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

In recent years there has been considerable progress in developing a quantitative, empirically-based framework that can mimic the dynamics of real and nominal variables over the business cycle. This research pays relatively less attention to understanding the dynamics of financial variables and their comovement with the real economy. Presumably, this reflects a view that asset market fluctuations represent passive responses to the type of shocks that appear in standard models and that asset markets are not themselves an important source of shocks or propagation. Our results challenge this view. We find that incorporating financial shocks and frictions substantially alters inference about the impulses and propagation mechanisms in financial fluctuations. We stress two findings in particular. We identify a new shock - a shock to 'risk' - which emanates from the financial sector, and which represents a significant source of economic fluctuations in the Euro Area (EA) and US. In addition, we emphasize the importance for propagation of a new nominal rigidity: the assumption that interest rates are non-state contingent in nominal terms. We summarize all our results in the form of five findings at the end of this introduction.

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 proposed in Chari, Christiano and Eichenbaum (1995) (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 Bernanke, Gertler and Gilchrist (1999)(BGG).

We first review the frictions stemming from asymmetric information.[1] 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. The relationship between entrepreneurs and banks is characterized by the presence of asymmetric information. The arrangements designed to mitigate these asymmetric information problems represent frictions

[1] 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), 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).

that play a key role in the propagation mechanisms in our model. The source of asymmetric information is an idiosyncratic productivity shock which affects the productivity of entrepreneurs' capital. This shock is observed by the entrepreneur, but can only be observed by the bank by paying a monitoring cost. The standard deviation of this productivity shock is itself the realization of a stochastic process, and we call it a risk shock. We find that the risk shock is an important impulse to economic fluctuations.

It is well known that in our type of asymmetric information environment, it is natural for entrepreneurs and lenders to use a 'standard debt contract'. A property of this contract is that the size of the loan is constrained by the net worth of borrowers. The contract specifies that entrepreneurs who are able to do so, pay a specified rate of interest. The premium of entrepreneurs' interest rate over the cost of funds to banks must be sufficiently high to cover losses associated with entrepreneurs who default. In the model, this premium fluctuates with the state of the economy, with changes in the amount of idiosyncratic risk affecting entrepreneurs and with variations in entrepreneurs' net worth.

Following Irving Fisher (1933) and as in Christiano, Motto and Rostagno (2003), we assume that the liabilities issued to households to finance loans to entrepreneurs are characterized by an important nominal rigidity. 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 '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 Bernanke, Gertler and Gilchrist (1999) and it tends to magnify the economic effects of a shock that raises economic activity. The second propagation mechanism, the 'Fisher effect' channel, refers to the movements in entrepreneurial net worth that occur when an unexpected change in the price level alters 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.[2]

We estimate our model using EA and US data, augmenting the standard real and nominal macroeconomic data set with a stock market index, a measure of the external finance

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

premium, the stock of credit, of M1, of M3, the spread between the short rate and the 10-year bond rate. We use now-standard Bayesian methods.

In our econometric analysis we consider two financial market shocks: the risk shock mentioned above and a shock to the survival probability of entrepreneurs. These shocks affect the economy via their impact on the external finance premium and the probability of entrepreneurial default. We assume that agents receive early information about disturbances to the two financial market 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 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 the model, 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 "CEE" model corresponds to the structure proposed in Christiano, Eichenbaum and Evans (2005), which largely abstracts from financial frictions. The CEE model incorporates the various shocks analyzed in Smets and Wouters (2003,2007). What we call the "BGG" specification adds the financial contract to the CEE model, but does not consider the banking technology for producing inside money in our baseline model. We report out-of-sample root mean squared forecast errors (RMSEs) for fourteen variables that are defined in the baseline model and, whenever possible, we report the same metric computed on the basis of CEE and BGG.

We now summarize our five findings.

- The two financial 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.[3] In the low frequencies (those corresponding to cycles with period 8 years and longer) the risk shock is the single most important shock driving output growth in the EA. In the US, the risk shock is a close second in terms of importance, after the persistent neutral technology shock. The risk shock accounts for 30 percent of the low frequency component of output growth in the EA and 22 percent in the case of the US. A reason that the risk shock is assigned so much importance is that it helps account for the pro-cyclical nature of investment, hours worked, the stock market and credit. In addition, it

[3]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.

accounts for the counter-cyclical nature of the external finance premium and of the excess of long term rates over short rates. There are two informal ways to understand why our risk shock is estimated to be an important source of economic fluctuations.

- Consider Figure 1, which displays dynamic properties of output and our measure of the external finance premium. 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. According to Figure 1, 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.[4]
- Standard econometric analyses of the boom of the 1990s 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 CEE 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 the BGG and baseline models, an expansionary disturbance to one of our financial shocks represents, in effect, a shift right 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.

[4]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).

- We find that advance information, or 'news', about the financial shocks is important for explaining the dynamics of credit and the stock market. Without the assumption of advanced information, we can explain one or the other variable, but not both. A quantitative measure of the importance of news is provided by the marginal likelihood, which jumps 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.[5] 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.

- The Fisher effect channel is important for obtaining good model fit in the EA and the US. We show this by estimating a version of our baseline model in which there is no Fisher effect because the interest payments received by households are not state contingent in real terms. We find that the marginal likelihood of the latter model is much smaller than that of our baseline model. The quantitative importance of the Fisher effect is also documented using the model's impulse response functions. In the case of shocks 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. In the case of shocks that drive output and the price level in opposite directions, the response of output is smaller than it is when we shