footnotes to the tables. Consider Table 2 first. The model understates somewhat the capital output ratio in both regions. This reflects a combination of the capital tax rate, as well as the financial frictions. Following BGG, we take the empirical analog of $N/(K-N)$ to be the equity to debt ratio of firms. Our EA model implies this ratio is around unity. Our US model implies a much higher value for this ratio. This is consistent with the analysis of McGrattan and Prescott (2004), who find that the equity to debt ratio in the US averaged 4.7 over the period 1960-1995 and then rose sharply thereafter. Finally, note that around one percent of labor and capital resources are in the banking sector in our EA and US models. The table reports that the empirical counterpart of this number is 5.9 percent. Although this suggests the model greatly understates amount of resources going into banking, this is probably not true. Our empirical estimate is the average share of employment in the finance, insurance and real estate sectors. These sectors are presumably substantially greater than the banking sector in our model.

Now consider the results in Table 3. The numbers in the left panel of that table pertain to monetary velocity measures. Note how the various velocity measures tend to be lower in the EA than in the US. The steady state of the model is reasonably consistent with these properties of the data. Note that we omit a measure of the velocity of credit for the EA. This is because the available data on credit for the EA are incomplete. We have bank loans to nonfinancial corporations, which have an average GDP velocity of 2.60 over the period 1998Q4-2003Q4. We suppose that this greatly overstates the correctly measured velocity of credit, because our EA measure of credit does not include corporate bonds. Note that

[41] McGrattan and Prescott (2004) report that the tax rate on capital has been coming down. For the period, 1960-1969 they report an average value of 45%.

according to the model, the velocity of credit in the EA is substantially smaller than it is in the US. This is consistent with the finding in Table 2, which indicates that the equity to debt ratio in the EA is much smaller than the corresponding value in the US.

The right panel of Table 3 reports various rates of return. The model's steady state matches the data reasonably well, in the cases where we have the data. In the case of the EA, the rate on demand deposits, R^a, corresponds to the overnight rate (the rate paid on demand deposits in the EA) and the rate of return on capital, R^k, is taken from estimates of the European Commission. As regards the US, the rate of return on capital is taken from Mulligan (2002), who shows that the real return was about 8 percent over the period 1987-1999.

We identify the external finance premium with the spread between the 'cost of external finance', Z and the return on household time deposits, R^e. Given that there is substantial uncertainty about the correct measure of the premium, we report a range based on findings in the literature and our own calculations. In the case of the US, Table 3 suggests a spread in the range of 200-298 basis points. This encompasses the values suggested by BGG, Levin, Natalucci and Zakrajsek (2004) and De Fiore and Uhlig (2005).[42] In the case of the EA the table suggests a range of 67-267 basis points. Although the results for the US and the EA might not be perfectly comparable, the evidence reported in the table suggests that the spread is probably higher in the US than in the EA. This is consistent with the findings of Carey and Nini (2004) and Cecchetti (1999), who report that the spread is higher in the US than in the EA by about 30-60 basis points. In order to match this evidence, we have chosen a calibration of the model that delivers a spread in the US that is 40 basis points higher than in the EA.

8 Appendix B: Data Sources

Credit: Credit in the EA is measured as 'bank loans to the private sector', available on the ECB website. Credit in the US is measured as 'credit of non-farm, non-financial corporate business plus credit of non-farm, non-corporate business', taken from the Flow of Funds data available on the US Federal Reserve Board website.

Interest rates: The long term interest rate, R_t^{10}, is the 10-year government bond rate.[43]

[42] Bernanke, Gertler and Gilchrist (1999) measure the external finance premium as approximately the historical average spread between the prime lending rate and the six-month Treasury bill rate, which amounts to 200 basis points. Levin, Natalucci and Zakrajsek (2004) report a spread of 227 basis points for the median firm included in their sample. De Fiore and Uhlig (2005) report that the spread between the prime rate on bank loans to business and the commercial paper is 298 basis points over the period 1997-2003. Carlstrom and Fuerst (1997) report a somewhat lower spread of 187 basis points.

[43] In the case of the US the bond is issued by the US Federal government and in the case

The interest rate, R_t^e, is measured for the US by the Federal Funds rate and for the EA it is the short-term interest rate taken from the Area Wide Model dataset described in Fagan, Henry and Mestre (2001). The interest rate, R_t^a, is measured in the US as the own rate of return on $M2$ (as reported on FRED, the Federal Reserve Bank of St. Louis' data website) and in the EA it is measured as the rate on overnight deposits.

Net worth: For both the EA and US models, we measure N_{t+1}/P_t by the value of the Dow Jones Industrial average, scaled by the GDP deflator.

Premium: For the US, the external finance premium is measured by the difference between BAA and AAA yield on corporate bonds. For the EA it is measured using the spread between, on the one hand, banks' lending rates and on the other hand, corporate bonds yields and government bonds of similar maturity. Here, the weights used to aggregate rates of return correspond to outstanding amounts.

Money: For the US, we measure broad money using $M2_t$ and for the EA we measure broad money using $M3_t$. For both the US and the EA, we measure inflation, π_t, using the GDP deflator.

Hours: For the US we use the Bureau of Labor Statistics' Nonfarm Business Sector Index, Hours of All Persons. For the EA, we use the hours worked data provided by the Groenigen database.

Wages: In the case of wages, for the US we use compensation per hour in the nonfarm business sector provided by the Bureau of Labor Statistics and for the EA we use the data on compensation from the Area Wide Model dataset.

9 Appendix C: News Shocks

We now modify our environment to allow the possibility that there are advance 'news' signals about some future variable, say x_t. The model –in the spirit of Gilchrist and Leahy (2002), as adopted in Christiano, Motto and Rostagno (2004), and extended by Davis (2007)– is as follows::

$$x_t = \rho_1 x_{t-1} + \rho_2 x_{t-2} + \varepsilon_t + \xi_{t-1}^1 + \xi_{t-2}^2 + ... + \xi_{t-p}^p, \tag{48}$$

where ξ_{t-j}^j is orthogonal to x_{t-s}, $s > 0$. The variable, ξ_{t-j}^j is realized at time $t - j$ and represents news about x_t. The superscript on the variable indicates how many dates in the future the news applies to. The subscript indicates the date that the news is realized. The model with news in effect has p additional parameters:

$$\sigma_1^2 = Var\left(\xi_{t-1}^1\right), \ \sigma_2^2 = Var\left(\xi_{t-2}^2\right), ..., \sigma_p^2 = Var\left(\xi_{t-p}^p\right).$$

of the EA, the bond corresponds to a weighted average of member country government bonds.

Note that the presence of news does not alter the fact that (48) is a scalar first order moving average representation for x_t.Obviously, the number of signals in x_t is not identified from observations on x_t alone. However, the cross equation restrictions delivered by an economic model can deliver identification of the σ_j^2's.

We now set this process up in state space/observer form. Suppose, to begin, that $p = 2$. Then,

$$x_t = \rho_1 x_{t-1} + \rho_2 x_{t-2} + \varepsilon_t + \xi_{t-1}^1 + \xi_{t-2}^2. \tag{49}$$

It is useful to set up some auxiliary variables, u_{t-1}^1 and u_{t-2}^2. Write (in the case, $\rho_2 = 0$)

$$\begin{bmatrix} x_t \\ u_t^2 \\ u_t^1 \end{bmatrix} = \begin{bmatrix} \rho & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_{t-1} \\ u_{t-1}^2 \\ u_{t-1}^1 \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \xi_t^2 \\ \xi_t^1 \end{bmatrix}. \tag{50}$$

It is easy to confirm that this is the same as (49). Write the first equation:

$$x_t = \rho x_{t-1} + u_{t-1}^1 + \varepsilon_t. \tag{51}$$

To determine u_{t-1}^1 evaluate (50) at the previous date:

$$\begin{aligned} u_{t-1}^2 &= \xi_{t-1}^2 \\ u_{t-1}^1 &= u_{t-2}^2 + \xi_{t-1}^1. \end{aligned}$$

The second of the above two expressions indicates that we must evaluate (50) at an earlier date:

$$\begin{aligned} u_{t-2}^2 &= \xi_{t-2}^2 \\ u_{t-2}^1 &= u_{t-3}^2 + \xi_{t-2}^1. \end{aligned}$$

Combining the first of these equations with the second of the previous set of two equations, we obtain:

$$u_{t-1}^1 = \xi_{t-2}^2 + \xi_{t-1}^1.$$

Substituting this into (51), we obtain (49), which is the result we sought. We can refer to u_{t-1}^1 as the "state of signals about x_t as of $t-1$". We can refer to ξ_{t-2}^2 as the "signal about x_t that arrives at time $t-2$". We can refer to ξ_{t-1}^1 as the "signal about x_t that arrives at time $t-1$".

We now consider the case of general p. Thus, we have

$$\begin{aligned}
x_t &= \rho x_{t-1} + \varepsilon_t + u^1_{t-1} \\
u^1_{t-1} &= u^2_{t-2} + \xi^1_{t-1} \\
u^2_{t-2} &= u^3_{t-3} + \xi^2_{t-2} \\
&\ldots \\
u^{p-1}_{t-(p-1)} &= u^p_{t-p} + \xi^{p-1}_{t-(p-1)} \\
u^p_{t-p} &= \xi^p_{t-p}.
\end{aligned}$$

According to this setup, there are p signals about x_t. The first arrives in $t-p$, the second in $t-p+1$ and the p^{th} in $t-1$. This is set up in state space form as follows:

$$\begin{bmatrix} x_t \\ x_{t-1} \\ u^p_t \\ u^{p-1}_t \\ \vdots \\ u^2_t \\ u^1_t \end{bmatrix} = \begin{bmatrix} \rho_1 & \rho_2 & 0 & 0 & \cdots & 0 & 1 \\ 1 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix} \begin{bmatrix} x_{t-1} \\ x_{t-2} \\ u^p_{t-1} \\ u^{p-1}_{t-1} \\ \vdots \\ u^2_{t-1} \\ u^1_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ 0 \\ \xi^p_t \\ \xi^{p-1}_t \\ \vdots \\ \xi^2_t \\ \xi^1_t \end{bmatrix}$$

We can write this in compact notation as follows:

$$\Psi_{x,t} = P_x \Psi_{x,t-1} + \varepsilon_{x,t},$$

where

$$\begin{aligned}
\Psi_{x,t} &= \begin{bmatrix} x_t \\ x_{t-1} \\ u^p_t \\ u^{p-1}_t \\ \vdots \\ u^2_t \\ u^1_t \end{bmatrix}, \ P_x = \begin{bmatrix} \rho_1 & \rho_2 & 0 & 0 & \cdots & 0 & 1 \\ 1 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix}, \ \varepsilon_{x,t} = \begin{bmatrix} \varepsilon_t \\ 0 \\ \xi^p_t \\ \xi^{p-1}_t \\ \vdots \\ \xi^2_t \\ \xi^1_t \end{bmatrix}, \\
E\varepsilon_{x,t}\varepsilon'_{x,t} &= \begin{bmatrix} \sigma^2_\varepsilon & 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & \sigma^2_1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & \sigma^2_p \end{bmatrix}.
\end{aligned}$$

Note,

$$
\varepsilon_{x,t} = \begin{bmatrix} \varepsilon_t \\ 0 \\ \xi_t^p \\ \xi_t^{p-1} \\ \vdots \\ \xi_t^2 \\ \xi_t^1 \end{bmatrix} = D \begin{bmatrix} \varepsilon_t \\ \xi_t^p \\ \xi_t^{p-1} \\ \vdots \\ \xi_t^2 \\ \xi_t^1 \end{bmatrix},
$$

so that D is the $p+1$ by $p+1$ identity matrix, augmented by inserting a row of zeros after the first row. In this way, D is $p+2$ by $p+1$.

We conserve on parameters by generating the σ^2's using the following four parameter system:

$$
\sigma_j^2 = \left(\sigma_{j-1}^2\right)^{\phi_1} \left(\sigma_{j-2}^2\right)^{\phi_2},
$$

for $j = 2, .., p$, and with $\sigma_0^2 \equiv \sigma_\varepsilon^2$. The parameters of this system are, $\sigma_\varepsilon^2, \sigma_1^2, \phi_1, \phi_2$. We could reduce this parameter space further by imposing the restriction, $\phi_1 = 1, \phi_2 = 0$, so that

$$
\sigma_j^2 = \sigma_1^2, \; j > 1.
$$

Allowing ϕ_2 to deviate from zero would allow some slope.

The u_t^j's are interesting for model diagnostic purposes. Note, that the sum of all signals about x_t is given by:

$$
u_{t-1}^1 = \xi_{t-1}^1 + \xi_{t-2}^2 + ... + \xi_{t-p}^p,
$$

so that if a smoothed estimate of u_{t-1}^1 is available, then we have the sum of all signals about x_t. It would be nice to break up the sum into the sum of the current year's signals plus the previous year's signals. Suppose $p = 8$. Then,

$$
u_{t-4}^4 = \xi_{t-4}^4 + \xi_{t-5}^5
$$

10 Appendix C: Second Moment Properties of the Model

The solution to the model is provided by

$$
z_t = Az_{t-1} + B\Psi_t,
$$

where z_t is a vector of variables whose values are determined at t and Ψ_t are the exogenous shocks, which have the following law of motion:

$$
\Psi_t = \rho\Psi_{t-1} + D\varepsilon_t.
$$

Here, the 24-dimensional vector of innovations is:

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{\lambda_f,t} & 1 \\ \varepsilon_{\pi^*,t} & 2 \\ \varepsilon_{\xi,t} & 3 \\ \varepsilon_{x^b,t} & 4 \\ \varepsilon_{\hat{\mu}_\Upsilon,t} & 5 \\ \varepsilon_{\hat{\chi},t} & 6 \\ \varepsilon_{\hat{g},t} & 7 \\ \varepsilon_{\hat{\mu},t} & 8 \\ \varepsilon_{\hat{\gamma},t} & 9 \\ \varepsilon_{\hat{\epsilon},t} & 10 \\ \varepsilon_{\hat{x}_{p,t}} & 11 \\ \varepsilon_{\hat{\sigma},t} & 12 \\ \xi_t^1, ..., \xi_t^8 & 13, ..., 20 \\ \varepsilon_{\hat{\zeta}_{c,t}} & 21 \\ \varepsilon_{\hat{\zeta}_{i,t}} & 22 \\ \varepsilon_{\tau_t^{oil}} & 23 \\ \text{term spread}_t & 24 \end{bmatrix}$$

The data used in estimation are as follows:

$$X_t = \left(\begin{array}{c} \Delta \log \left(\frac{N_{t+1}}{P_t} \right) \\ \pi_t \\ \log \left(\text{per capita hours}_t \right) \\ \Delta \log \left(\frac{\text{per capita credit}_t}{P_t} \right) \\ \Delta \log \left(\text{per capita GDP}_t \right) \\ \Delta \log \left(\frac{W_t}{P_t} \right) \\ \Delta \log \left(\text{per capita } I_t \right) \\ \Delta \log \left(\frac{\text{per capita } M1_t}{P_t} \right) \\ \Delta \log \left(\frac{\text{per capita } M3_t}{P_t} \right) \\ \Delta \log \left(\text{per capita consumption}_t \right) \\ \text{External Finance Premium}_t \\ R_t^{long} - R_t^e \\ R_t^e \\ \Delta \log P_{I,t} \\ \Delta \log \text{real oil price}_t \\ \Delta \log (\frac{\text{per capita Bank Reserves }_t}{P_t}) \end{array} \right), \tag{52}$$

In the case of the EA, X_t does not include in the last entry, the growth rate in bank reserves.

Log-linearizing the mapping from z_t and Ψ_t to the objects in X_t :

$$X_t = \alpha + \tau z_t + \tau^s \Psi_t + \bar{\tau} z_{t-1}.$$

We express the system in state-space/observer form for the purpose of estimation as follows. Let

$$\xi_t = \left(\begin{array}{c} z_t \\ z_{t-1} \\ \Psi_t \end{array} \right), F = \left[\begin{array}{ccc} A & 0 & B\rho \\ I & 0 & 0 \\ 0 & 0 & \rho \end{array} \right], \ V = E\varepsilon_t \varepsilon_t'.$$

so that the state space evolution system is:

$$\xi_t = F\xi_{t-1} + u_t, \ Q \equiv Eu_t u_t' = \left[\begin{array}{ccc} BDVD'B' & 0 & BDVD' \\ 0 & 0 & 0 \\ DVD'B' & 0 & DVD' \end{array} \right].$$

The observer system is:

$$X_t = H\xi_t + w_t, \ Ew_t w_t' = R,$$

where R denotes the matrix of measurement errors and

$$H = \left[\begin{array}{ccc} \tau & \bar{\tau} & \tau^s \end{array} \right].$$

We are interested in the second moment properties of a linear transformation on X_t :

$$W_t = \left[\begin{array}{c} \log GDP_t \\ \log C_t \\ \log I_t \\ \log h_t \\ \log \pi_t \\ \log \left(\frac{N_{t+1}}{P_t} \right) \\ \log \left(\frac{\text{credit}_t}{P_t} \right) \\ Z_t - R_t^e \\ \log \frac{GDP_t}{h_t} \\ R_t^{long} - R_t^e \\ R_t^e \\ \log \left(\frac{\text{per capita } M1_t}{P_t} \right) \\ \log \left(\frac{\text{per capita } M3_t}{P_t} \right) \end{array} \right] = J(L) X_t,$$

where

$$J(L) = \left[\begin{array}{ccccccccccccccc} 0 & 0 & 0 & 0 & \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{1-L} & 0 & 0 & 0 & 0 & 0 & 0 \end{array} \right]$$

In the case of the US, W_t has in its last element log bank reserves, and $J(L)$ has an additional row and column. The last row and column has all zeros except the 16^{th} element, which has

$1/(1-L)$. We compute second moment propeties of W_t after it is filtered with the Hodrick-Prescott filter. In frequency domain, this filter has the following representation:

$$f(L)=\frac{g\,(1-L)\,(1-L)\,(1-L^{-1})\,(1-L^{-1})}{(1-g_1L-g_2L^2)\,(1-g_1L^{-1}-g_2L^{-2})},$$

where g, g_1, g_2 are constants, functions of the HP filter smoothing parameter. Thus, we seek the second moment properties of

$$\tilde{W}_t=f(L)\,J(L)\,X_t.$$

We do this using a standard spectral procedure. The moving average representation of the state is

$$\xi_t=[I-FL]^{-1}\,u_t,$$

so that $\tilde{W}_t$ may be expressed as follows:

$$\tilde{W}_t=f(L)\,J(L)\,H\,[I-FL]^{-1}\,u_t+f(L)\,J(L)\,w_t.$$

The spectral density of $\tilde{W}_t$ is:

$$S(z)=f(z)\,J(z)\,H\,[I-Fz]^{-1}\,Q\left[I-F'z^{-1}\right]^{-1}H'J\left(z^{-1}\right)'f\left(z^{-1}\right)+f(z)\,J(z)\,RJ\left(z^{-1}\right)'f\left(z^{-1}\right).$$

Because $J(z)$ is not well defined for $z=1$, while $f(z)\,J(z)$ is, it is convenient to have an expression for the latter:

$$f(z)\,J(z)=\begin{bmatrix}
0 & 0 & 0 & 0 & \tilde{f}(z) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \tilde{f}(z) & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & \tilde{f}(z) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & f(z) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
\tilde{f}(z) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & \tilde{f}(z) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & f(z) & 0 & 0 & 0 & 0\\
0 & 0 & -f(z) & 0 & \tilde{f}(z) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & f(z) & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & f(z) & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \tilde{f}(z) & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \tilde{f}(z) & 0 & 0 & 0 & 0 & 0
\end{bmatrix},$$

where

$$\tilde{f}(z)=\frac{g\,(1-z)\,(1-z^{-1})\,(1-z^{-1})}{(1-g_1z-g_2z^2)\,(1-g_1z^{-1}-g_2z^{-2})},\ g=-g_2$$

In the case of the US, there is an additional row and column of $f(z)J(z)$, with the last row and column having all zeros but the bottom 16×16 element of fJ which has $\tilde{f}(z)$. By the usual inverse Fourier transform result, we have

$$E\tilde{W}_t\tilde{W}_{t-k} = \frac{1}{2\pi}\int_{-\pi}^{\pi} S\left(e^{-i\omega}\right)e^{i\omega k}d\omega$$

We approximate this using the Riemann sum:

$$\frac{1}{2\pi}\sum_{j=-\frac{N}{2}+1}^{\frac{N}{2}} S\left(e^{-i\omega_j}\right)e^{i\omega_j k}\left(\omega_j - \omega_{j-1}\right).$$

Letting $\omega_j = 2\pi j/N$,

$$E\tilde{W}_t\tilde{W}_{t-k} \simeq \frac{1}{N}\sum_{j=-\frac{N}{2}+1}^{\frac{N}{2}} S\left(e^{-i\omega_j}\right)e^{i\omega_j k},$$

where the approximation is arbitrarily accurate for sufficiently large N (we consider N even). Taking into account

$$S\left(e^{-i\omega_j}\right) = S\left(e^{i\omega_j}\right)',$$

(the '′' indicates non-conjugate transposition) we find

$$\begin{aligned}
\frac{1}{N}\sum_{j=-\frac{N}{2}+1}^{\frac{N}{2}} S\left(e^{-i\omega_j}\right)e^{i\omega_j k} &= \frac{1}{N}S\left(e^0\right) + \frac{1}{N}\left[S\left(e^{-i\omega_1}\right)e^{i\omega_1 k} + S\left(e^{-i\omega_1}\right)' e^{-i\omega_1 k}\right] \\
&+\frac{1}{N}\left[S\left(e^{-i\omega_2}\right)e^{i\omega_2 k} + S\left(e^{-i\omega_2}\right)' e^{-i\omega_2 k}\right] \\
&+ ... + \frac{1}{N}\left[S\left(e^{-i\omega_{N/2-1}}\right)e^{i\omega_{N/2-1} k} + S\left(e^{-i\omega_{N/2-1}}\right)' e^{-i\omega_{N/2-1} k}\right] \\
&+\frac{1}{N}S\left(e^{-i\omega_{N/2}}\right)e^{i\omega_{N/2} k}
\end{aligned}$$

We are also interested in the correlations of the variables after they have been first difference to induce stationarity:

$$\begin{bmatrix} \Delta \log GDP_t \\ \Delta \log C_t \\ \Delta \log I_t \\ \Delta \log h_t \\ \log \pi_t \\ \Delta \log \left(\frac{N_{t+1}}{P_t} \right) \\ \Delta \log \left(\frac{\text{credit}_t}{P_t} \right) \\ Z_t - R_t^e \\ \Delta \log \frac{GDP_t}{h_t} \\ R_t^{long} - R_t^e \\ R_t^e \\ \Delta \log \left(\frac{\text{per capita } M1_t}{P_t} \right) \\ \Delta \log \left(\frac{\text{per capita } M3_t}{P_t} \right) \end{bmatrix} = JX_t$$

where

$$J = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1-L & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -(1-L) & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

In the case of the US, there is an additional column and row composed of zeroes, except the 16^{th} element, which contains unity.

Table 1: Model Parameters, EA and US (Time unit of Model: quarterly)			
		Euro Area	US
Panel A: Household Sector			
β	Discount rate	0.999	0.9966
σ_L	Curvature on Disutility of Labor	1.00	1.00
υ	Weight on Utility of Money	0.001	0.001
σ_q	Curvature on Utility of Money	-6.00	-7.00
θ	Power on Currency in Utility	0.74	0.77
χ	Power on Saving Deposits in Utility	0.49	0.55
b	Habit persistence parameter	0.56	0.63
λ_w	Steady state markup, suppliers of labor	1.05	1.05
Panel B: Goods Producing Sector			
μ_z	Growth Rate of the economy (APR)	1.50	1.36
ψ_k	Fraction of capital rental costs that must be financed	0.92	0.45
ψ_l	Fraction of wage bill that must be financed	0.92	0.45
δ	Depreciation rate on capital.	0.02	0.03
α	Power on capital in production function	0.36	0.40
λ_f	Steady state markup, intermediate good firms	1.20	1.20
Φ	Fixed cost, intermediate goods	0.262	0.042
Panel C: Entrepreneurs			
γ	Percent of Entrepreneurs Who Survive From One Quarter to the Next	97.80	97.62
μ	Fraction of Realized Profits Lost in Bankruptcy	0.1	0.33
$F(\bar{\omega})$	Percent of Businesses that go into Bankruptcy in a Quarter	2.60	1.30
$\sigma \equiv Var(log(\omega))$	Variance of (Normally distributed) log of idiosyncratic productivity parameter	0.12	0.67
Panel D: Banking Sector			
ξ	Power on Excess Reserves in Deposit Services Technology	0.94	0.94
x^b	Constant In Front of Deposit Services Technology	101.91	52.15
Panel E: Policy			
τ	Bank Reserve Requirement	0.02	0.01
τ^c	Tax Rate on Consumption	0.20	0.05
τ^k	Tax Rate on Capital Income	0.28	0.32
τ^l	Tax Rate on Labor Income	0.45	0.24
x	Growth Rate of Monetary Base (APR)	3.37	3.71

Table 2: Steady State Properties, Model versus Data, EA and US				
Variable	Model, EA	Data, EA 1998:1-2003:4	Model, US	Data, US 1998:1-2003:4
$\frac{k}{y}$	8.74	12.5[1]	6.99	10.7[2]
$\frac{i}{y}$	0.21	0.20[3]	0.22	0.25[4]
$\frac{c}{y}$	0.56	0.57	0.58	0.56
$\frac{g}{y}$	0.23	0.23	0.20	0.20
r^k	0.042	n.a.	0.059	n.a.
$\frac{N}{K-N}$ ('Equity to Debt')	1.09	1.08-2.19[5]	7.67	>4.7[6]
Transfers to Entrepreneurs (as % of Goods Output)	1.54	n.a.	4.31	n.a.
Banks Monitoring Costs (as % of Output Goods)	0.96	n.a.	0.27	n.a.
Output Goods (in %) Lost in Entrepreneurs Turnover	0.20	n.a.	1.50	n.a.
Percent of Aggregate Labor and Capital in Banking	0.93	n.a.	0.95	5.9[7]
Inflation (APR)	1.84	1.84[8]	2.32	2.32[9]

Note: n.a. - Not available. [1] Capital stock includes also government capital, as disaggregated data are not available. Source: Euro Area Wide Model (EAWM), G.Fagan, J.Henry and R.Mestre (2001) [2] Capital stock includes private non-residential fixed assets, private residential, stock of consumer durables and stock of private inventories. Source: BEA. [3] Investment includes also government investment and does not include durable consumption, as disaggregated data are not available. Source: EAWM. [4] Investment includes residential, non-residential, equipment, plants, business durables, change in inventories and durable consumption. Source: BEA. [5] The equity to debt ratio for corporations in the euro area is 1.08 in 1995, 2.19 in 1999 and afterwards moves down reaching 1.22 in 2002. Taking into account the unusual movements in asset prices in the second half of the 1990s, the steady-state equity to debt ratio is probably closer to the lower end of the range reported in the Table. Debt includes loans, debt securities issued and pension fund reserves of non-financial corporations. Equity includes quoted and non-quoted shares. Source: Euro area Flow of Funds. [6] E.McGrattan and E.Prescott (2004) estimates the equity to debt ratio for the corporate sector over the period 1960-2001. Over the period 1960-1995 the ratio is quite stable and averaged at 4.7. In 1995 it started exhibiting an extraordinary rise. In 2001, the last year included in their sample, the ratio is 60. The unprecedented sharp rise that occurred in the second half of the 1990s makes the calibration of such ratio for the purpose of our analysis very difficult. For comparison, Masulis (1988) reports an equity to debt ratio for US corporations in the range of 1.3-2 for the period 1937-1984. [7] Based on analysis of data on the finance, insurance and real estate sectors over the period 1987-2002. [8] Average inflation (annualised), measured using GDP deflator. [9] Average inflation (annualised), measured using GDP Price Index over the period 1987-2003.

Table 3: Money and Interest Rates. Model versus Data, EA and US									
Money	Model, EA	Data, EA	Model, US	Data, US	Interest Rates (APR)	Model, EA	Data, EA	Model, US	Data, US
M1 Velocity	3.31	3.31	6.42	6.92	Demand Deposits, R^a	0.82	0.76	0.52	n.a.
Broad Money Velocity	1.31	1.32	1.68	1.51	Saving Deposits, R^m	3.29	2.66	4.54	n.a.
Base Velocity	14.58	14.83	24.34	23.14	Long-term Assets	3.78	4.86	5.12	5.99
Currency/Base	0.69	0.69	0.75	0.75	Rate of Return on Capital, R^k	8.21	8.32	10.52	10.0
Currency/Total Deposits	0.07	0.06	0.05	0.05	Cost of External Finance, Z	6.04	4.3-6.3	7.79	7.1-8.1
(Broad Money-M1)/Base	6.75	6.76	10.69	12.16	Gross Rate on Work. Capit. Loans	4.09	n.a.	7.14	7.07
Credit Velocity	0.78	n.a.	3.16	3.25	Time Deposits, R^e	3.78	3.60	5.12	5.12

Notes to Table 3:

Data for the Euro area: the sample is 1998:4-2003:4

(1) ‘Broad Money’ is M3. (2) The interest rate on ‘Demand Deposits’ is the overnight rate. (3) The interest rate on ‘Saving Deposits’ is the own rate on (M3-M1). (4) The interest rate on ‘Longer-term Assets’ is the rate on 10-year Government Bonds. (5) The ‘Rate of Return on Capital’ is the Net Return on Net Capital Stock (source: European Commission). (6) The ‘Cost of External Finance’ is obtained by adding a measure of the external finance premium to R^e. We consider three different measures of the external finance premium: (i) we follow De Fiore and Uhlig (2005), who estimate that the spread is 267 basis points, based on studying the spread between short term bank lending rates to enterprises and a short-term risk free rate. (ii) we consider the spread between BAA and AAA bonds, which amounts at 135 basis.points. (iii) we computed a weighted average of three items (a) the spread between short-term bank lending rates to enterprises and the risk-free rate of corresponding maturity, (b) the spread between long-term bank lending rates and the risk-free rate of corresponding maturity, and (c) the spread between yields on corporate bonds and the risk-free rate of corresponding maturity. We use outstanding stocks to compute the weights. The resulting spread estimate is 67 basis points. Adding these spreads to our measure of the risk-free rate gives the range displayed in the table. (6) We were not able to find EA data corresponding to ‘Gross Rate on Working Capital Loans’. (7) The Rate on ‘Time Deposits’ is the 3-month Euribor.

Data for the US: the left column refers to 1959-2003; the right column to 1987:1-2003:4.

(1) ‘Broad Money’ is M2. (2) The interest rate on ‘Longer-term Assets’ is the rate on 10-year Government Bonds. (3) Rate of Return on Capital: based on Mulligan’s (2002) estimate of the real return over the period 1987-1999 to which we added average inflation. (4) ‘Cost of External Finance’: Bernanke, Gertler and Gilchrist (1999) suggest a spread of 200 basis points over the risk-free rate. Levin, Natalucci and Zakrajsek (2004) find a spread of 227 basis points for the median firm in their sample over 1997-2003. De Fiore and Uhlig (2005) find a spread of 298 basis points. Adding these spreads to our measure of the risk-free rate gives the range displayed in the table. (5) The rate on ‘Working Capital Loans’ is the rate on commercial and industrial loans (source: Survey of terms of business lending, Federal Reserve Board of Governors). (6) The interest rate on ‘Time Deposits’ is the Federal Funds Rate. (7) ‘Credit velocity’ is nominal GDP divided credit, where credit is the sum of bank loans to businesses plus securities other than equity issued by businesses. (8) We have not yet obtained US data on R^a, R^m and R^k.

Table 4. CMR Parameter Estimates: Euro area and US

		Prior			Posterior Euro area			Posterior US		
		Type	Mean	Std. dev.	Mode	Std. dev. (Hess.)	90% Prob. Interval	Mode	Std. dev. (Hess.)	90% Prob. Interval
ξ_p	Calvo prices	Beta	0.75* 0.375	0.05	0.719	0.028	0.67-0.77	0.669	0.043	0.60-0.74
ξ_w	Calvo wages	Beta	0.75* 0.375	0.1	0.747	0.035	0.69-0.81	0.694	0.028	0.65-0.74
H''	Curvature on currency demand**	Normal	2.0	2.0	0.027	0.011	0.01-0.05	/	/	/
ι	Weight on steady state inflation	Beta	0.5	0.15	0.923	0.037	0.86-0.99	0.327	0.160	0.06-0.59
ι_w	Weight on steady state inflation	Beta	0.5	0.15	0.614	0.117	0.44-0.81	0.638	0.168	0.46-0.92
ϑ	Weight on technology growth	Beta	0.5	0.15	0.917	0.037	0.85-0.98	0.935	0.030	0.89-0.99
S''	Investment adjust. cost	Normal	10.0	5	39.149	3.534	33.35-44.95	29.220	3.172	24.00-34.44
σ_a	Capacity utilization	Gamma	6	5	26.730	7.345	15.72-39.74	20.389	5.144	11.93-28.85
α_π	Weight on inflation in Taylor rule	Normal	1.75	0.1	1.824	0.090	1.67-1.97	1.852	0.093	1.70-2.01
α_y	Weight on output growth in Taylor rule	Normal	0.25	0.1	0.251	0.090	0.09-0.41	0.313	0.099	0.16-0.48
$\alpha_{d\pi}$	Weight on change in infl. in Taylor rule	Normal	0.3	0.1	0.256	0.097	0.10-0.42	0.205	0.098	0.04-0.36
α_C	Weight on credit groth in Taylor rule**	Normal	0.05	0.025	0.066	0.025	0.02-0.11	/	/	/
ρ_i	Coeff. on lagged interest rate	Beta	0.8	0.05	0.871	0.013	0.85-0.89	0.878	0.013	0.86-0.90
ρ	Banking technol. shock (x_t^b)	Beta	0.5	0.2	0.978	0.010	0.96-0.999	0.985	0.008	0.97-0.999
ρ	Bank reserve demand shock (ξ_t)***	Beta	0.5	0.2	/	/	/	0.492	0.098	0.33-0.75
ρ	Term premium shock ($\sigma_t^{\aleph}$)	Beta	0.5	0.2	0.936	0.013	0.91-0.96	0.869	0.027	0.83-0.92
ρ	Investm. specific shock ($\mu_{\Upsilon,t}$)	Beta	0.5	0.2	0.977	0.013	0.96-0.999	0.983	0.007	0.97-0.99
ρ	Money demand shock (χ_t)	Beta	0.5	0.2	0.981	0.013	0.96-0.999	0.979	0.012	0.96-0.999
ρ	Government consumption shock (g_t)	Beta	0.5	0.2	0.988	0.010	0.97-0.999	0.945	0.023	0.91-0.98
ρ	Persistent product. shock ($\mu_{z,t}^*$)	Beta	0.5	0.2	0.071	0.052	0.-0.16	0.177	0.073	0-0.30
ρ	Transitory product. shock (ϵ_t)	Beta	0.5	0.2	0.971	0.010	0.84-0.99	0.945	0.023	0.91-0.97
ρ	Financial wealth shock (γ_t)	Beta	0.5	0.1****	0.872	0.024	0.83-0.91	0.561	0.026	0.52-0.60
ρ	Riskiness shock (σ_t)	Beta	0.5	0.2****	0.958	0.009	0.94-0.97	0.850	0.023	0.81-0.89
ρ	Consump. prefer. shock ($\zeta_{c,t}$)	Beta	0.5	0.2	0.933	0.016	0.91-0.96	0.903	0.016	0.88-0.93
ρ	Margin. effic. of invest. shock ($\zeta_{i,t}$)	Beta	0.5	0.05	0.599	0.050	0.52-0.68	0.443	0.045	0.37-0.52
ρ	Oil price shock (τ_t^{oil})	Beta	0.5	0.2	0.953	0.019	0.92-0.98	0.951	0.016	0.91-0.98
ρ	Price mark-up shock ($\lambda_{f,t}$)	Beta	0.5	0.2****	0.979	0.014	0.92-0.999	0.723	0.046	0.65-0.80

Table 4, continued

		Prior			Posterior Euro area			Posterior US		
		Type	Mode	Df.	Mode	Std. dev. (Hess.)	90% Prob. Interval	Mode	Std. dev. (Hess.)	90% Prob. Interval
σ	Banking technol. shock (x_t^b)	Inv. Gamma	0.1	5 d	0.0909	0.0082	0.08-0.10	0.0794	0.0061	0.07-0.09
σ	Bank reserve demand shock (ξ_t)***	Inv. Gamma	0.01	5 d	/	/	/	0.0071	0.0005	0.006-0.008
σ	Term premium shock ($\sigma_t^{\aleph}$)	Inv. Gamma	0.01	5 d	0.0030	0.0006	0.002-0.004	0.0057	0.0015	0.003-0.008
σ	Investm. specific shock ($\mu_{\Upsilon,t}$)	Inv. Gamma	0.003	5 d	0.0034	0.0002	0.003-0.004	0.0033	0.0002	0.002-0.004
σ	Money demand shock (χ_t)	Inv. Gamma	0.001	5 d	0.0263	0.0021	0.020-0.030	0.0183	0.0014	0.016-0.021
σ	Government consumption shock (g_t)	Inv. Gamma	0.01	5 d	0.0121	0.0009	0.010-0.020	0.0207	0.0015	0.018-0.024
σ	Persistent product. shock ($\mu_{z,t}^*$)	Inv. Gamma	0.001	5 d	0.0045	0.0004	0.003-0.005	0.0067	0.0005	0.005-0.009
σ	Transitory product. shock (ϵ_t)	Inv. Gamma	0.001	5 d	0.0040	0.0003	0.003-0.005	0.0043	0.0003	0.003-0.005
σ	Financial wealth shock (γ_t)	Inv. Gamma	0.001	5 d	0.0036	0.0006	0.002-0.005	0.0040	0.0003	0.003-0.006
σ	Signal on Fin. wealth shock (γ_{signal})	Inv. Gamma	$0.001/\sqrt[2]{8}$	5 d	0.0011	0.0002	0.0006-0.002	0.0003	0.0001	0.0001-0.0004
σ	Riskiness shock (σ_t)	Inv. Gamma	0.001	5 d	0.0458	0.0083	0.03-0.06	0.1190	0.0161	0.09-0.15
σ	Signal on Riskiness shock (σ_{signal})	Inv. Gamma	$0.001/\sqrt[2]{8}$	5 d	0.0280	0.0026	0.02-0.04	0.0522	0.0059	0.04-0.06
σ	Consump. prefer. shock ($\zeta_{c,t}$)	Inv. Gamma	0.001	5 d	0.0160	0.0023	0.011-0.021	0.0193	0.0020	0.014-0.022
σ	Margin. effic. of invest. shock ($\zeta_{i,t}$)	Inv. Gamma	0.001	5 d	0.0180	0.0015	0.011-0.022	0.0183	0.0014	0.015-0.218
σ	Oil price shock (τ_t^{oil})	Inv. Gamma	0.01	5 d	0.1502	0.0108	0.13-0.17	0.1342	0.0096	0.11-0.15
σ	Monetary policy shock (ε_t)	Inv. Gamma	0.25	10 d	0.4534	0.0372	0.39-0.52	0.5263	0.0413	0.46-0.59
σ	Price markup shock ($\lambda_{f,t}$)	Inv. Gamma	0.0005	5 d	0.0091	0.0012	0.007-0.014	0.0147	0.0029	0.009-0.019

* Upper numbers refer to EA, lower numbers to US. The US priors was taken from LOWW. The EA prior for prices is consistent with the results produced by the Inflation Persistent Network (see Altissimo et al., 2006). Probability intervals based on Laplace approximation.

** This parameter is set equal to zero in the US model.

*** This shock is not used for the estimation of the euro area model.

**** The standard deviations of the autocorrelation parameters of the price mark-up shock, the financial wealth shock and the riskiness shock are set equal to 0.05, 0.025 and 0.05, respectively, in the US model.

Table 5. CMR Model, Measurement Errors: Parameter Estimates

	Prior			Euro area		US	
				Posterior			
	Type	Mode	b	Mode	St.error (Hessian)	Mode	St.error (Hessian)
Real Credit Growth	Weibull	0.00067 0.0095	5	0.00065	0.00014	0.00090	0.00020
Real M1 Growth	Weibull	0.00098 0.00151	5	0.00098	0.00020	0.00155	0.00030
Real M3 Growth	Weibull	0.00049 0.00074	5	0.00047	0.00010	0.00071	0.00016
Real Net Worth Growth	Weibull	0.00899 0.0090	5	0.01437	0.00109	0.01655	0.00078
External Finance Premium	Weibull	0.00010 0.00005	5	0.0001	0.00002	0.00005	0.00003
Short-term Nominal Interest Rate	Weibull	0.00023 0.00046	5	0.00026	0.00004	0.00025	0.00008
Spread (Long-Short Rate)	Weibull	0.00015 0.00034	5	0.00013	0.00003	0.00026	0.00007
Bank reserves*	Weibull	/ 0.00071	5	/	/	0.00068	0.00015

* The bank reserve demand shock is not used for the estimation of the euro area model.

Table 6a: EA, Properties of the Economic Shocks' Innovations																							
	$\lambda_{f,t}$	π_t^*	xb_t	$\mu_{\Upsilon,t}$	χ_t	g_t	$\mu_{z,t}$	γ_t	ϵ_t	$M.Pol.$	σ_t	σ_t^8	σ_t^7	σ_t^6	σ_t^5	σ_t^4	σ_t^3	σ_t^2	σ_t^1	$\zeta_{c,t}$	$\zeta_{i,t}$	τ_t^{oil}	$Spread$
Mean	0.00	-0.00	0.01	0.00	0.00	0.00	-0.00	0.00	-0.00	0.04	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	0.00	0.00	-0.01	0.00
Auto-Correlation	-0.28	0.26	0.23	0.18	0.21	-0.05	-0.28	-0.14	-0.13	0.55	0.78	0.77	0.7	0.48	0.42	0.26	0.18	0.19	0.3	-0.03	-0.09	0.21	0.4
Cross-Correlation																							
$\lambda_{f,t}$	0.01	0.22	0.06	0.46	0.04	0.15	0.19	0.12	-0.07	-0.35	0.13	-0	-0.04	-0.03	-0.02	0.03	-0.06	-0.01	0.09	-0.1	0.04	-0.44	0.19
π_t^*		0.01	-0.52	-0.06	0.11	-0.23	0.18	0.1	0.06	0.34	0.08	-0.25	-0.26	-0.24	-0.24	-0.14	-0.16	-0.07	0.02	0.75	0.21	0.13	0.06
xb_t			0.09	0.05	0.63	0.2	0.04	-0.18	-0.14	-0.47	0.2	0.28	0.29	0.2	0.23	0.28	0.26	0.15	0.15	-0.61	-0.06	-0.11	-0.15
$\mu_{\Upsilon,t}$				0.01	-0.04	0.14	0.15	0.09	-0.17	-0.19	0.09	0.12	0.05	0.08	0.09	0.02	0.01	0.04	0.09	-0.15	-0.04	-0.52	0.19
χ_t					0.03	0.01	0.26	-0.15	-0.1	-0.05	0.25	0.19	0.17	0.15	0.2	0.28	0.3	0.19	0.23	0.02	-0.1	0.02	-0.13
g_t						0.02	-0.36	0.16	0.29	-0.14	0.08	-0.08	-0.12	-0.13	-0.11	-0.02	-0.11	-0.12	0.08	-0.26	0.11	-0.38	-0.02
$\mu_{z,t}$							0.01	-0.01	-0.49	0.08	-0.05	0.27	0.25	0.33	0.34	0.3	0.25	0.08	0.04	0.08	-0.08	0.05	-0.06
γ_t								0.01	0.16	0.01	-0.01	-0.18	-0.3	-0.41	-0.42	-0.28	-0.32	-0.4	-0.26	-0.05	0.21	-0.26	0.1
ϵ_t									0.01	-0	0.11	-0.19	-0.23	-0.34	-0.3	-0.17	-0.15	-0.25	-0.09	0.17	-0.25	-0.02	0.1
$M.Pol.$										0.45	-0.13	-0.04	-0.05	0.03	0.05	0.03	0.07	0.06	0.03	0.5	0.03	0.17	-0.25
σ_t											0.03	-0.21	-0.26	-0.2	-0.15	0.05	0.3	0.49	0.74	0.03	0.29	-0.03	-0.07
σ_t^8												0.02	0.8	0.66	0.61	0.44	0.13	-0.06	-0.11	-0.08	-0.4	-0.01	-0.21
σ_t^7													0.02	0.76	0.56	0.48	0.29	0.03	-0.19	-0.11	-0.39	0.04	-0.29
σ_t^6														0.02	0.71	0.48	0.43	0.29	0.03	-0.07	-0.42	0.12	-0.28
σ_t^5															0.02	0.6	0.31	0.32	0.15	-0.1	-0.41	0.12	-0.3
σ_t^4																0.02	0.51	0.29	0.25	-0	-0.18	0.04	-0.25
σ_t^3																	0.02	0.59	0.35	-0.06	-0.23	0.16	-0.24
σ_t^2																		0.02	0.68	0.03	0.01	0.26	-0.2
σ_t^1																			0.02	0.08	0.13	-0.01	-0.09
$\zeta_{c,t}$																				0.02	0.08	0.23	0.13
$\zeta_{i,t}$																					0.02	-0	0.19
τ_t^{oil}																						0.16	-0.22
$Spread$																							0.01

Note: Figures refer to the smoothed innovations.

Table 6b: US, Properties of the Economic Shocks' Innovations

		$\lambda_{f,t}$	π_t^*	ξ_t	xb_t	$\mu_{\Upsilon,t}$	χ_t	g_t	$\mu_{z,t}$	γ_t	ϵ_t	$M.Pol.$	σ_t	σ_t^8	σ_t^7	σ_t^6	σ_t^5	σ_t^4	σ_t^3	σ_t^2	σ_t^1	$\zeta_{c,t}$	$\zeta_{i,t}$	τ_t^{oil}	$Spread$
Mean		-0.00	-0.00	0.00	0.01	0.00	-0.00	0.001	-0.00	0.00	0.00	-0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	-0.01	0.00
Auto-Correlation		0.02	0.9	-0.22	0.7	0.51	0.41	-0.29	0.01	0	-0.12	0.61	0.23	0.64	0.36	0.39	0.11	0.07	-0.09	-0.07	-0.35	0.19	-0.25	0.19	0.26
Cross-Correlation																									
	$\lambda_{f,t}$	0.02	-0.39	0.16	-0.06	0.01	-0.1	0.22	-0.15	-0.19	0.2	-0.25	-0.2	0.28	0.3	0.23	0.22	0.22	0.12	-0.04	-0.06	-0.21	0.08	-0.15	-0.15
	π_t^*		0.01	0.11	0.13	0.05	0.49	-0.12	0.26	0.39	-0.2	-0.08	0.11	-0.3	-0.27	-0.25	-0.21	-0.16	-0.11	-0.04	-0	0.01	-0.12	0.14	-0.04
	ξ_t			0.01	-0.17	-0.05	0.55	0.01	0.08	0.18	-0.07	0.08	-0.29	-0.02	-0.06	0.04	-0.09	-0	-0.16	-0.25	-0.27	-0	-0.06	0.05	-0.19
	xb_t				0.08	0.28	0.07	-0.06	0.2	0.05	-0.18	-0.69	0.14	0.16	0.09	0.07	0.05	0.08	0.08	0.05	0.07	-0.52	0.01	-0.16	0.14
	$\mu_{\Upsilon,t}$					0.01	0.21	0.13	0.05	0.16	0.1	-0.22	0.07	-0	0.01	-0.09	-0.07	-0.04	-0.03	-0.1	-0.02	0.02	0.02	-0.11	-0.1
	χ_t						0.02	-0	0.17	0.19	-0.14	0.16	0.15	-0.25	-0.2	-0.11	-0.05	0.05	-0	-0	0.06	0.22	-0.04	0.21	-0.08
	g_t							0.03	-0.46	-0.06	0.61	0.18	-0.11	0.08	0.03	0.1	-0.04	0.05	-0.08	-0.06	-0.08	0.08	0.3	-0.08	-0.23
	$\mu_{z,t}$								0.01	0.05	-0.52	-0.24	0.2	-0.05	0.07	0.04	0.15	0.02	0.18	0.06	0.18	-0.28	-0.02	-0.09	0.19
	γ_t									0.01	-0.32	-0.04	-0.44	-0.48	-0.67	-0.63	-0.7	-0.75	-0.7	-0.72	-0.65	-0.06	0.2	-0.23	-0.02
	ϵ_t										0.01	0.21	0.09	0.15	0.18	0.3	0.17	0.25	0.12	0.2	0.15	0.26	-0.16	0.1	-0.33
	$M.Pol.$											0.51	0.03	-0.39	-0.29	-0.21	-0.15	-0.12	-0.09	0.01	0.02	0.58	-0	0.14	-0.01
	σ_t												0.09	0.09	0.26	0.29	0.46	0.56	0.69	0.8	0.88	0.15	-0.15	0.2	0.09
	σ_t^8													0.03	0.75	0.71	0.61	0.52	0.39	0.32	0.2	-0.2	-0.07	0.13	-0.04
	σ_t^7														0.03	0.76	0.73	0.65	0.57	0.47	0.42	-0.21	-0.19	0.16	-0.09
	σ_t^6															0.03	0.73	0.69	0.59	0.52	0.42	-0.12	-0.19	0.12	-0.01
	σ_t^5																0.03	0.76	0.73	0.65	0.6	-0.03	-0.25	0.25	0.08
	σ_t^4																	0.03	0.77	0.73	0.67	-0.04	-0.26	0.18	0.01
	σ_t^3																		0.03	0.8	0.78	-0.05	-0.32	0.17	0.03
	σ_t^2																			0.03	0.84	0.15	-0.24	0.29	0.1
	σ_t^1																				0.03	0.12	-0.26	0.24	0.11
	$\zeta_{c,t}$																					0.02	0.16	0.33	0.05
	$\zeta_{i,t}$																						0.02	-0.08	0.22
	τ_t^{oil}																							0.14	-0.04
	$Spread$																								0.01

Note: Figures refer to the smoothed innovations.

Table 7a: EA, Variance Decomposition at Business Cycle Frequencies in Alternative Models (in percent)																		
	$\lambda_{f,t}$	π_t^*	xb_t	$\mu_{\Upsilon,t}$	χ_t	g_t	$\mu_{z,t}$	γ_t	$\gamma_t^{signals}$	ϵ_t	*Mon. Pol.*	σ_t	$\sigma_t^{signals}$	$\zeta_{c,t}$	$\zeta_{i,t}$	τ_t^{oil}	*Spread*	*M.Err.*
Stock Market	2.7	0.3	0	0.2	0	0	0.2	16.5	4.5	0.1	5.5	20	44	0	2	0	0	3
	(3)	(0)	(–)	(0)	(–)	(0)	(0)	(22)	(1)	(0)	(5)	(12)	(49)	(0)	(3)	(0)	(–)	(3)
Inflation	28	6	0.5	0.1	0	1	1	5	5	15	5	1	6	13	10	2	0	0
	(40)	(2)	(–)	(0)	(–)	(1)	(1)	(4)	(0)	(17)	(3)	(0)	(2)	(12)	(14)	(3)	(–)	(0)
	[44]	[2]	[–]	[0]	[–]	[1]	[1]	[–]	[–]	[20]	[5]	[–]	[–]	[5]	[20]	[3]	[–]	[0]
Hours	20	0	0.4	0.2	0	3	1	1	1	7	5	5	10	12	33	0	0	0
	(22)	(0)	(–)	(0)	(–)	(3)	(1)	(2)	(0)	(6)	(4)	(4)	(6)	(12)	(37)	(0)	(–)	(0)
	[19]	[0]	[–]	[1]	[–]	[4]	[2]	[–]	[–]	[7]	[6]	[–]	[–]	[10]	[52]	[0]	[–]	[0]
Credit	11	0	0	0	0	0	0	27	17	3	1	6	27	1	3	1	0	0
	(11)	(0)	(–)	(0)	(–)	(0)	(0)	(30)	(21)	(6)	(2)	(2)	(19)	(4)	(5)	(1)	(–)	(0)
GDP	18	0.2	0.5	0.3	0	3	3	4	2	11	6	4	12	11	25	0.5	0	0
	(18)	(0)	(–)	(0)	(–)	(4)	(4)	(3)	(0)	(11)	(6)	(1)	(8)	(13)	(30)	(0)	(–)	(0)
	[13]	[0]	[–]	[1]	[–]	[5]	[3]	[–]	[–]	[13]	[6]	[–]	[–]	[10]	[48]	[1]	[–]	[0]
Investment	4	0	0	0.1	0	0	0.2	8	6	0.5	1	6	24	0	50	0	0	0
	(2)	(0)	(–)	(0)	(–)	(0)	(0)	(10)	(0)	(0)	(1)	(3)	(16)	(1)	(64)	(0)	(–)	(0)
	[5]	[0]	[–]	[0]	[–]	[0]	[0]	[–]	[–]	[2]	[1]	[–]	[–]	[0]	[91]	[0]	[–]	[0]
Real M1	42	0.3	5	0	12	0.4	0.3	1.2	1.6	10	15	4	5	1	2	0	0	0.2
Real M3	1	1	42	0	15	0	1	2	2	1	3	1	5	17	8	0	0	0
Consumption	25	0.4	1	0	0	3	1	1	1	22	11	0	1	30	2	2	0	0
	(26)	(0)	(–)	(0)	(–)	(3)	(1)	(1)	(0)	(21)	(10)	(0)	(0)	(33)	(1)	(1)	(–)	(0)
	[16]	[0]	[–]	[0]	[–]	[5]	[1]	[–]	[–]	[22]	[11]	[–]	[–]	[40]	[3]	[1]	[–]	[0]
Premium	0	0	0	0	0	0	0	7	2	0	1	31	56	0	0	0	0	0
	(0)	(0)	(–)	(0)	(–)	(0)	(0)	(7)	(0)	(0)	(2)	(24)	(66)	(0)	(0)	(0)	(–)	(0)
Term Structure	11	0	0	0	0	0	0	2	2	3	24	1	5	3	10	1	37	0
Interest Rate	15	1	0	0	0	0	1	3	4	8	32	1	7	11	13	2	0	1
	(22)	(1)	(–)	(0)	(–)	(1)	(1)	(6)	(0)	(10)	(22)	(1)	(5)	(13)	(15)	(2)	(–)	(0)
	[26]	[1]	[–]	[0]	[–]	[1]	[1]	[–]	[–]	[11]	[30]	[–]	[–]	[5]	[23]	[2]	[–]	[0]

Note For each variable, figures for the benchmark model are in the first row. The alternative models, if present, are in the following rows. Financial Accelerator model is denoted by (). Simple model is denoted by []. Rows may not sum up to 100 due to rounding.

Table 7b: US, Variance Decomposition at Business Cycle Frequencies in Alternative Models (in percent)

	$\lambda_{f,t}$	π_t^*	ξ_t	xb_t	$\mu_{\Upsilon,t}$	χ_t	g_t	$\mu_{z,t}$	γ_t	$\gamma_t^{signals}$	ϵ_t	*Mon. Pol.*	σ_t	$\sigma_t^{signals}$	$\zeta_{c,t}$	$\zeta_{i,t}$	τ_t^{oil}	*Spread*	*M.Err.*
Stock Market	1	0	0	0	0	0	0	0.2	10	0	0.2	1.4	37	43	0	2	0	0	7
	(1)	(0)	(–)	(–)	(0)	(–)	(0)	(0)	(11)	(0)	(0)	(2)	(20)	(55)	(0)	(2)	(0)	(–)	(8)
Inflation	39	3	0	0.2	0.1	0	2	3	1	0	19	4	0	5	15	5	3	0	0
	(50)	(1)	(–)	(–)	(0)	(–)	(2)	(2)	(0)	(0)	(17)	(4)	(0)	(4)	(10)	(7)	(3)	(–)	(0)
	[53]	[1]	[–]	[–]	[0]	[–]	[2]	[1]	[–]	[–]	[15]	[4]	[–]	[–]	[4]	[14]	[4]	[–]	[0]
Hours	5	0.2	0	0.3	0.2	0	11	3	4	0.1	13	5	2	16	16	23	1	0	0
	(6)	(0)	(–)	(–)	(0)	(–)	(10)	(3)	(3)	(0)	(8)	(7)	(1)	(14)	(17)	(28)	(0)	(–)	(0)
	[7]	[0]	[–]	[–]	[1]	[–]	[12]	[4]	[–]	[–]	[9]	[6]	[–]	[–]	[10]	[50]	[1]	[–]	[0]
Credit	2	0	0	0	0	0	0.1	0	23	1	1	0.2	18	53	1	0	0	0	0
	(1)	(0)	(–)	(–)	(0)	(–)	(0)	(0)	(37)	(0)	(1)	(0)	(9)	(49)	(1)	(1)	(1)	(–)	(0)
GDP	5	0.1	0	0.5	0.3	0	10	8	2	0	13	5	4	15	15	22	1	0	0
	(5)	(0)	(–)	(–)	(0)	(–)	(12)	(8)	(1)	(0)	(11)	(6)	(2)	(12)	(17)	(27)	(1)	(–)	(0)
	[6]	[0]	[–]	[–]	[1]	[–]	[14]	[6]	[–]	[–]	[11]	[6]	[–]	[–]	[9]	[46]	[1]	[–]	[0]
Investment	0.4	0	0	0	0.3	0	0	1	5	0.2	0.5	0.3	7	31	0	53	0	0	0
	(0)	(0)	(–)	(–)	(0)	(–)	(0)	(1)	(4)	(0)	(0)	(0)	(3)	(23)	(0)	(68)	(0)	(–)	(0)
	[1]	[0]	[–]	[–]	[0]	[–]	[0]	[0]	[–]	[–]	[3]	[1]	[–]	[–]	[2]	[91]	[0]	[–]	[0]
Real M1	35	0.2	0	6	0	11	1	0.3	0.7	0	15	17	0.4	3	5	1	3.6	0	0.2
Real M2	16	0.5	0	27	0	5	1	3	1	0	6	8	0.3	5	21	5	0	0	0.5
Consumption	8	0.3	0	1	0	0	5	2	1	0	26	9	1	4	38	2	4	0	0
	(9)	(0)	(–)	(–)	(0)	(–)	(4)	(2)	(0)	(0)	(24)	(12)	(0)	(0)	(45)	(1)	(2)	(–)	(0)
	[9]	[0]	[–]	[–]	[0]	[–]	[5]	[2]	[–]	[–]	[17]	[10]	[–]	[–]	[50]	[3]	[3]	[–]	[0]
Premium	0	0	0	0	0	0	0	0	3	0	0	0	47	50	0	0	0	0	0
	(0)	(0)	(–)	(–)	(0)	(–)	(0)	(0)	(2)	(0)	(0)	(0)	(37)	(62)	(0)	(0)	(0)	(–)	(0)
Term Structure	24	0.2	0	0	0	0	1	1	1	0	9	16	1	11	9	8	1	19	0.7
Interest Rate	25	1	0	0.2	0	0	2	2	1.5	0	14	18	0	8	17	7	3	0	1
	(30)	(1)	(–)	(–)	(0)	(–)	(2)	(3)	(2)	(0)	(14)	(14)	(0)	(6)	(15)	(9)	(3)	(–)	(0)
	[35]	[1]	[–]	[–]	[0]	[–]	[3]	[2]	[–]	[–]	[13]	[16]	[–]	[–]	[6]	[20]	[4]	[–]	[0]

Note For each variable, figures for the benchmark model are in the first row. The alternative models, if present, are in the following rows. Financial Accelerator model is denoted by (). Simple model is denoted by []. Rows may not sum up to 100 due to rounding.

Table 8a: EA, Variance Decomposition at Low Frequencies in Alternative Models (in percent)

	$\lambda_{f,t}$	π_t^*	xb_t	$\mu_{\Upsilon,t}$	χ_t	g_t	$\mu_{z,t}$	γ_t	$\gamma_t^{5:8}$	$\gamma_t^{1:4}$	$M.Pol.$	σ_t	σ_t^8	σ_t^7	σ_t^6	σ_t^5	σ_t^4	σ_t^3	σ_t^2	σ_t^1	$\zeta_{c,t}$	$\zeta_{i,t}$	τ_t^{oil}	$Spread$	$M.Err.$
$\Delta(N/P)$	2 (2)	0 (0)	0 (–)	0 (0)	0 (–)	0 (0)	0 (0)	24 (33)	7 (4)	4 (4)	3 (2)	7 (7)	5 (4)	6 (5)	6 (5)	6 (5)	6 (5)	6 (5)	6 (5)	5 (5)	0 (0)	3 (3)	0 (0)	0 (–)	4 (4)
π	16 (14) [26]	10 (7) [19]	0 (–) [–]	0 (0) [1]	0 (–) [–]	1 (1) [1]	1 (1) [2]	9 (18) [–]	4 (4) [–]	4 (4) [–]	5 (3) [7]	1 (1) [–]	2 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (0) [–]	19 (23) [5]	8 (7) [22]	2 (1) [2]	0 (–) [–]	0 (0) [0]
$Log,\ H$	32 (33) [33]	0 (0) [0]	0 (–) [–]	0 (0) [1]	0 (–) [–]	7 (4) [20]	1 (1) [2]	8 (17) [–]	4 (4) [–]	4 (4) [–]	3 (2) [4]	1 (1) [–]	2 (2) [–]	2 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	5 (4) [2]	22 (21) [35]	0 (0) [0]	0 (–) [–]	0 (0) [0]
$\Delta Loans$	3 (1)	0 (0)	0 (–)	0 (0)	0 (–)	0 (0)	1 (0)	18 (27)	5 (4)	4 (4)	1 (1)	6 (7)	9 (8)	8 (8)	8 (7)	7 (7)	7 (6)	6 (6)	6 (5)	5 (5)	1 (2)	4 (4)	0 (0)	0 (–)	0 (0)
ΔY	12 (12) [20]	0 (0) [0]	0 (–) [–]	0 (0) [2]	0 (–) [–]	1 (1) [3]	5 (5) [10]	12 (22) [–]	4 (4) [–]	4 (4) [–]	3 (2) [3]	3 (3) [–]	4 (3) [–]	4 (3) [–]	4 (3) [–]	3 (3) [–]	3 (3) [–]	3 (3) [–]	3 (2) [–]	3 (2) [–]	4 (3) [3]	15 (14) [34]	0 (0) [1]	0 (–) [–]	0 (0) [0]
$\Delta(W/P)$	38 (35) [41]	0 (0) [0]	0 (–) [–]	0 (0) [1]	0 (–) [–]	0 (0) [1]	15 (15) [23]	7 (15) [–]	4 (4) [–]	4 (4) [–]	1 (0) [0]	1 (1) [–]	2 (1) [–]	2 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	0 (0) [0]	6 (6) [8]	2 (1) [2]	0 (–) [–]	0 (0) [0]
ΔI	5 (4) [16]	0 (0) [0]	0 (–) [–]	0 (0) [4]	0 (–) [–]	0 (0) [0]	1 (1) [2]	17 (29) [–]	8 (4) [–]	8 (4) [–]	1 (1) [1]	4 (4) [–]	5 (4) [–]	5 (4) [–]	5 (4) [–]	5 (4) [–]	4 (3) [–]	4 (3) [–]	4 (3) [–]	3 (3) [–]	0 (1) [1]	23 (20) [64]	0 (0) [0]	0 (–) [–]	0 (0) [0]
$\Delta M1$	37	1	6	0	13	0	1	5	4	4	5	1	1	1	1	1	1	1	1	1	4	2	2	0	0
$\Delta M3$	2	1	41	0	4	0	2	6	4	4	1	1	2	2	2	1	1	1	1	1	17	7	0	0	0
ΔC	14 (14) [12]	0 (0) [0]	1 (–) [–]	0 (0) [2]	0 (–) [–]	3 (2) [10]	3 (3) [6]	8 (18) [–]	4 (4) [–]	4 (4) [–]	3 (2) [4]	1 (2) [–]	2 (2) [–]	2 (2) [–]	2 (2) [–]	2 (2) [–]	2 (1) [–]	1 (1) [–]	1 (1) [–]	1 (1) [–]	17 (15) [25]	6 (6) [10]	1 (1) [1]	0 (–) [–]	0 (0) [0]
$Premium$	0 (0)	0 (0)	0 (–)	0 (0)	0 (–)	0 (0)	0 (0)	13 (21)	4 (4)	4 (3)	1 (1)	14 (15)	6 (5)	6 (6)	7 (6)	8 (7)	8 (7)	9 (8)	10 (9)	10 (9)	0 (0)	1 (1)	0 (0)	0 (–)	0 (0)
$Spread$	5	1	0	0	0	0	0	9	4	4	4	2	3	3	2	2	2	2	1	1	7	8	1	37	0
R	7 (6) [17]	3 (2) [10]	0 (–) [–]	0 (0) [4]	0 (–) [–]	1 (1) [2]	2 (1) [4]	12 (23) [–]	6 (4) [–]	8 (6) [–]	4 (2) [12]	2 (1) [–]	3 (2) [–]	3 (2) [–]	2 (2) [–]	2 (2) [–]	2 (1) [–]	2 (1) [–]	2 (1) [–]	1 (1) [–]	22 (27) [5]	7 (6) [31]	1 (1) [2]	0 (–) [–]	0 (0) [0]
$\Delta(P^I/P)$	0 (0) [0]	0 (0) [0]	0 (–) [–]	100 (100) [100]	0 (–) [–]	0 (0) [0]	0 (0) [0]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [0]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [0]	0 (0) [0]	0 (0) [0]	0 (–) [–]	0 (0) [0]
$\Delta(P^{oil}/P)$	0 (0) [0]	0 (0) [0]	0 (–) [–]	0 (0) [0]	0 (–) [–]	0 (0) [0]	0 (0) [0]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [0]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [–]	0 (0) [0]	0 (0) [0]	100 (100) [100]	0 (–) [–]	0 (0) [0]

Legend: For each variable, figures for the benchmark model are in the first row. The alternative models, if present, are in the following rows. Financial Accelerator model is denoted by (). Simple model is denoted by []. Note: Variance decomposition corresponds to periodic components with cycles of 33-1000 quarters, obtained using the model spectrum.

Table 8b: US, Variance Decomposition at Low Frequencies in Alternative Models (in percent)

	$\lambda_{f,t}$	π_t^*	ξ_t	xb_t	$\mu_{\Upsilon,t}$	χ_t	g_t	$\mu_{z,t}$	γ_t	ϵ_t	$M.Pol.$	σ_t	$\sigma_{1,t}$	$\sigma_{2,t}$	$\sigma_{3,t}$	$\sigma_{4,t}$	$\sigma_{5,t}$	$\sigma_{6,t}$	$\sigma_{7,t}$	$\sigma_{8,t}$	$\zeta_{c,t}$	$\zeta_{i,t}$	τ_t^{oil}	$Spread$	$M.Err.$
$\Delta(N/P)$	1	0	0	0	0	0	0	1	14	0	1	9	7	7	7	6	6	5	5	4	0	4	0	0	23
	(0)	(0)	(–)	(–)	(0)	(–)	(0)	(1)	(14)	(0)	(1)	(9)	(7)	(7)	(7)	(6)	(6)	(5)	(5)	(4)	(0)	(4)	(0)	(–)	(24)
π	14	9	0	0	0	0	4	6	2	18	8	1	2	1	1	1	1	0	0	0	24	4	4	0	0
	(14)	(10)	(–)	(–)	(0)	(–)	(4)	(7)	(2)	(18)	(6)	(1)	(2)	(2)	(1)	(1)	(1)	(1)	(0)	(0)	(22)	(5)	(3)	(–)	(0)
	[21]	[14]	[–]	[–]	[1]	[–]	[4]	[6]	[–]	[14]	[10]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[8]	[18]	[4]	[–]	[0]
$Log,\ H$	2	0	0	0	1	0	18	6	4	6	7	1	4	3	2	2	1	1	0	0	19	22	0	0	0
	(1)	(0)	(–)	(–)	(1)	(–)	(15)	(6)	(4)	(5)	(7)	(1)	(4)	(3)	(3)	(2)	(1)	(1)	(1)	(0)	(18)	(26)	(0)	(–)	(0)
	[2]	[0]	[–]	[–]	[2]	[–]	[16]	[8]	[–]	[2]	[9]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[4]	[56]	[1]	[–]	[0]
$\Delta Loans$	0	0	0	0	0	0	0	0	13	1	0	9	14	13	11	10	9	7	5	4	1	1	0	0	0
	(0)	(0)	(–)	(–)	(0)	(–)	(0)	(0)	(13)	(1)	(0)	(9)	(14)	(13)	(11)	(10)	(9)	(7)	(6)	(4)	(1)	(1)	(0)	(–)	(0)
ΔY	1	0	0	1	1	0	4	28	5	12	3	2	4	4	3	3	2	2	1	1	7	16	1	0	0
	(1)	(0)	(–)	(–)	(1)	(–)	(4)	(26)	(5)	(10)	(3)	(2)	(5)	(4)	(3)	(3)	(2)	(2)	(1)	(1)	(7)	(19)	(1)	(–)	(0)
	[2]	[0]	[–]	[–]	[2]	[–]	[6]	[25]	[–]	[17]	[4]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[6]	[37]	[1]	[–]	[0]
$\Delta(W/P)$	16	0	0	0	1	0	1	44	2	19	1	0	1	1	1	1	1	0	0	0	2	5	4	0	0
	(16)	(0)	(–)	(–)	(1)	(–)	(1)	(44)	(2)	(19)	(1)	(0)	(1)	(1)	(1)	(1)	(1)	(0)	(0)	(0)	(2)	(7)	(3)	(–)	(0)
	[17]	[0]	[–]	[–]	[1]	[–]	[1]	[49]	[–]	[14]	[1]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[1]	[11]	[4]	[–]	[0]
ΔI	0	0	0	0	2	0	0	7	12	1	0	4	9	7	6	5	4	3	2	2	0	36	1	0	0
	(0)	(0)	(–)	(–)	(1)	(–)	(0)	(6)	(11)	(1)	(0)	(4)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(2)	(0)	(39)	(0)	(–)	(0)
	[1]	[0]	[–]	[–]	[4]	[–]	[1]	[6]	[–]	[10]	[2]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[7]	[68]	[0]	[–]	[0]
$\Delta M1$	15	1	0	10	0	20	1	3	2	16	7	1	2	2	1	1	1	1	0	0	7	3	5	0	0
$\Delta M3$	4	1	0	40	0	7	1	6	2	3	2	0	1	1	1	1	0	0	0	0	24	3	1	0	0
ΔC	2	0	0	1	1	0	6	16	3	22	5	1	3	2	2	2	1	1	1	1	21	7	3	0	0
	(1)	(0)	(–)	(–)	(1)	(–)	(4)	(17)	(3)	(22)	(5)	(1)	(3)	(3)	(2)	(2)	(2)	(1)	(1)	(1)	(21)	(9)	(2)	(–)	(0)
	[2]	[0]	[–]	[–]	[2]	[–]	[6]	[16]	[–]	[14]	[4]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[41]	[13]	[2]	[–]	[0]
$Premium$	0	0	0	0	0	0	0	0	6	0	0	40	4	5	5	6	7	8	9	10	1	1	0	0	0
	(0)	(0)	(–)	(–)	(0)	(–)	(0)	(0)	(6)	(0)	(0)	(39)	(4)	(5)	(5)	(6)	(7)	(8)	(9)	(10)	(0)	(1)	(0)	(–)	(0)
$Spread$	6	1	0	0	0	0	3	3	4	10	5	1	3	2	2	1	1	1	1	0	22	6	3	24	0
R	4	4	0	0	1	0	5	11	3	16	5	1	2	2	2	1	1	1	1	0	32	5	4	0	0
	(4)	(4)	(–)	(–)	(1)	(–)	(4)	(12)	(4)	(15)	(6)	(1)	(3)	(2)	(2)	(2)	(1)	(1)	(1)	(1)	(28)	(6)	(3)	(–)	(0)
	[9]	[7]	[–]	[–]	[3]	[–]	[5]	[15]	[–]	[13]	[7]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[11]	[25]	[4]	[–]	[0]
$\Delta(P^I/P)$	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(0)	(0)	(–)	(–)	(100)	(–)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(–)	(0)
	[0]	[0]	[–]	[–]	[100]	[–]	[0]	[0]	[–]	[0]	[0]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[0]	[0]	[0]	[–]	[0]
$\Delta(P^{oil}/P)$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0
	(0)	(0)	(–)	(–)	(0)	(–)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(100)	(–)	(0)
	[0]	[0]	[–]	[–]	[0]	[–]	[0]	[0]	[–]	[0]	[0]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[0]	[0]	[100]	[–]	[0]
$Reserves$	8	1	18	7	0	21	2	2	2	12	5	1	2	1	1	1	1	1	0	0	9	3	3	0	0

Legend: For each variable, figures for the benchmark model are in the first row. The alternative models, if present, are in the following rows. Financial Accelerator model is denoted by (). Simple model is denoted by []. Note: Variance decomposition corresponds to periodic components with cycles of 33-1000 quarters, obtained using the model spectrum.

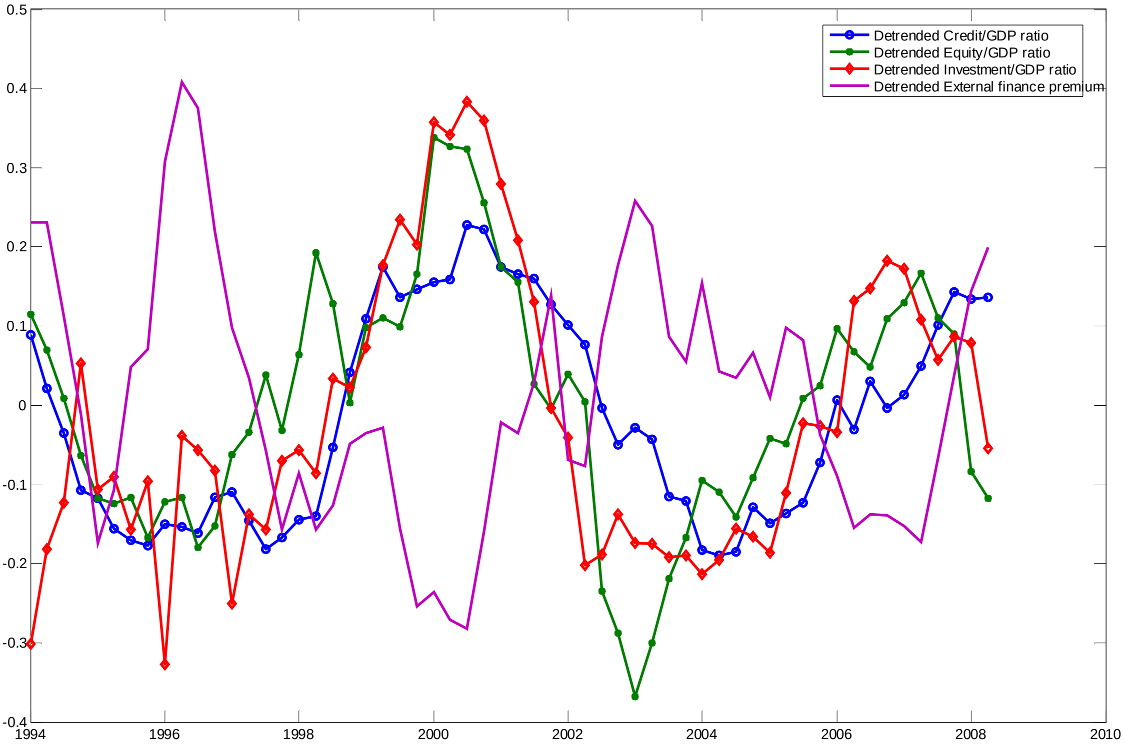
Table 9: Log Marginal Data Densities

	Baseline Model	No Signals	Signals on Technology Shocks Only ($\mu_{z_t^*}, \epsilon_t, \zeta_{i,t}$)	No Fisher Debt-Deflation Channel
EA, Log Marginal Data Density	4947.8	4644.8	4877.5	4888.2
US, Log Marginal Data Density	4586.7	4458.32	4466.8	4553.8

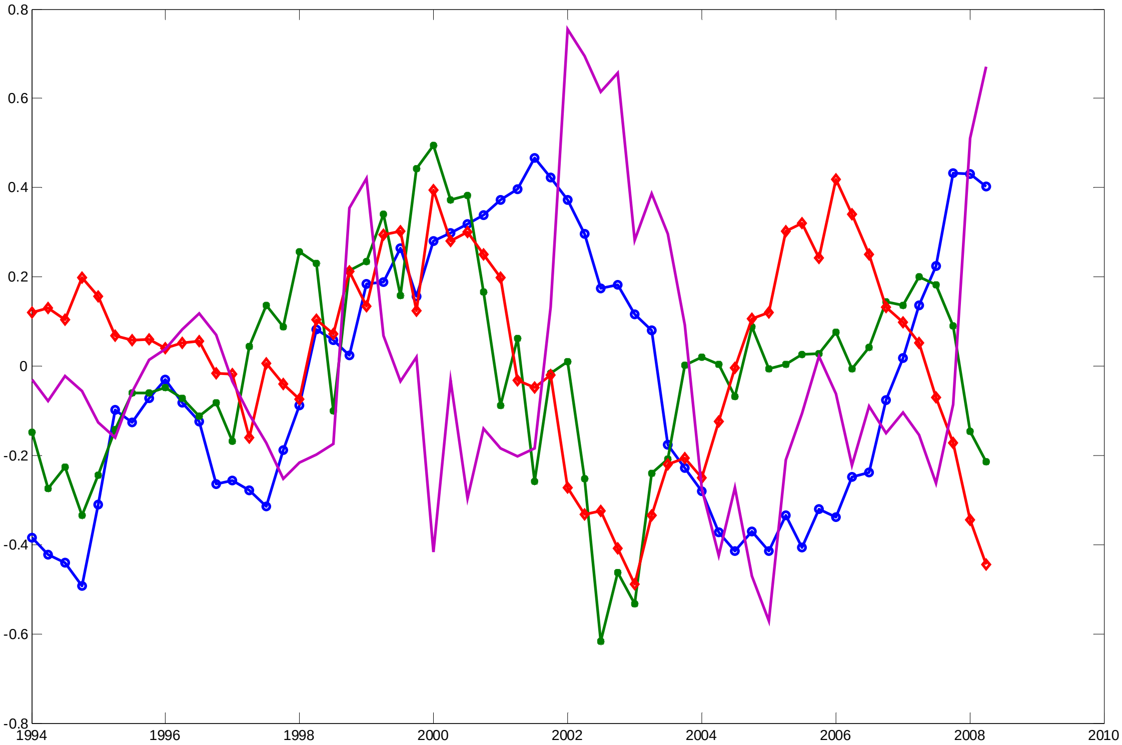
Note: The log marginal data densities are computed on the basis of the Laplace approximation.

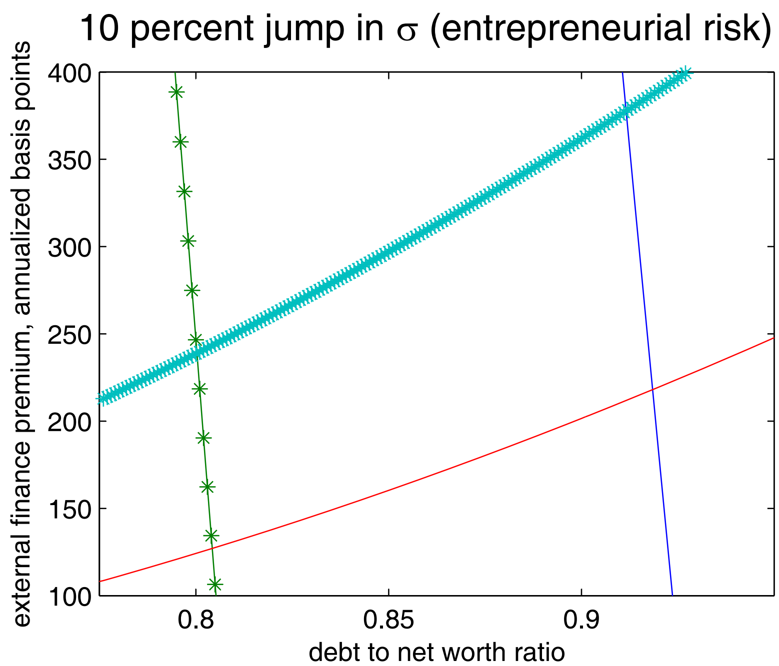
Figure 1. Financial Variables and the Business Cycle: 1994-2008

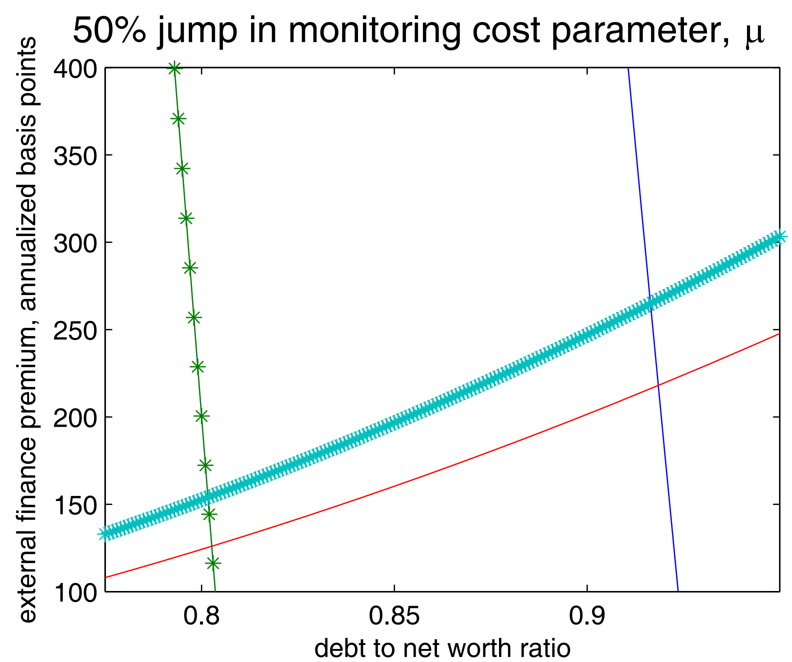
(a) Euro Area

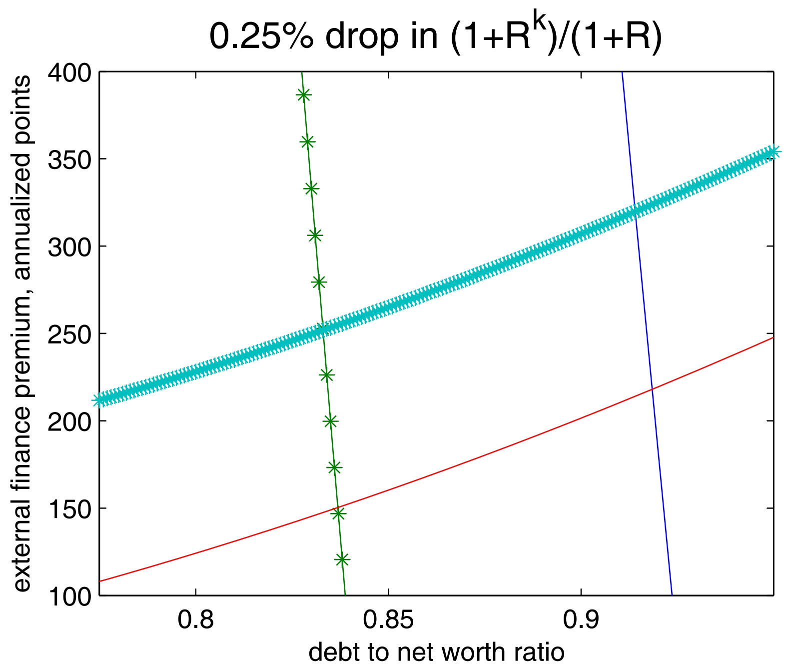


(b) US









Lines with positive slope: bank zero profit condition
Lines with negative slope: first order condition for contract
Solid line: baseline
Starred line: perturbed

Figure 2: properties of standard debt contract

Figure 3a: EA, Actual (solid line) and Fitted (dotted line) Data

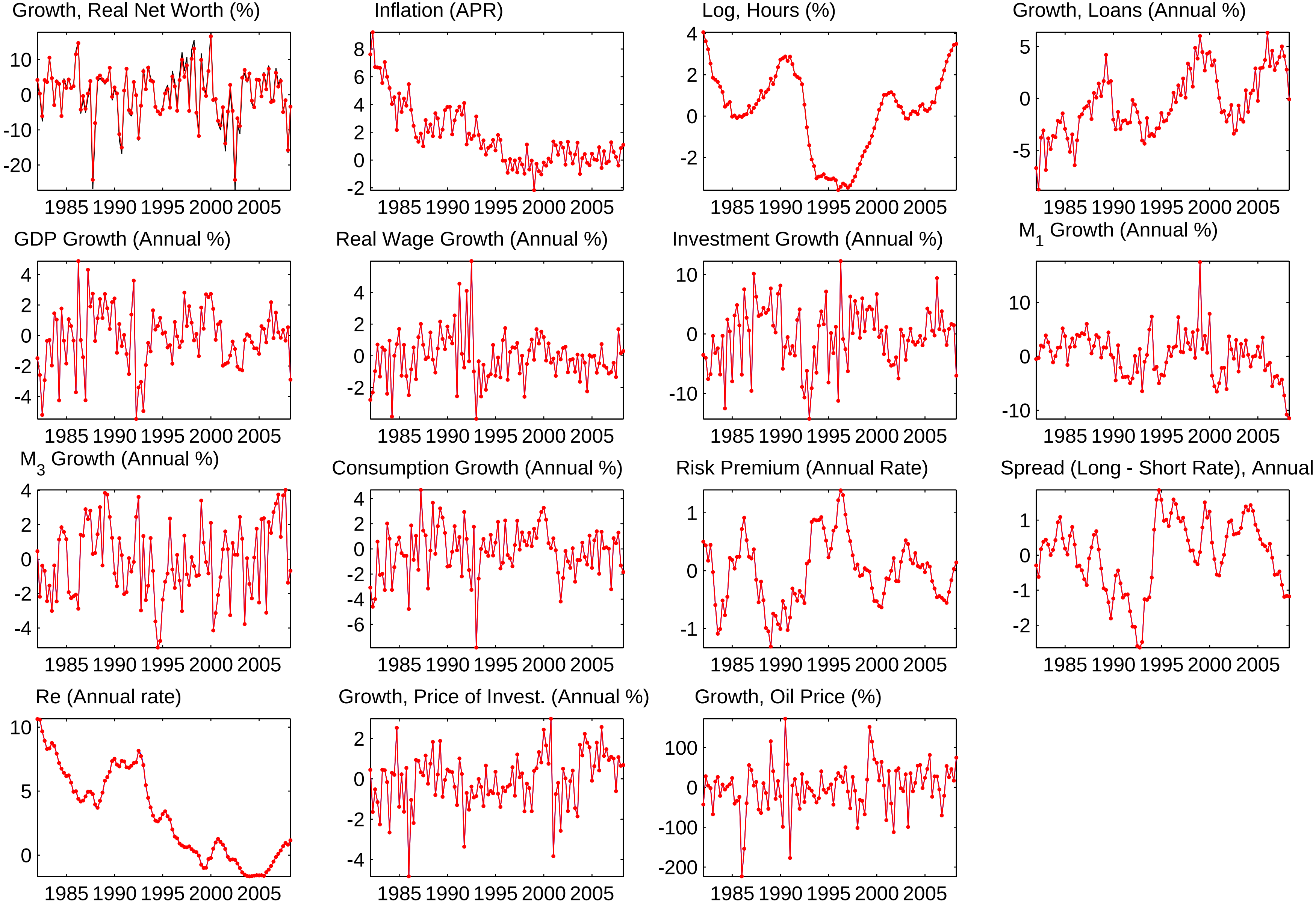


Figure 3b: US, Actual (solid line) and Fitted (dotted line) Data

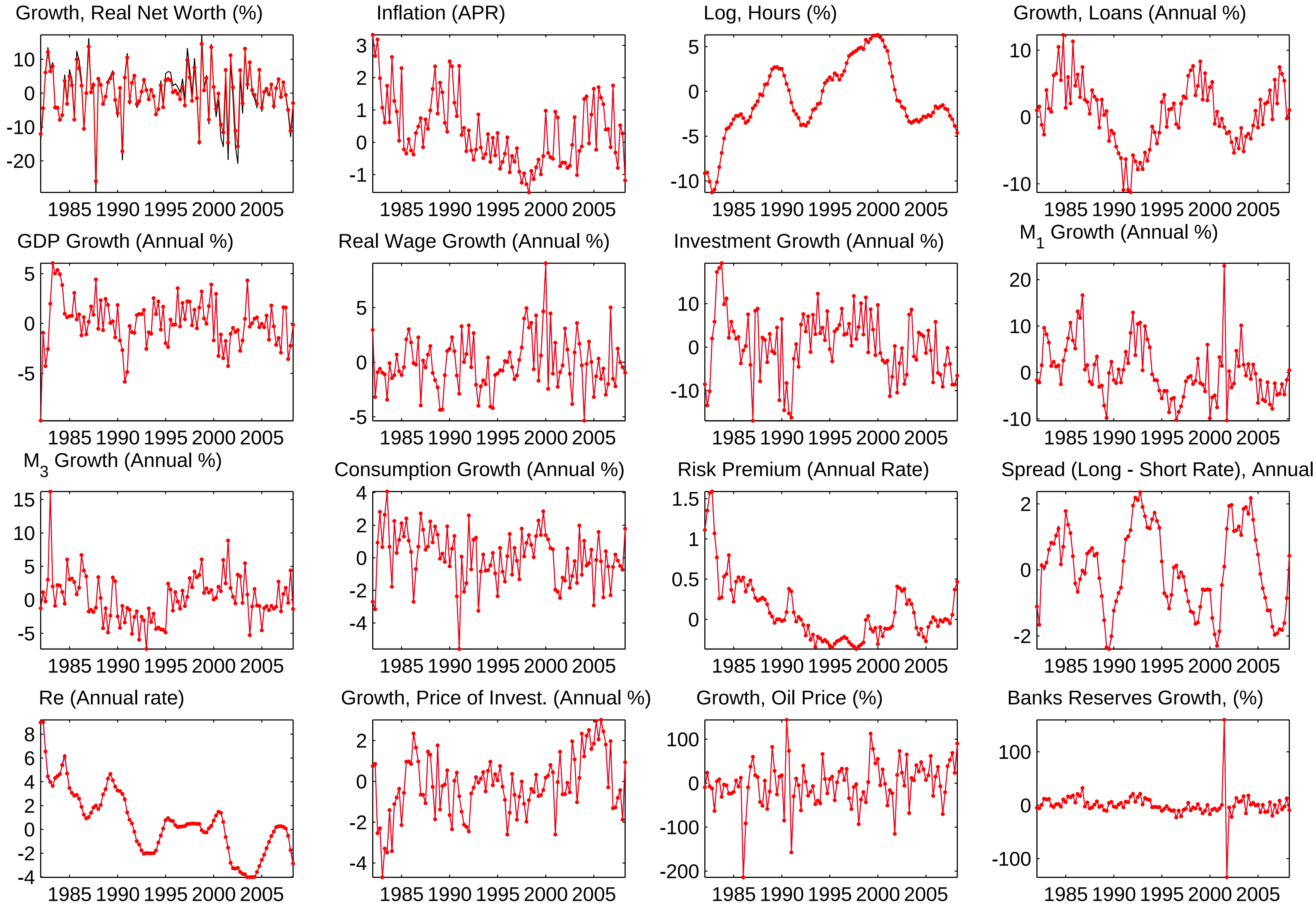


Figure 4a: Priors and Posteriors (US - thick line, EA - thin line). Model Parameters

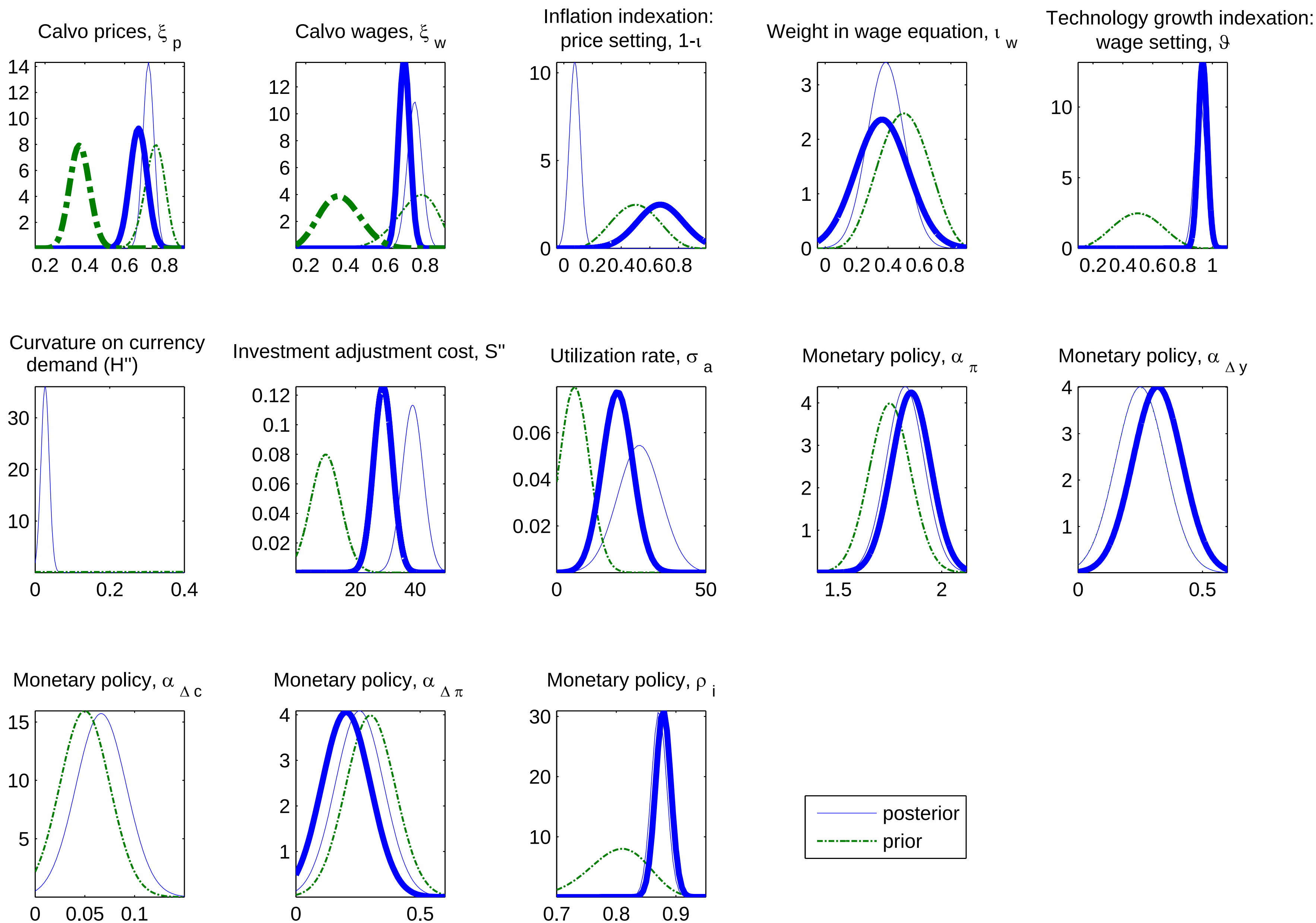
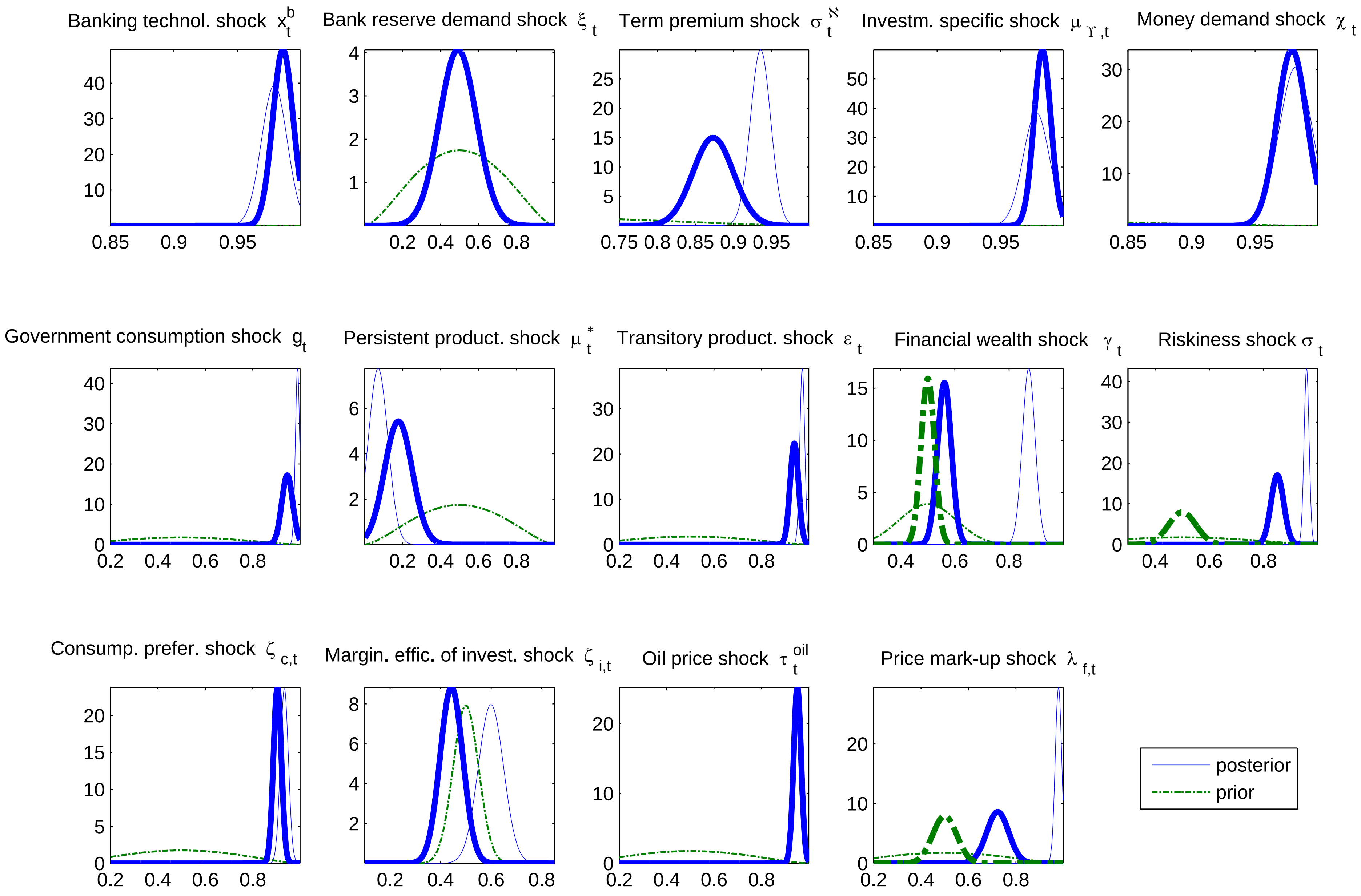


Figure 4b: Priors and Posteriors (US - thick line, EA - thin line). Autoregressive coefficients



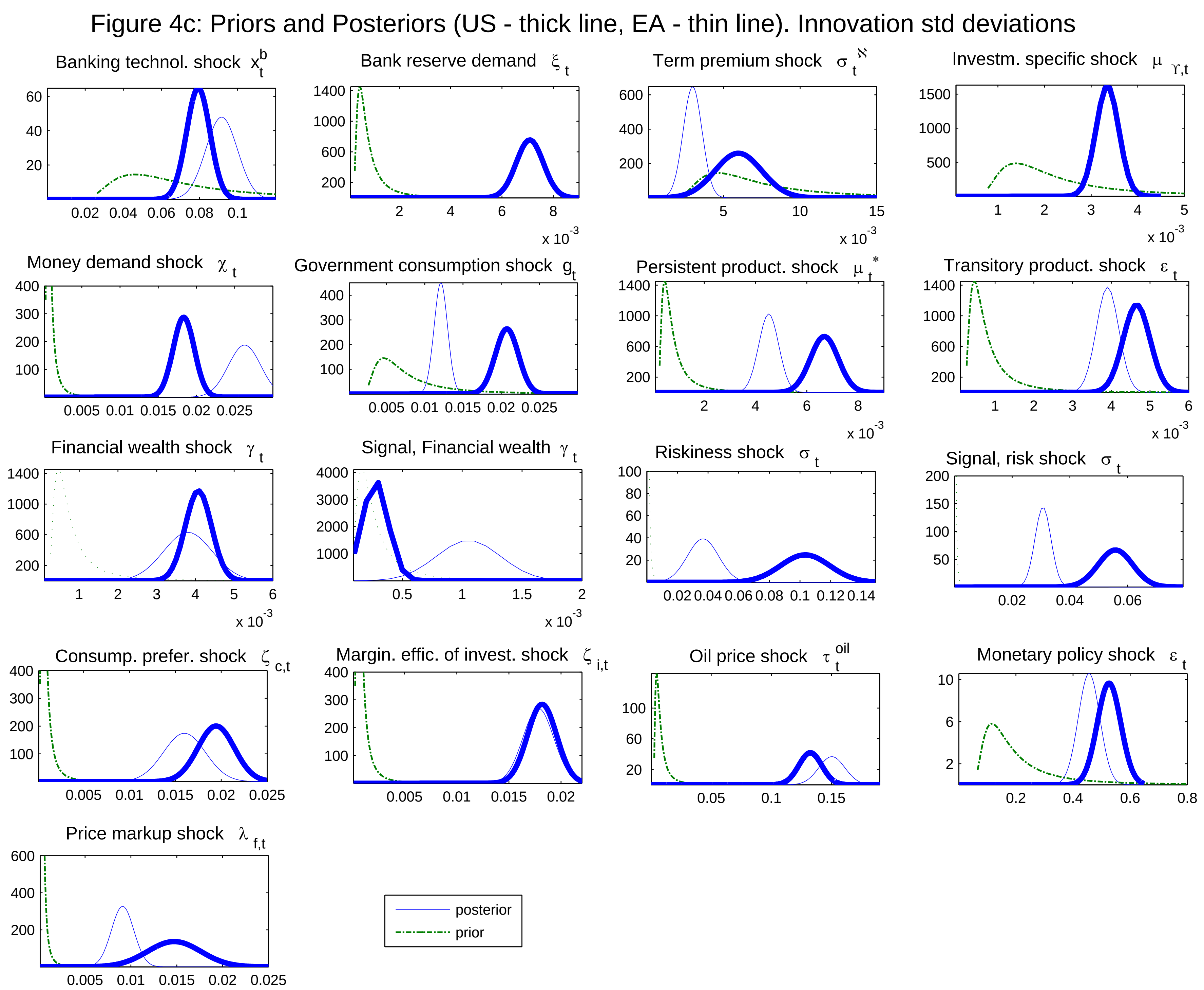


Figure 4c: Priors and Posteriors (US - thick line, EA - thin line). Innovation std deviations
Banking technol. shock
Bank reserve demand
Term premium shock
Investm. specific shock
Money demand shock
Government consumption shock
Persistent product. shock
Transitory product. shock
Financial wealth shock
Signal, Financial wealth
Riskiness shock
Signal, risk shock
Consump. prefer. shock
Margin. effic. of invest. shock
Oil price shock
Monetary policy shock
Price markup shock
posterior
prior

Figure 5a: EA, Estimated Economic Shocks

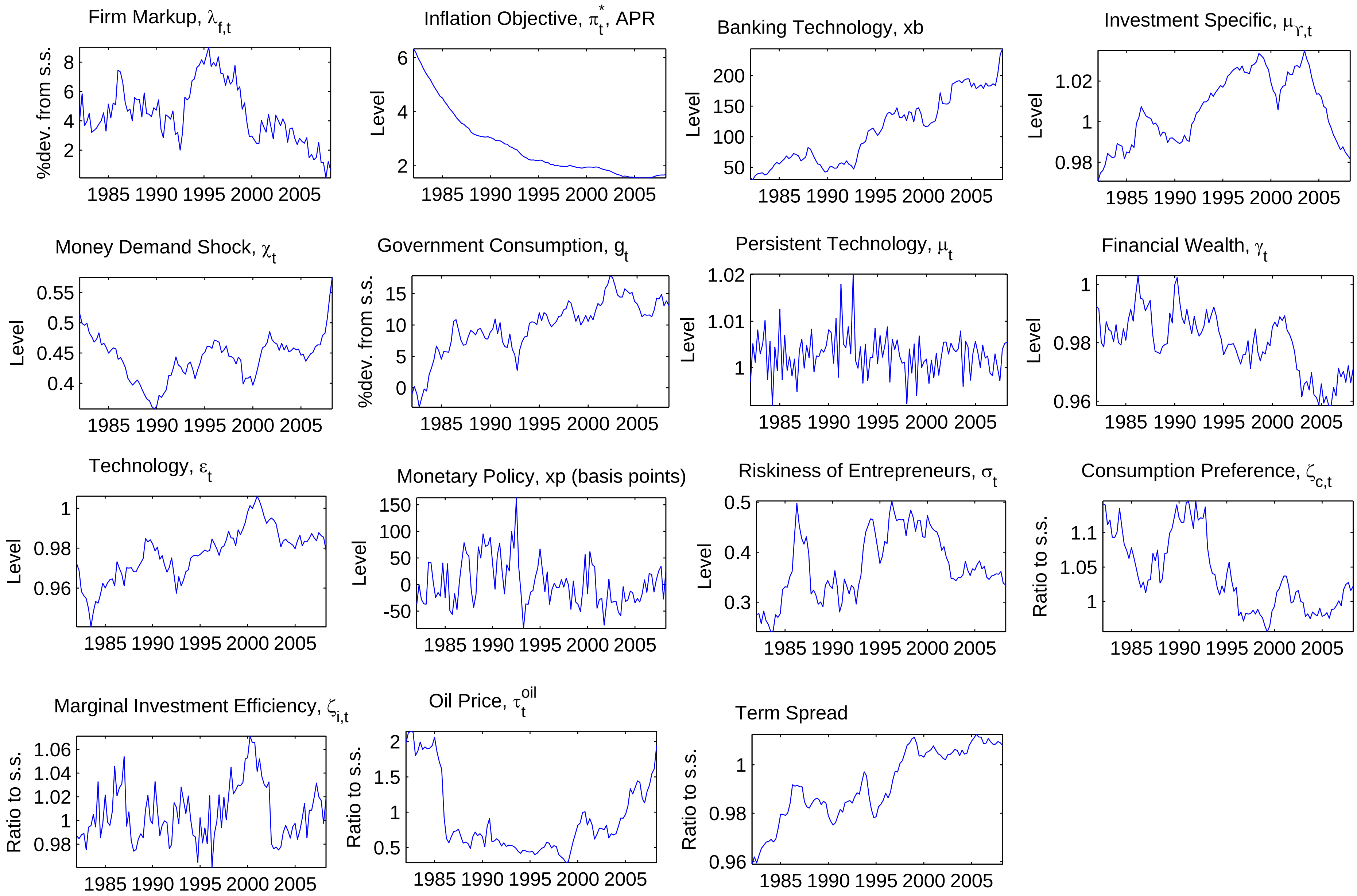


Figure 5b: US, Estimated Economic Shocks

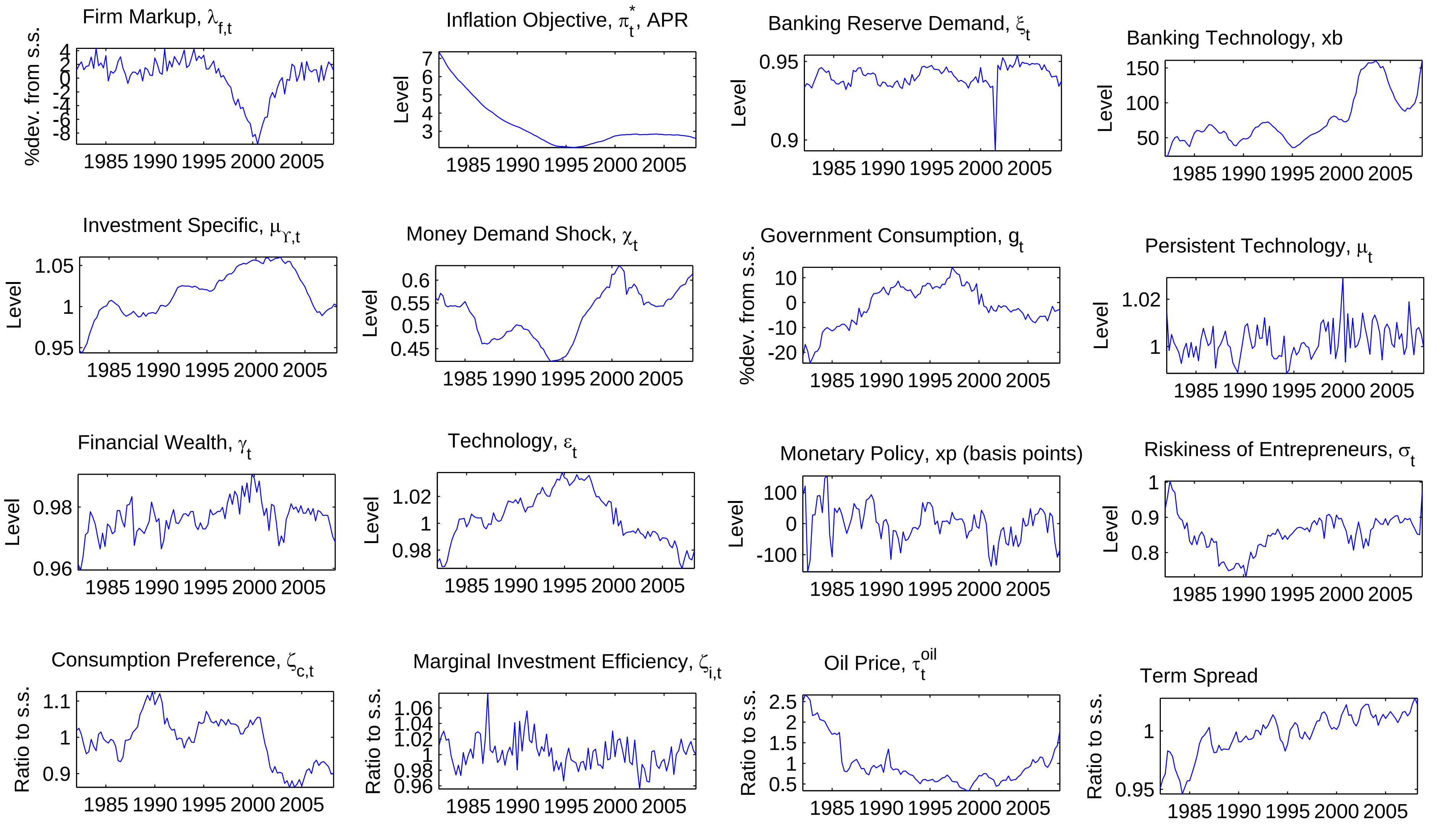


Figure 6a: EA, Autocorrelations: DSGE (Median), DSGE (5-95 percent), and Data (VAR(2))

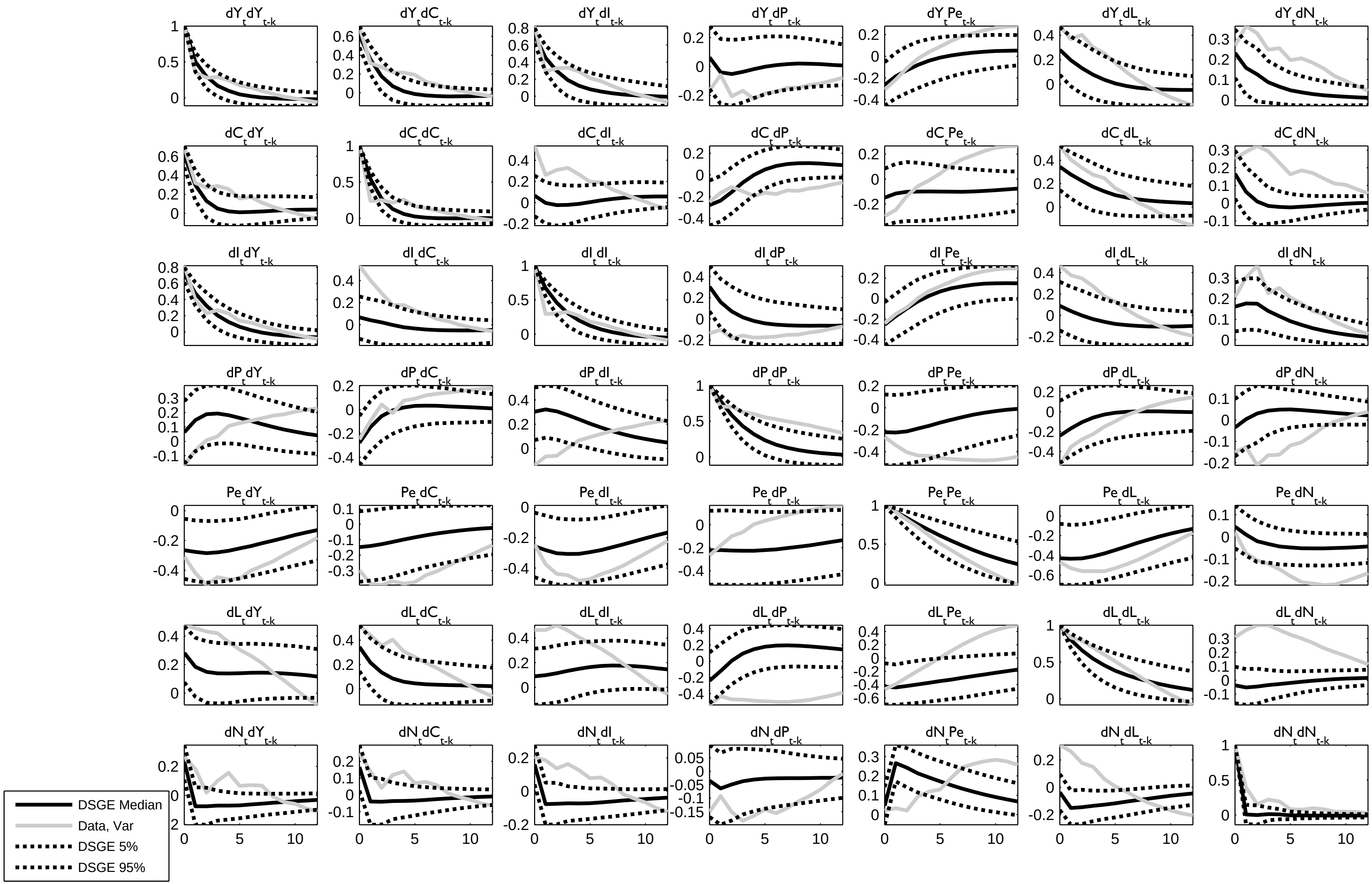


Figure 6b: US, Autocorrelations: DSGE (Median), DSGE (5-95 percent), and Data (VAR(2))

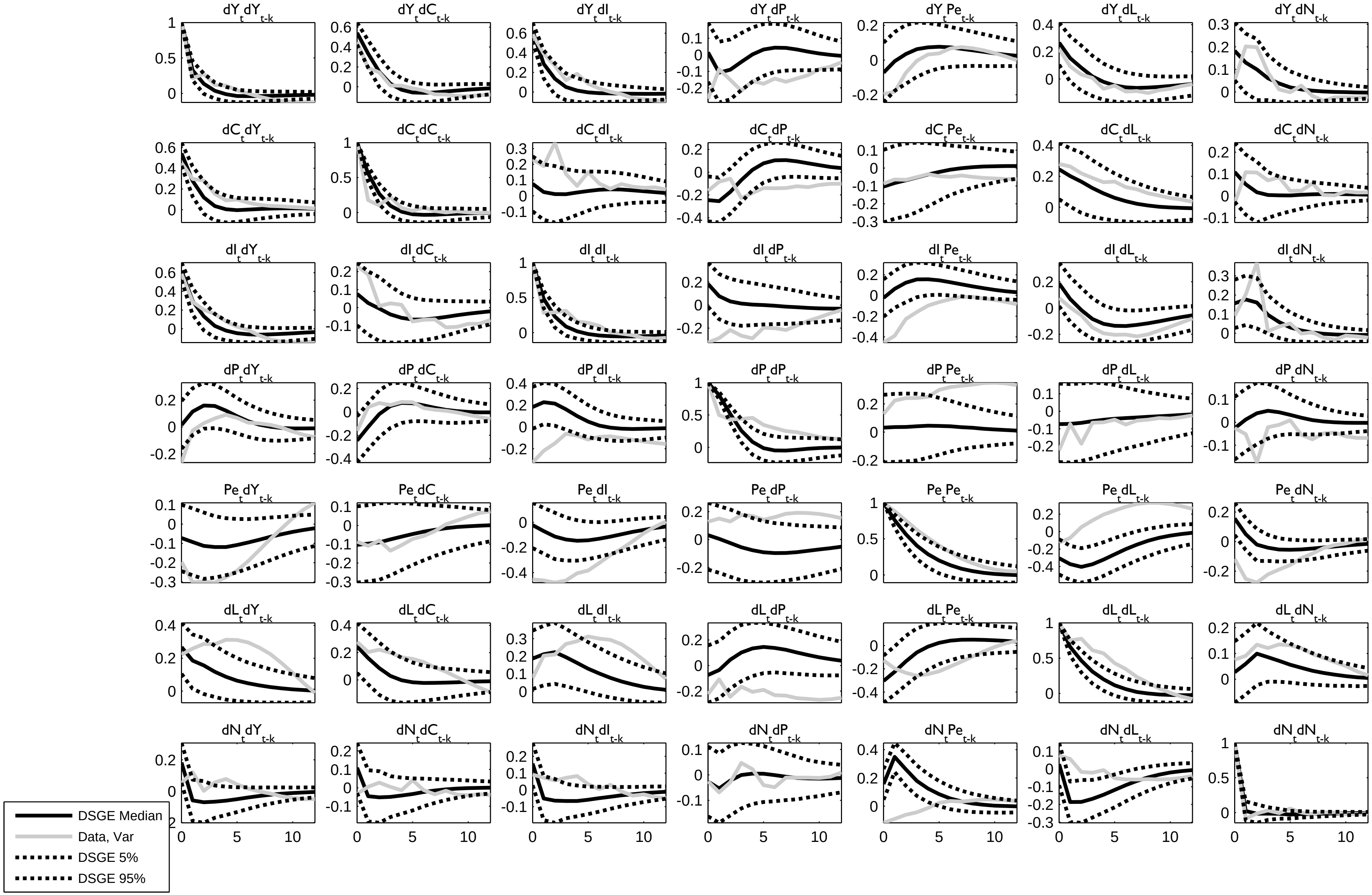


Figure 6c: EA, Autocorrelations: Model (solid line) and Model with Risk Shock Only (dotted line)

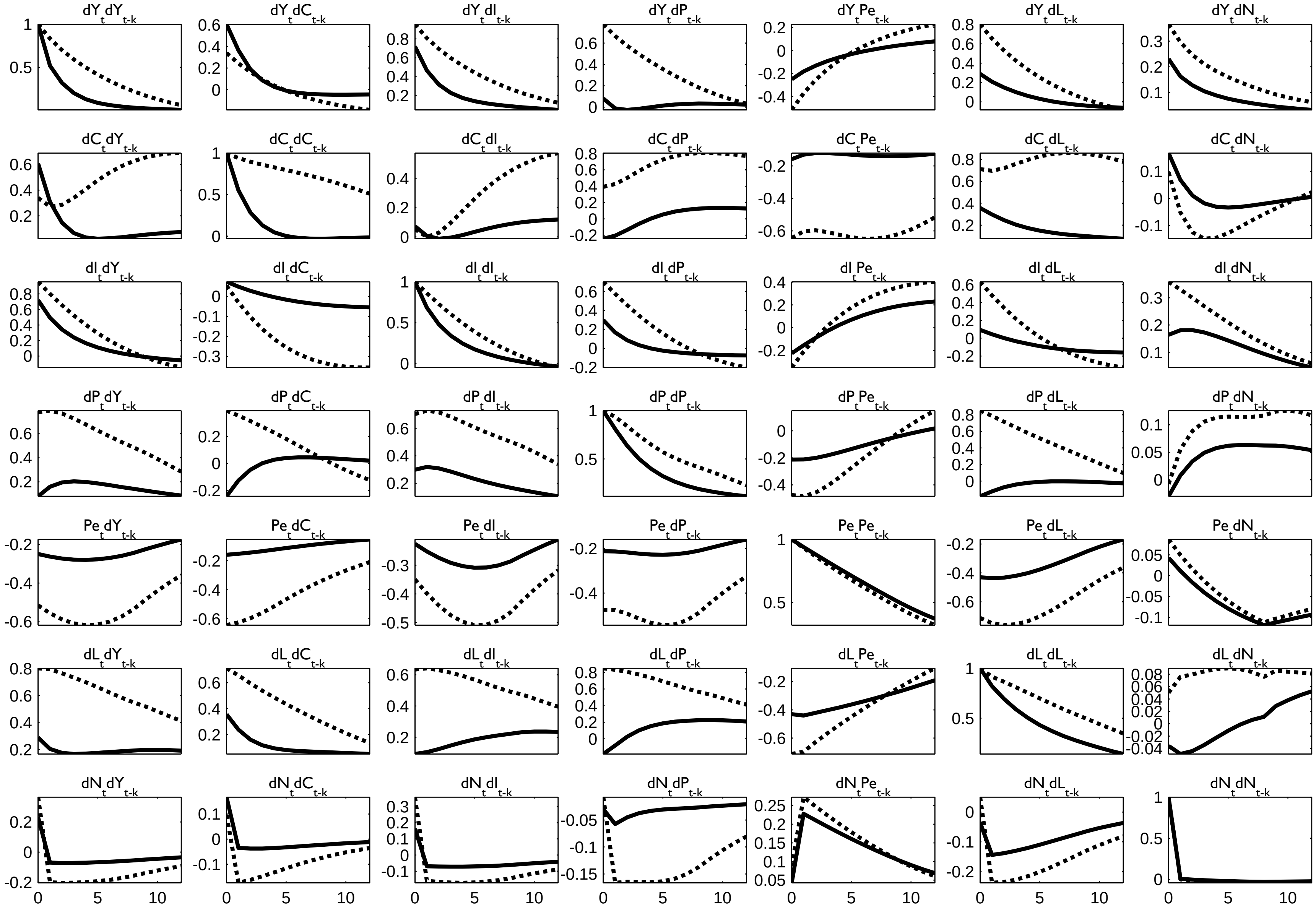


Figure 6d: US, Autocorrelations: Model (solid line) and Model with Risk Shock Only (dotted line)

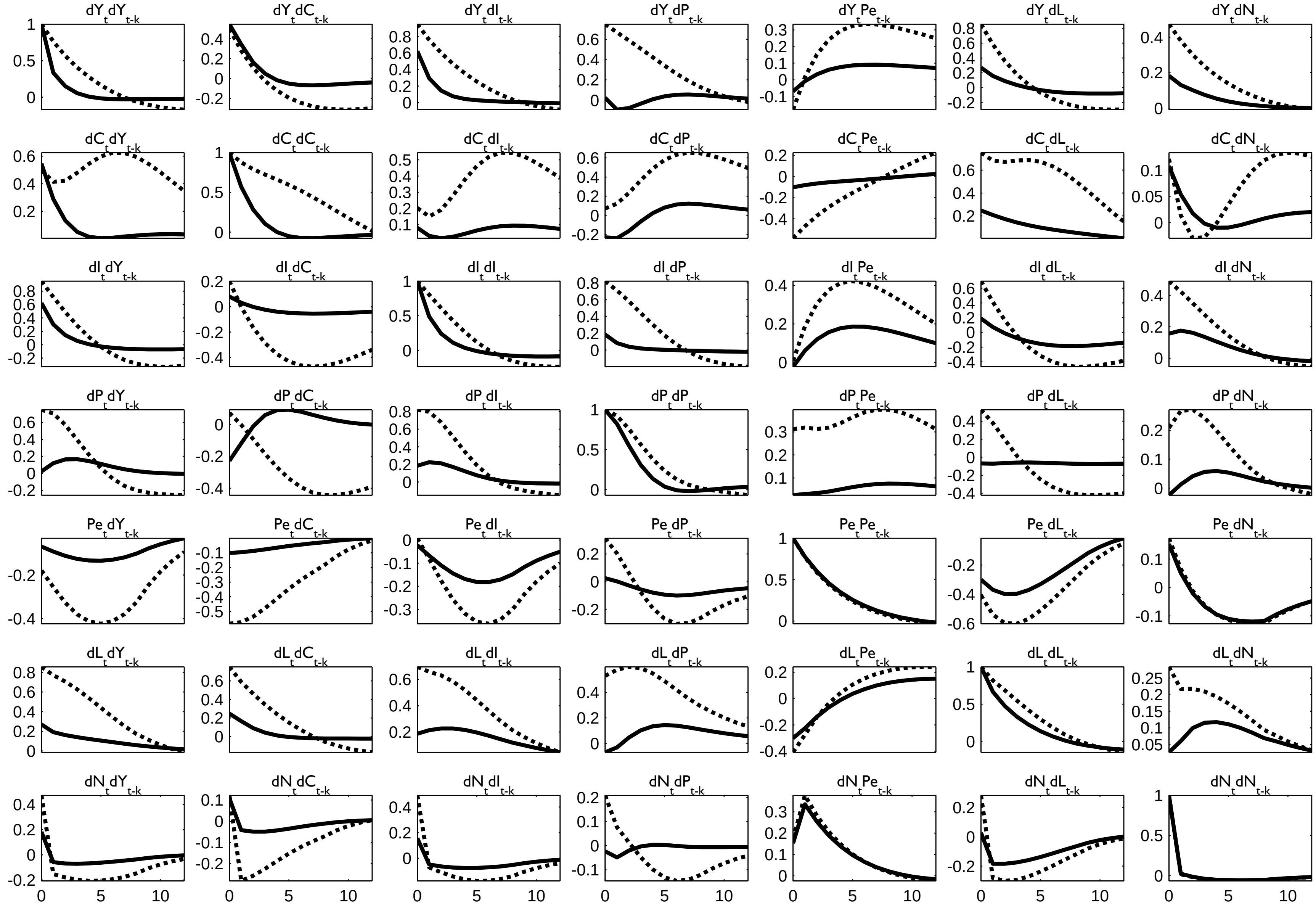


Figure 7a. EA. RMSE: Confidence band represents 2 std and is centred around BVAR (in percent)

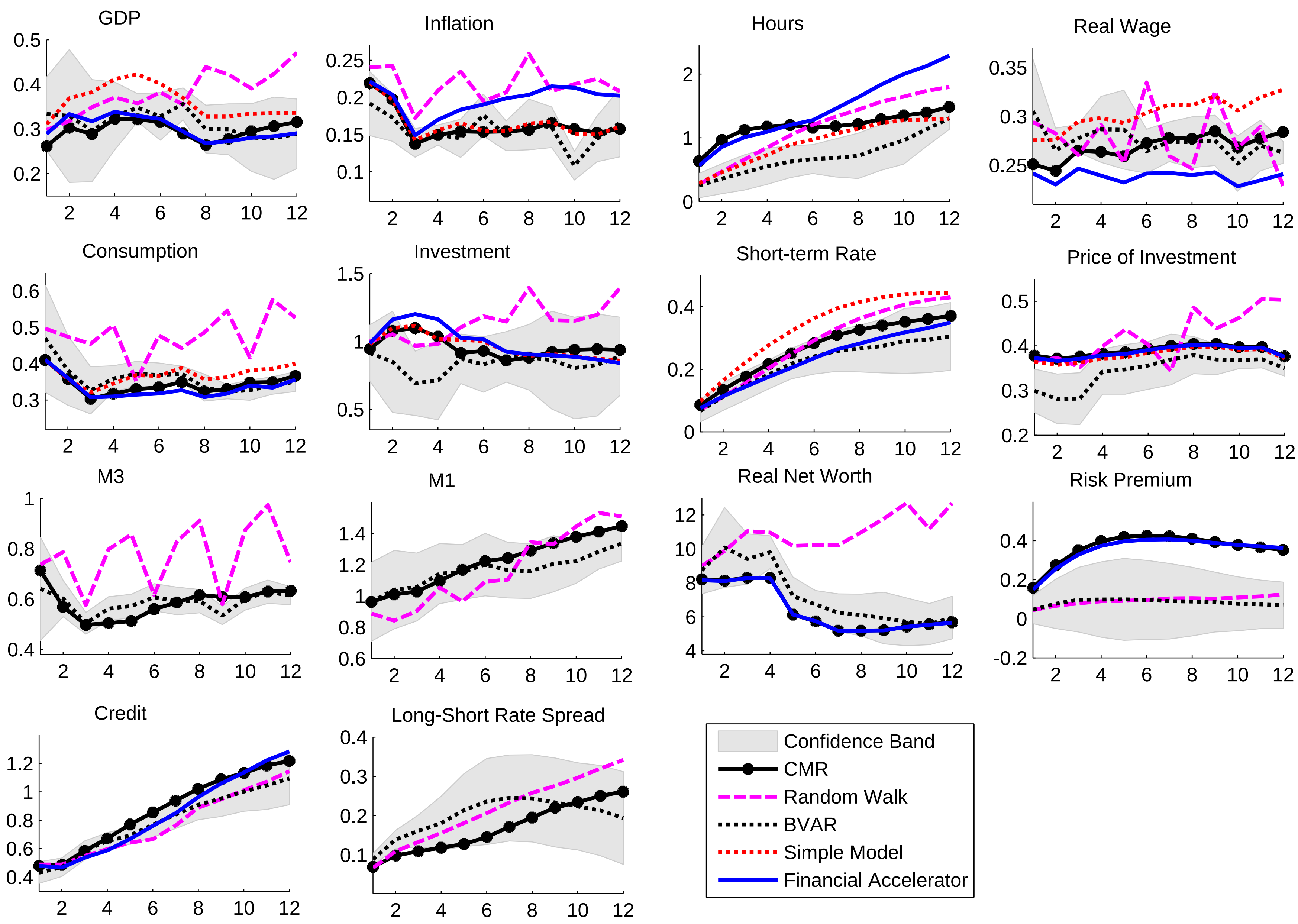


Figure 7b. US. RMSE: Confidence band represents 2 std and is centred around BVAR (in percent)

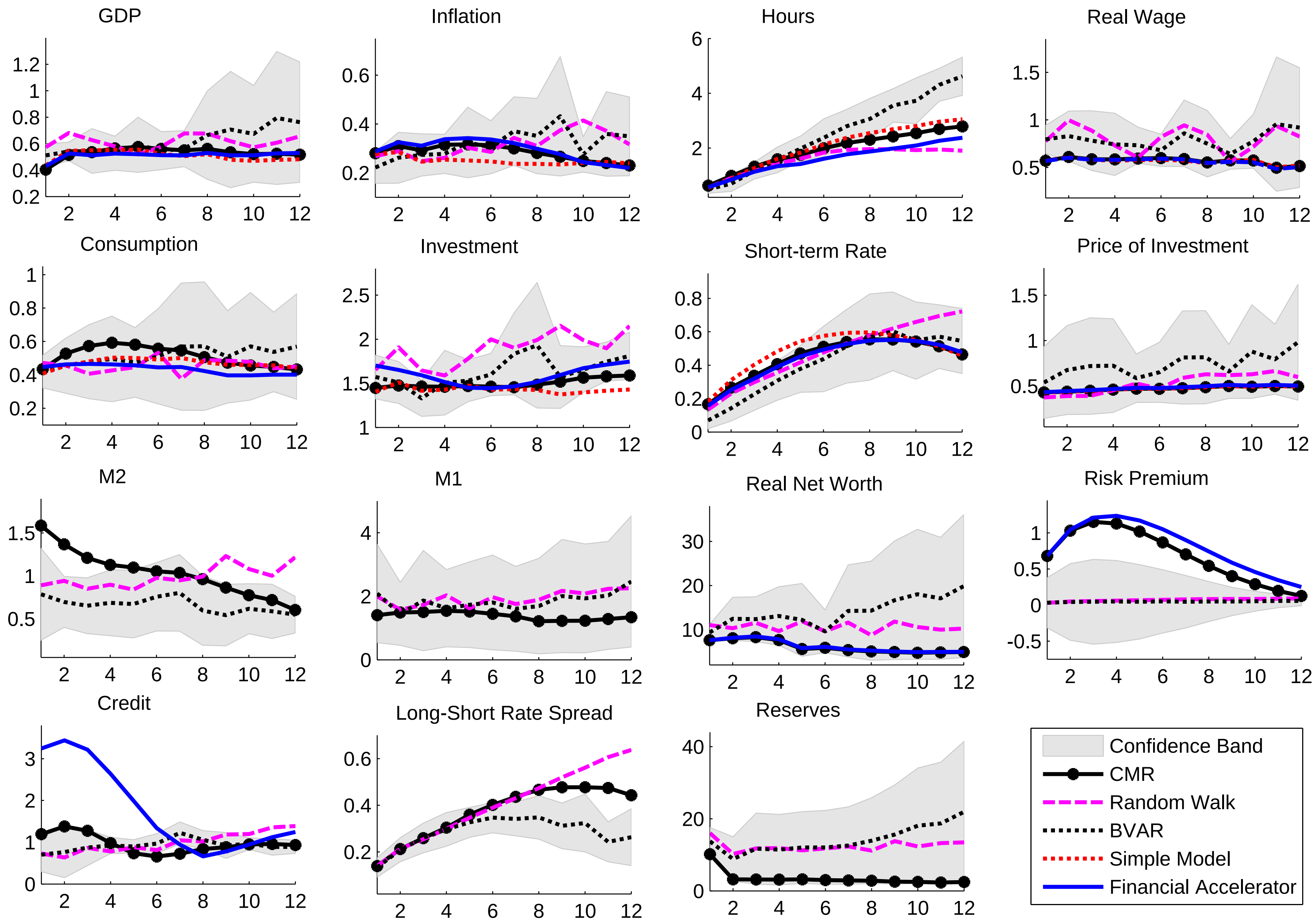
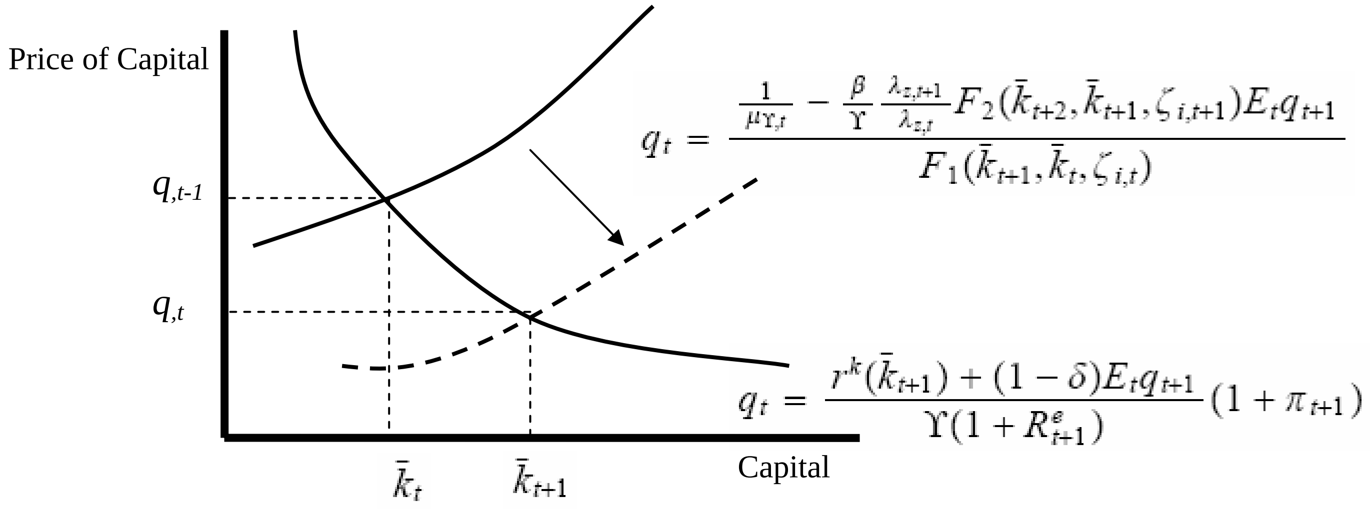


Figure 8. The Demand for and the Supply of Capital

Simple Model



Baseline Model, Financial Accelerator Model and No-Fisher-Effect Model

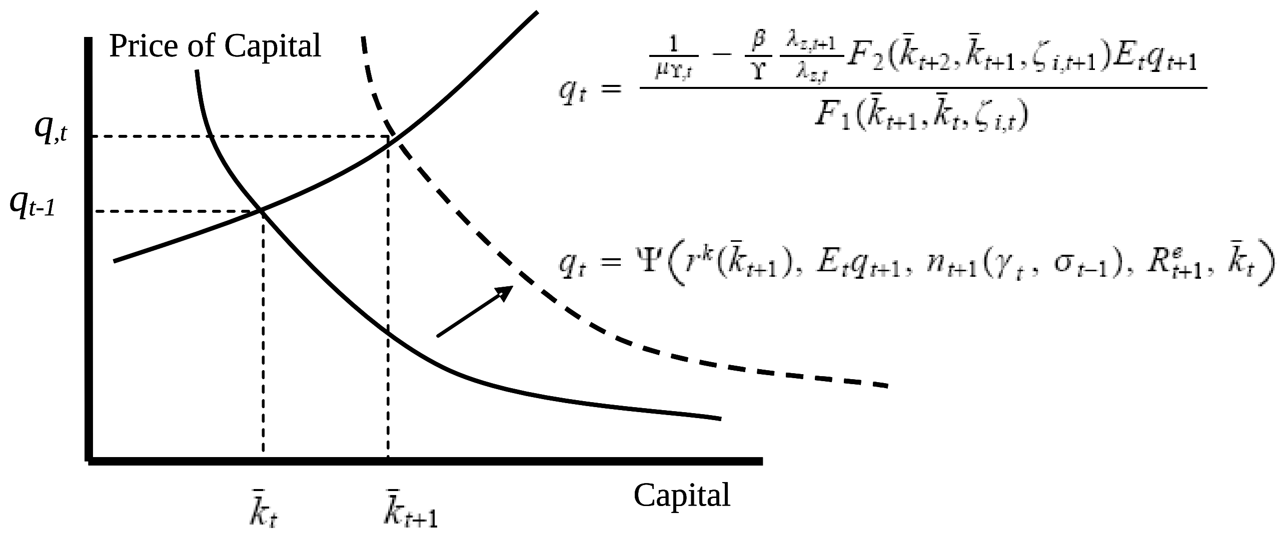


Figure 9a. EA, Marginal Efficiency of Investment Shock, Price of Investment Shock and Riskiness Shock

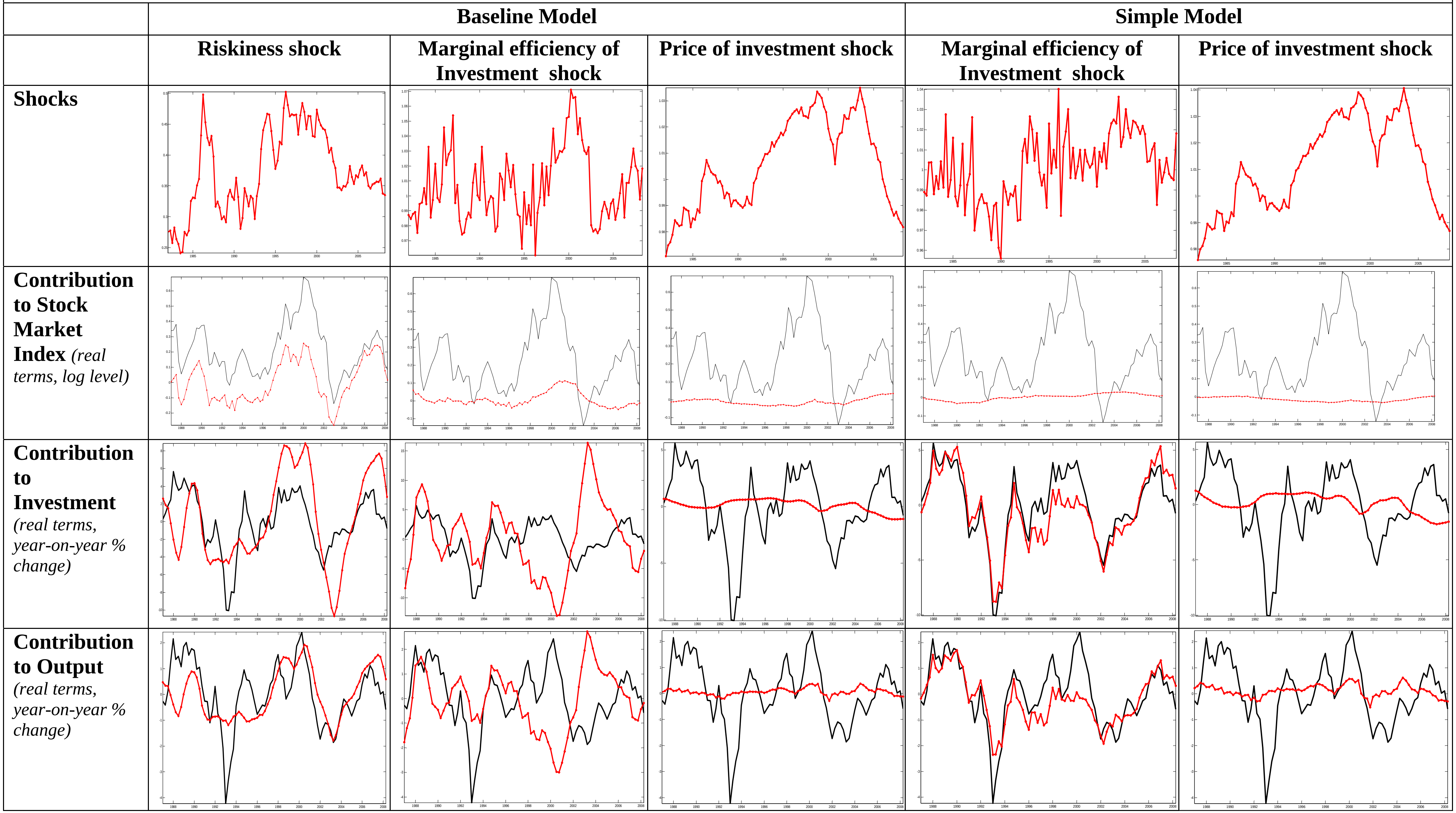
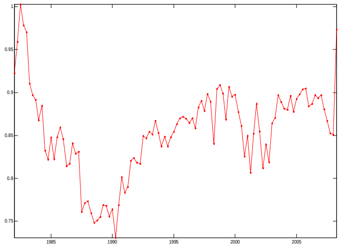
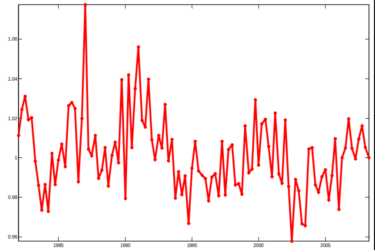
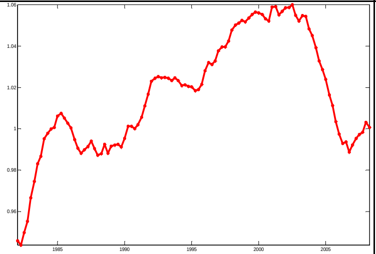
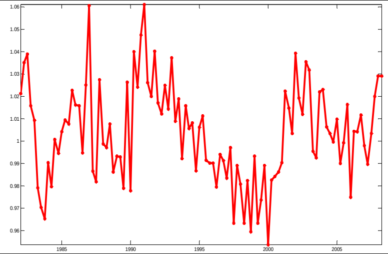
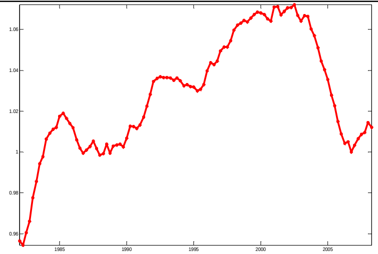
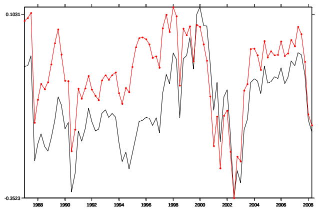
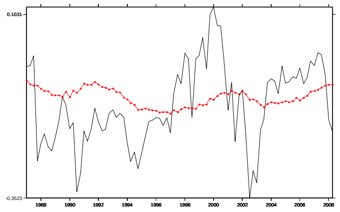
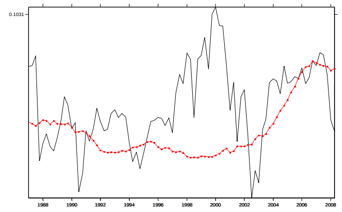
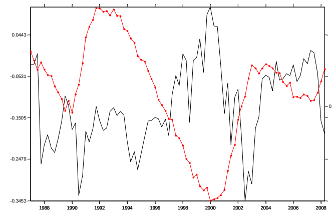
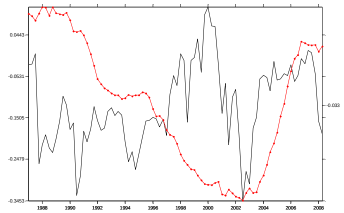
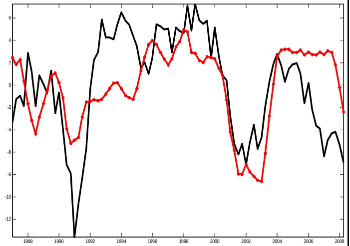
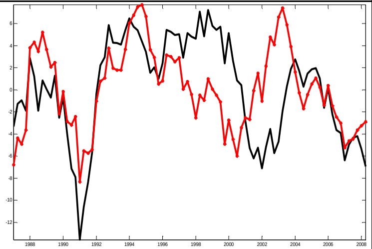
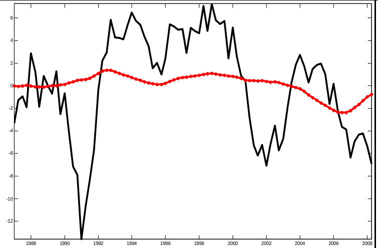
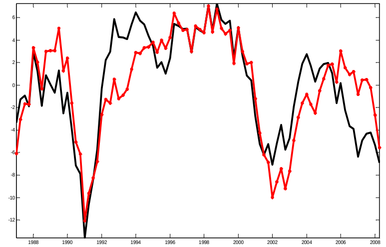
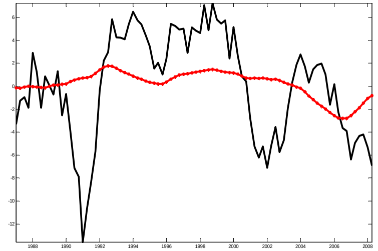
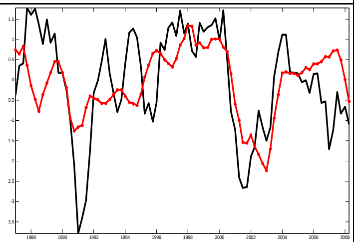
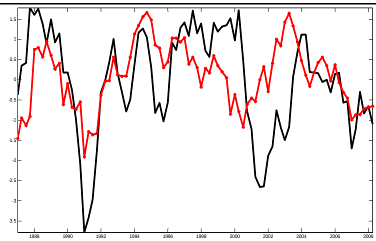
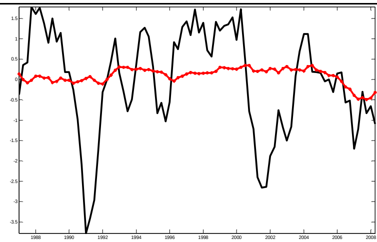
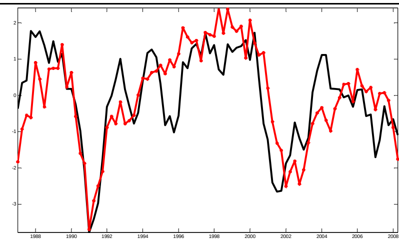
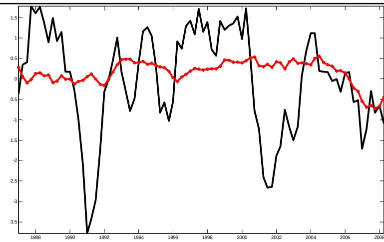


Figure 9b. US, Marginal Efficiency of Investment Shock, Price of Investment Shock and Riskiness Shock					
	Baseline Model			**Simple Model**	
	Riskiness shock	**Marginal efficiency of Investment shock**	**Price of investment shock**	**Marginal efficiency of Investment shock**	**Price of investment shock**
Shocks					
Contribution to Stock Market Index *(real terms, log level)**					
Contribution to Investment *(real terms, year-on-year % change)*					
Contribution to Output *(real terms, year-on-year % change)*					

(*)The contribution to the stock market index is on the right-hand scale, whereas the stock market index itself is on the left-hand scale.

Figure 10a. EA, Importance of the signals on demand for capital shocks for Model Fit

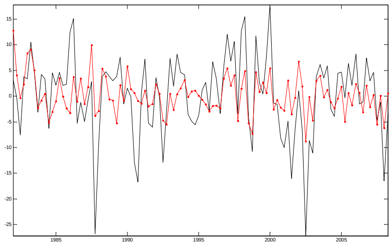
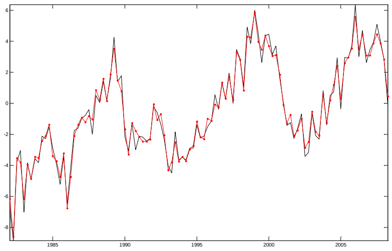
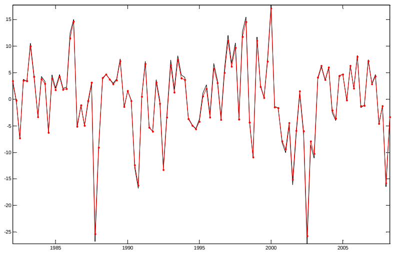
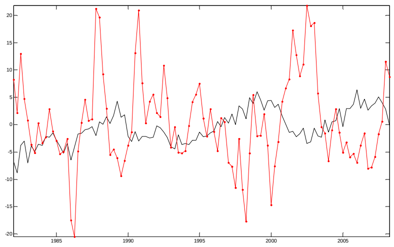
Model Fit	**Stock Market Index** *(real terms, quarter-on-quarter % change)*	**Credit** *(real terms, quarter-on-quarter % change)*
… when estimated without signals on demand for capital shocks and including credit *and* stock market as observable variables		
… when estimated without signals on demand for capital shocks and including only the stock market as observable variable		

Figure 10b. US, Importance of the signals on demand for capital shocks for Model Fit

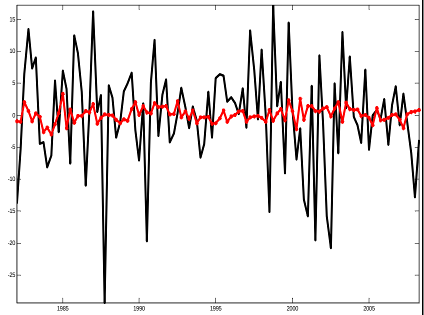
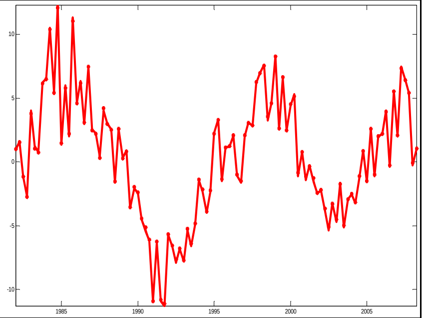
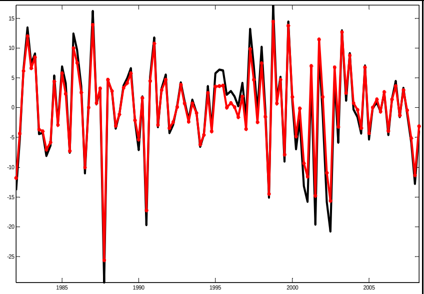
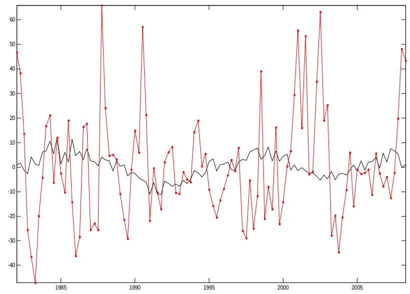
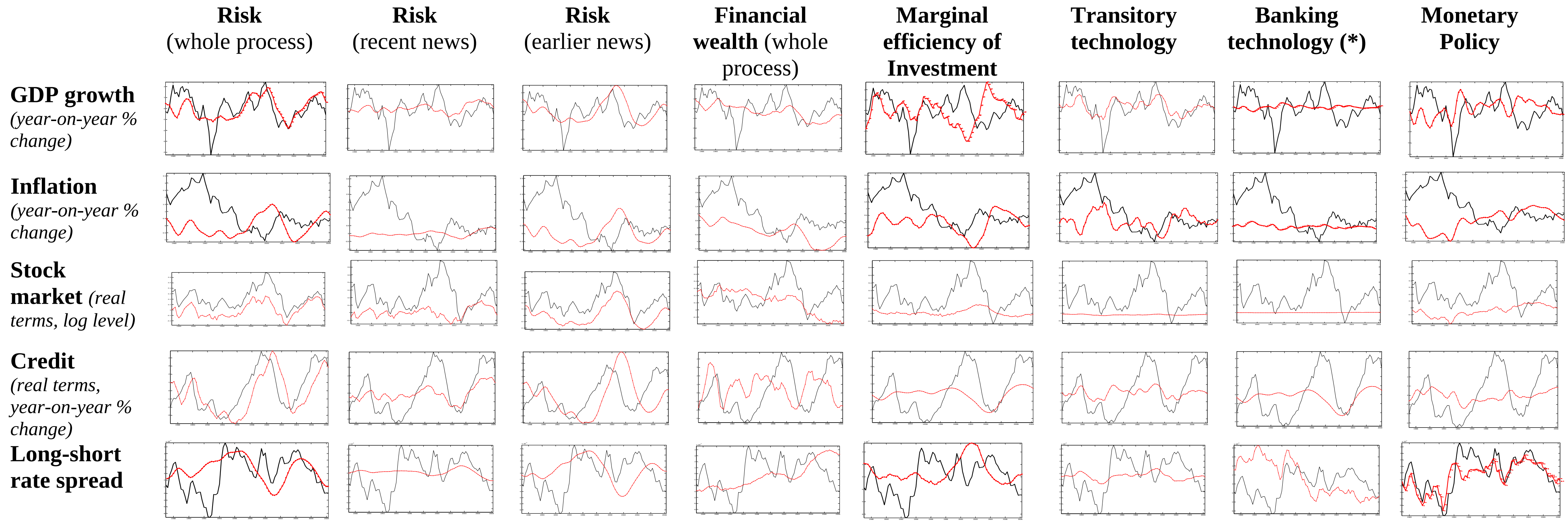
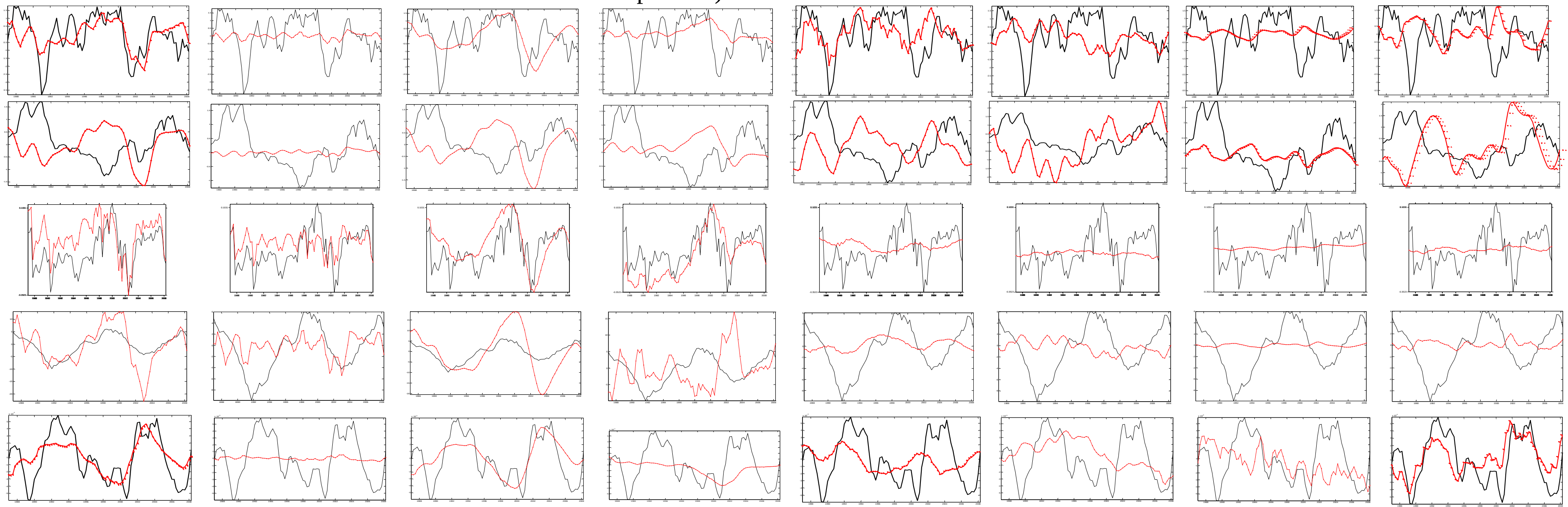
Model Fit	**Stock Market Index** *(real terms, quarter-on-quarter % change)*	**Credit** *(real terms, quarter-on-quarter % change)*
… when estimated without signals on demand for capital shocks and including credit *and* stock market as observable variables		
… when estimated without signals on demand for capital shocks and including only the stock market as observable variable		

Figure 11a. EA, Contributions of Individual Shocks



(*) For the Long-term premium, this refers to the term premium shock

Figure 11b. US, Contributions of Individual Shocks



(*) For the Long-term premium, this refers to the term premium shock. (**) The contribution to the stock market is on the right-hand scale, whereas the stock market index itself is on the left-hand scale.

Figure 12a: EA, Impulse Response to a Riskiness Shock

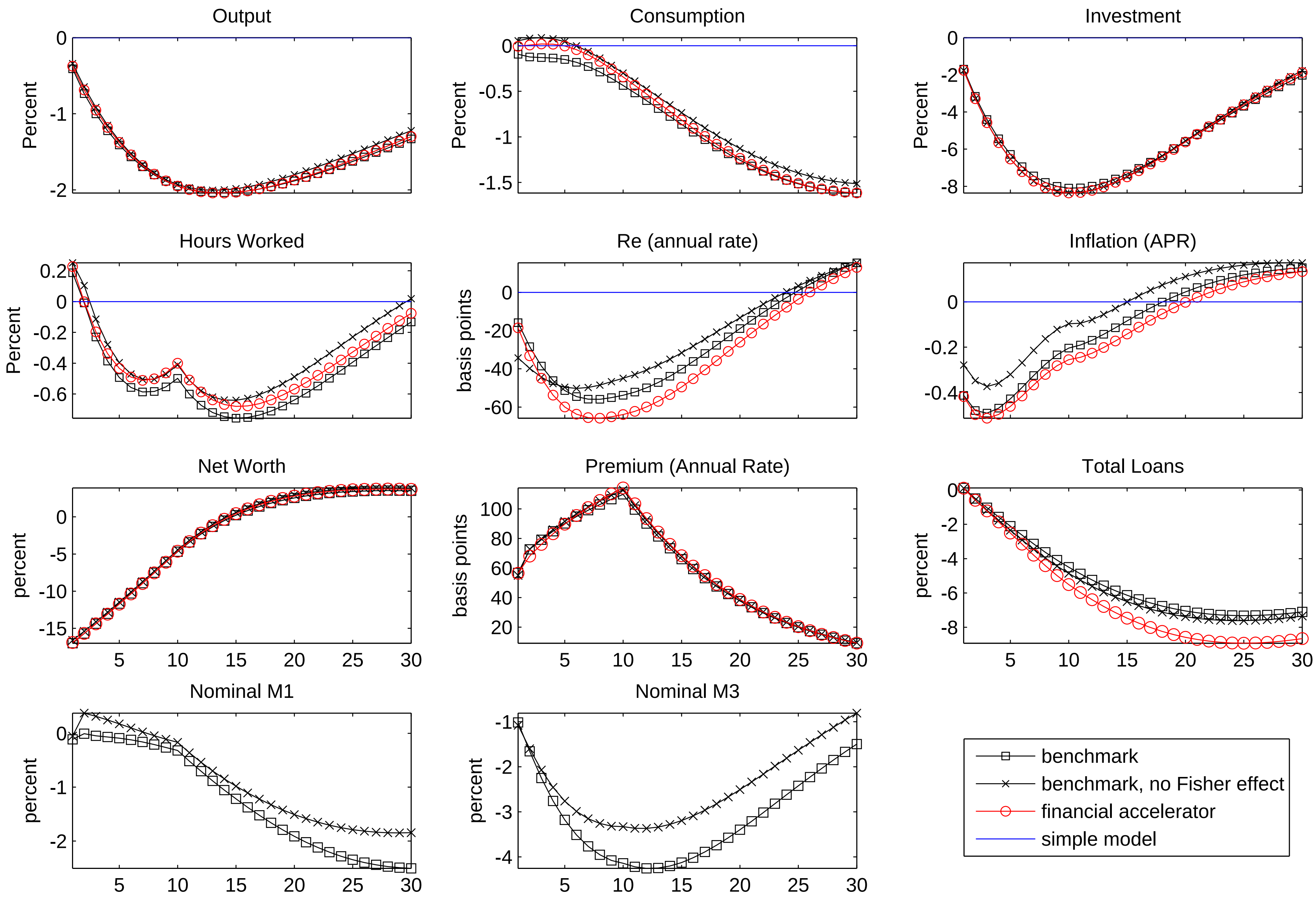


Figure 12b: US, Impulse Response to a Riskiness Shock

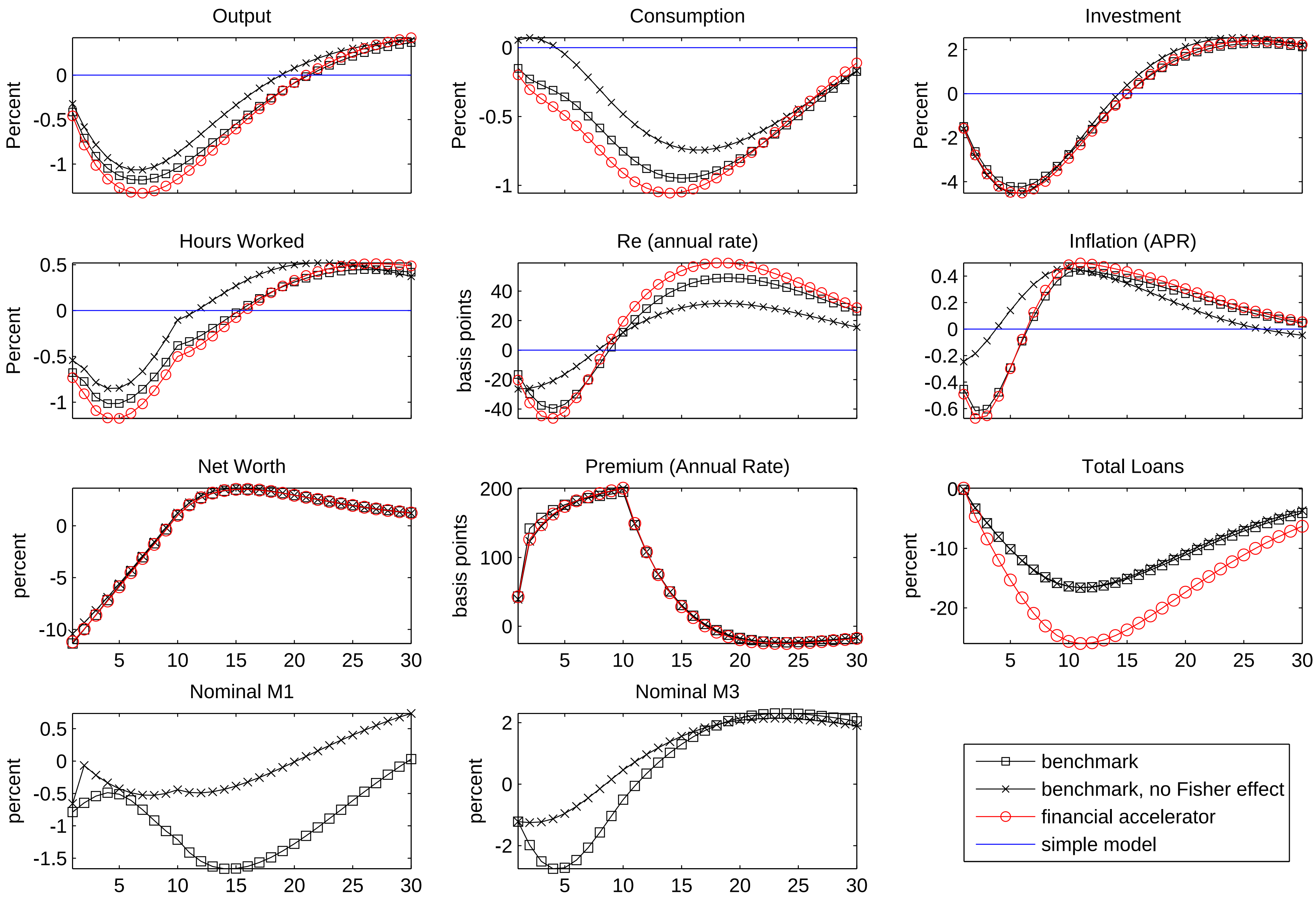


Figure 13a: EA, Impulse Response to a Monetary Policy Shock

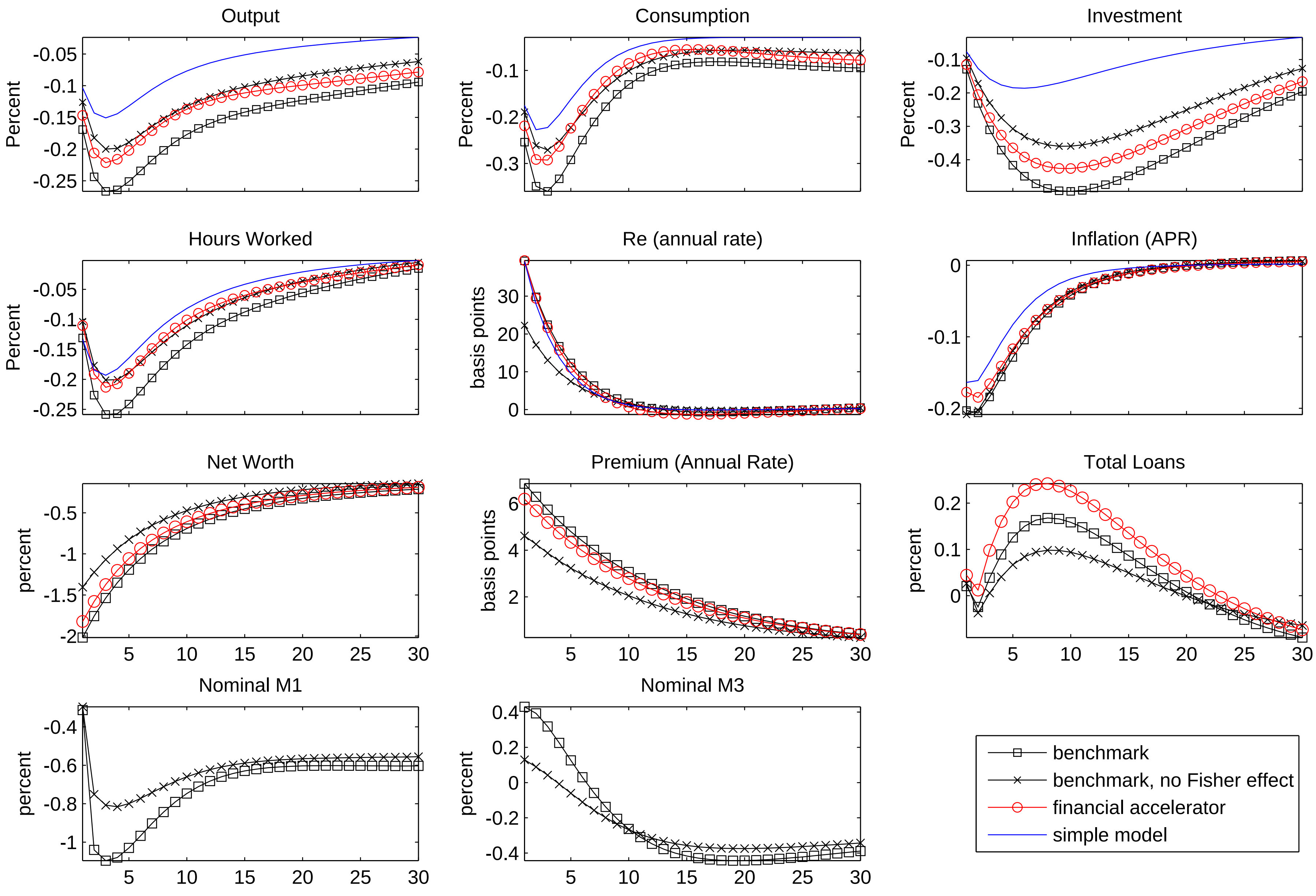


Figure 13b: US, Impulse Response to a Monetary Policy Shock

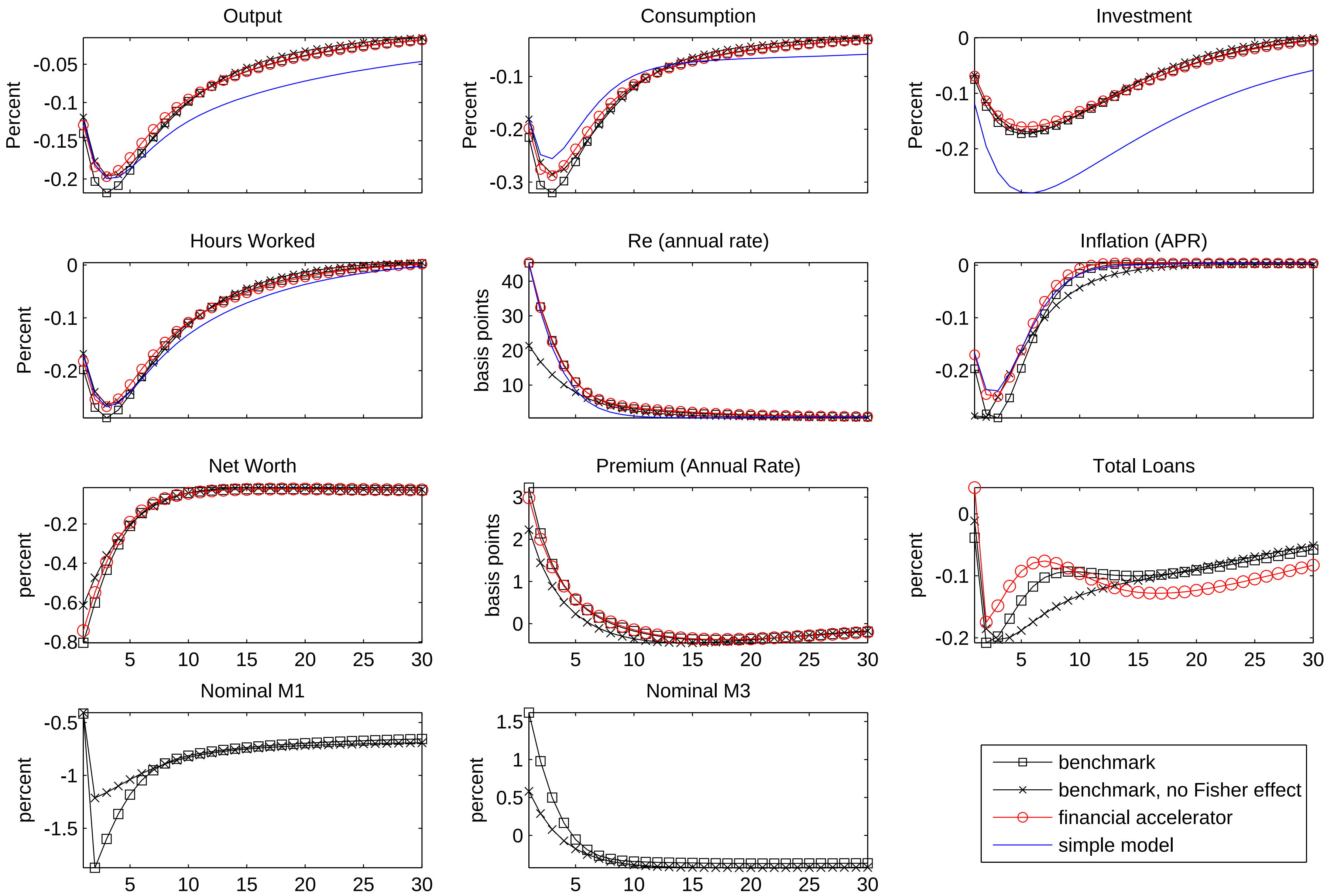


Figure 14a: EA, Impulse Response to a Transitory Technology Shock

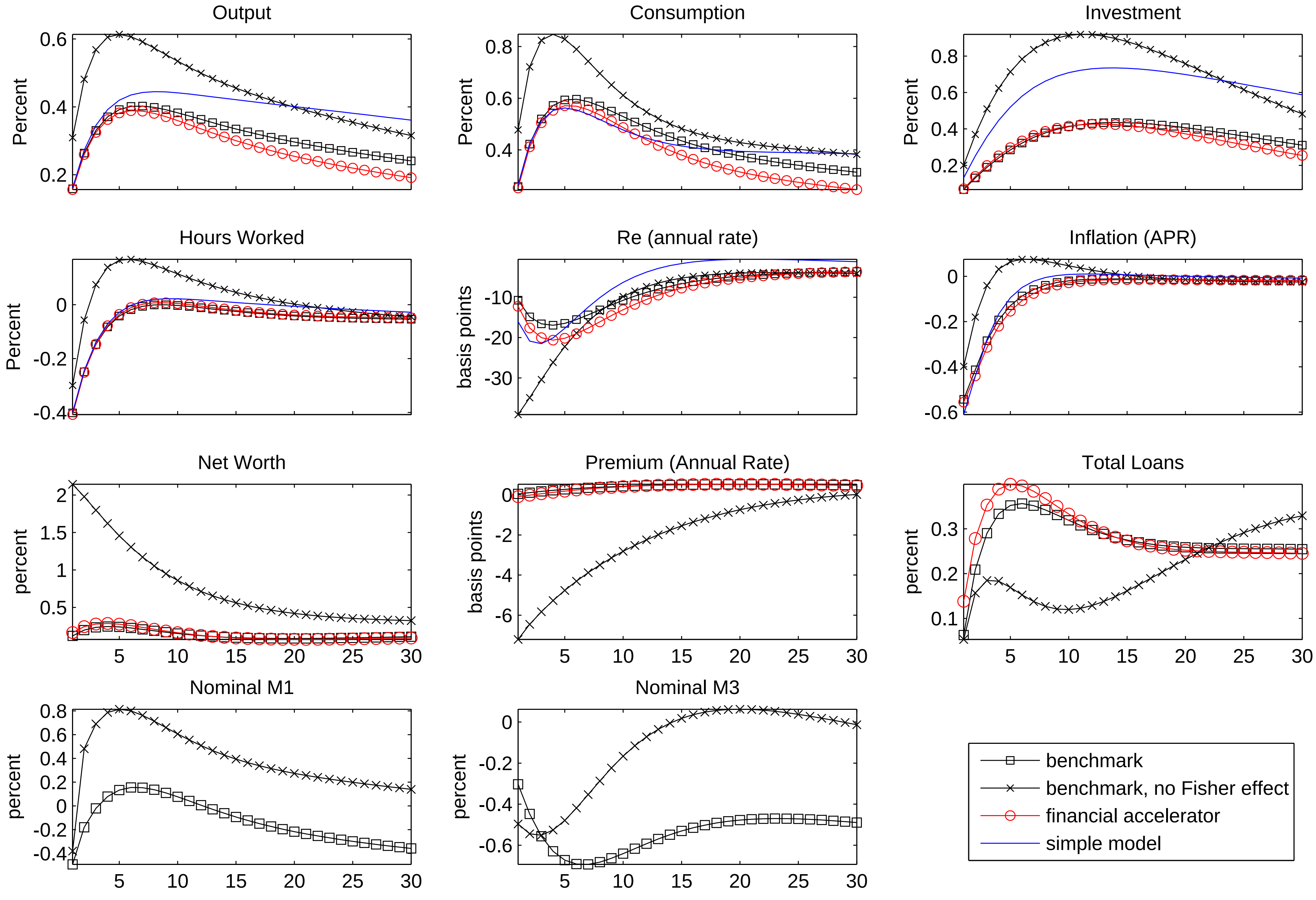


Figure 14b: US, Impulse Response to a Transitory Technology Shock

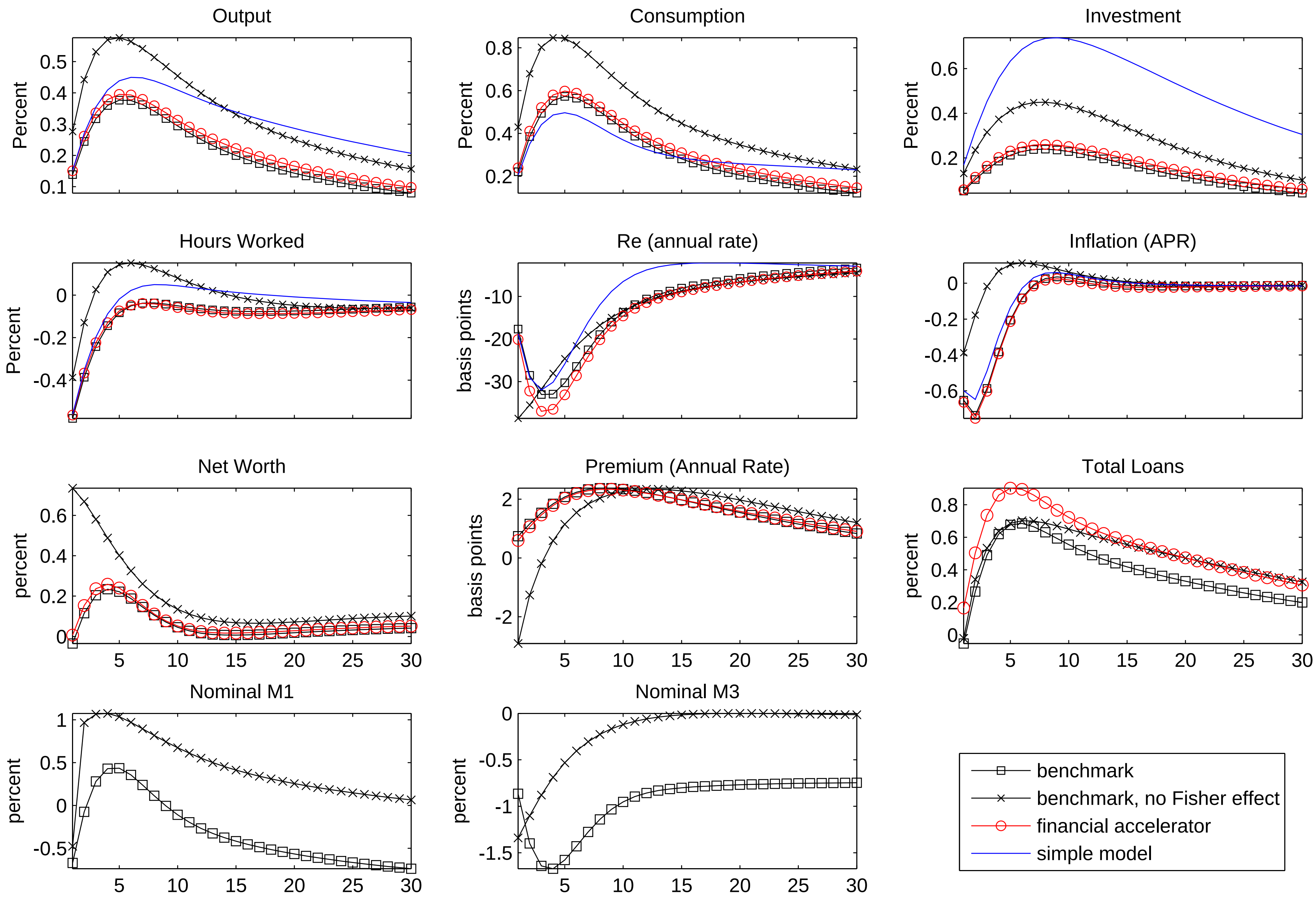


Figure 15a, US, Comparing Model-Predictions with Bankruptcy Data

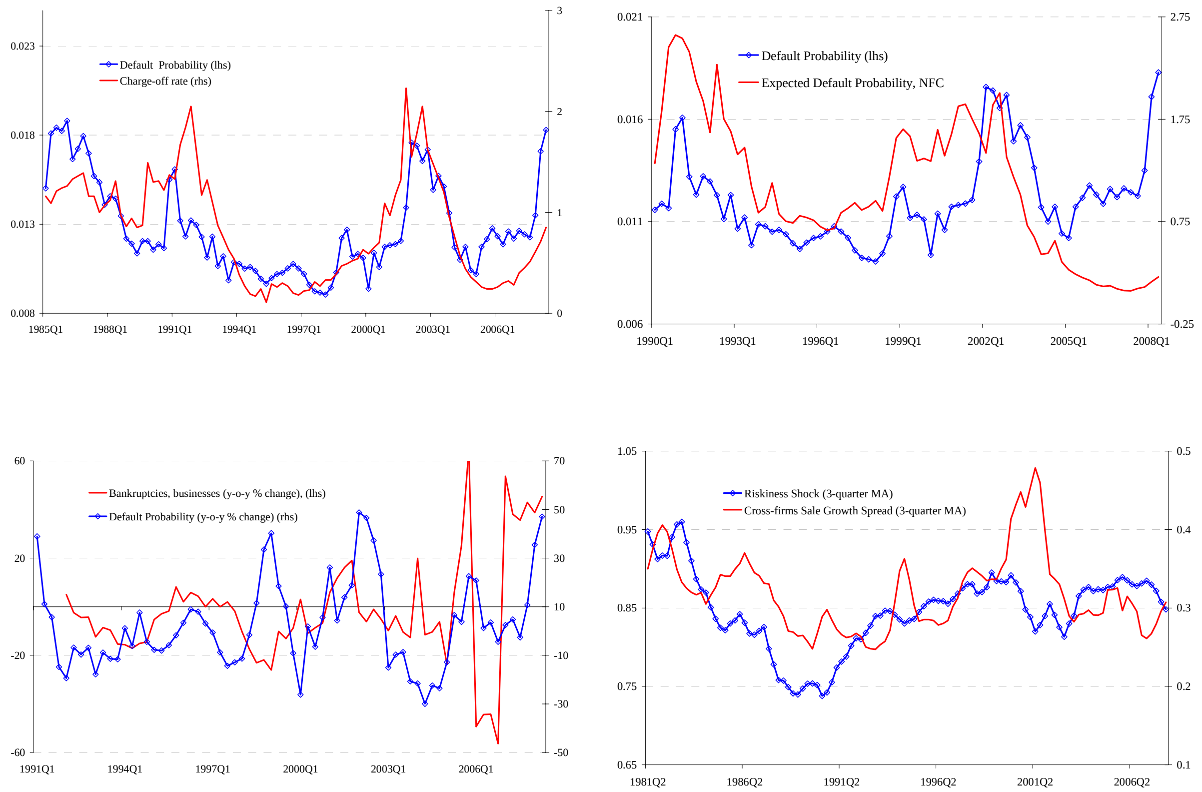
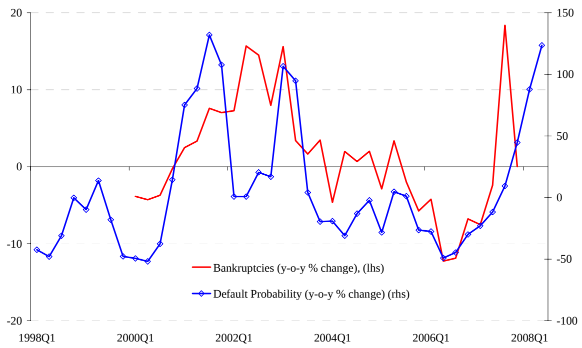


Figure 15b, EA, Comparing Model-Predictions with Bankruptcy Data



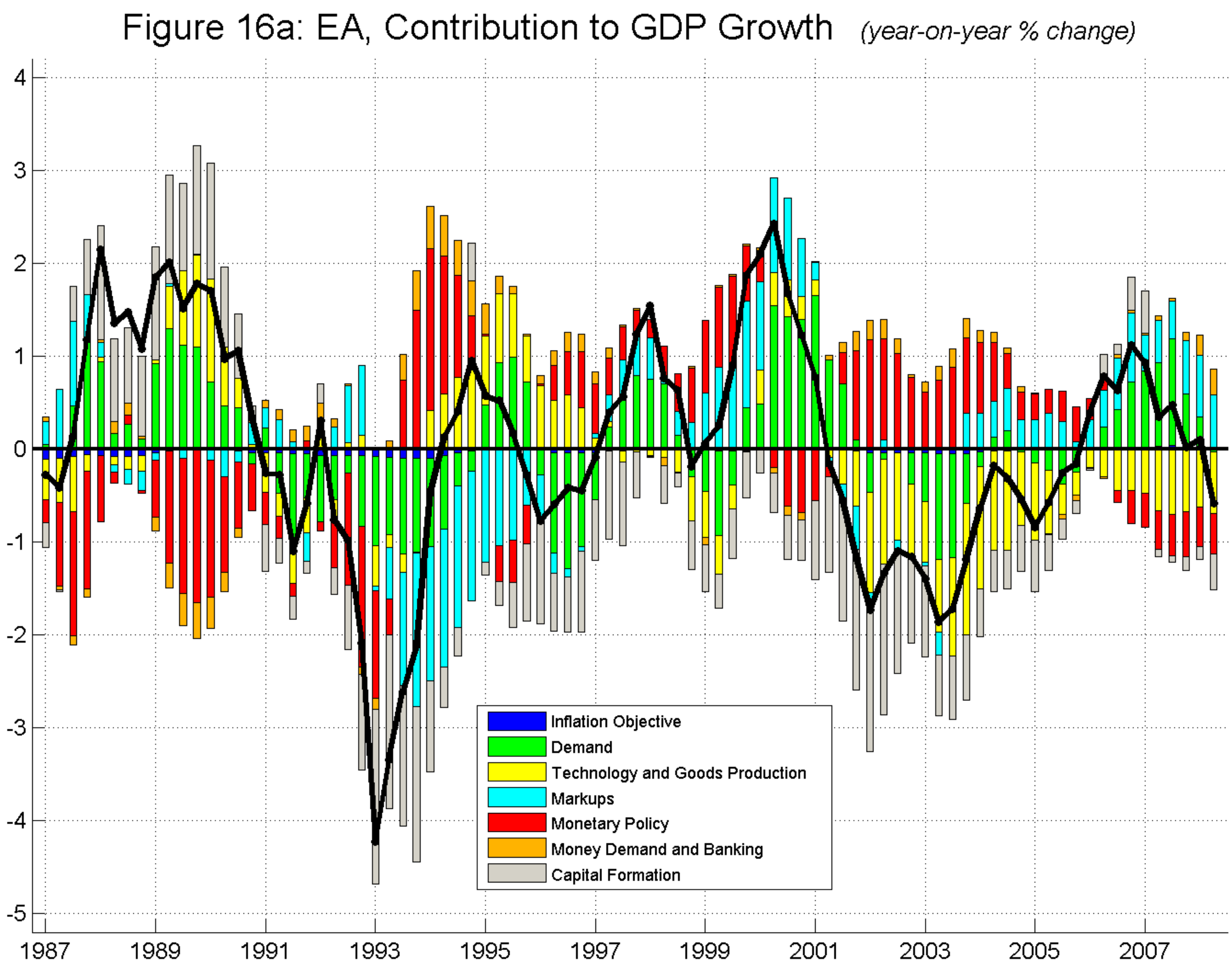


Figure 16a: EA, Contribution to GDP Growth (year-on-year % change)
4
3
2
1
0
-1
-2
-3
-4
-5
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
Inflation Objective
Demand
Technology and Goods Production
Markups
Monetary Policy
Money Demand and Banking
Capital Formation

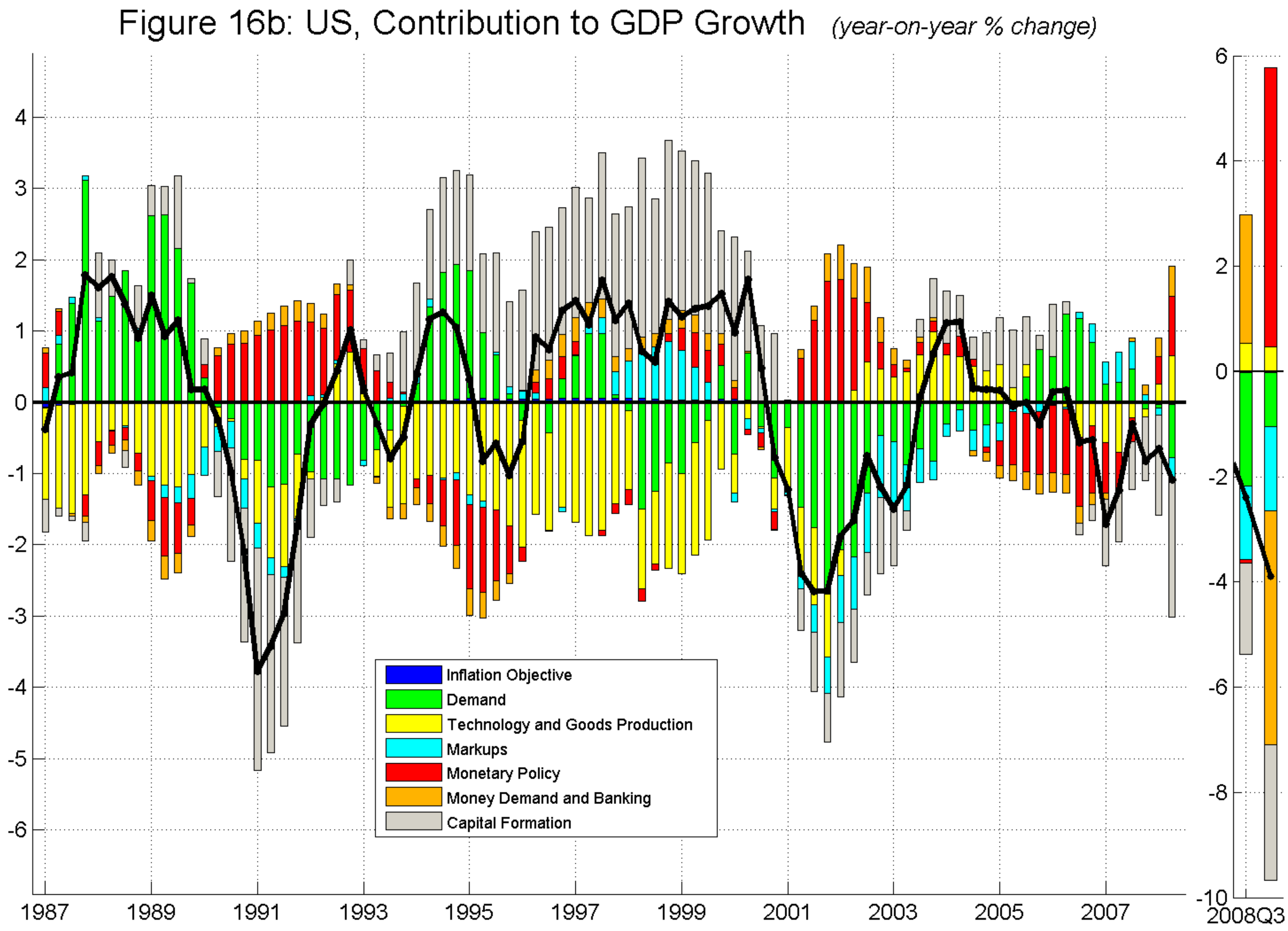


Figure 16b: US, Contribution to GDP Growth (year-on-year % change)
Inflation Objective
Demand
Technology and Goods Production
Markups
Monetary Policy
Money Demand and Banking
Capital Formation
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2008Q3

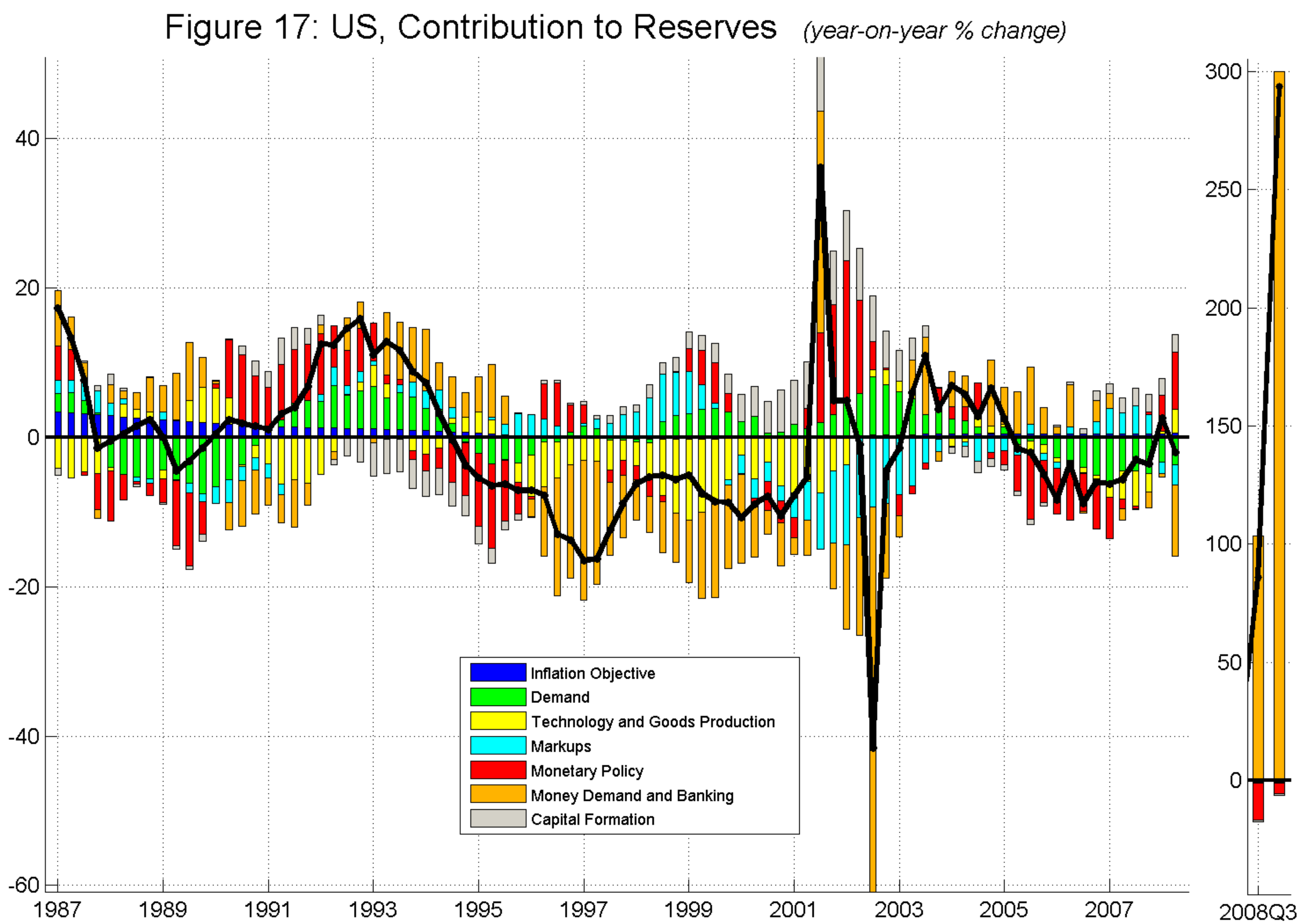


Figure 17: US, Contribution to Reserves (year-on-year % change)
40
20
0
-20
-40
-60
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
300
250
200
150
100
50
0
2008Q3
Inflation Objective
Demand
Technology and Goods Production
Markups
Monetary Policy
Money Demand and Banking
Capital Formation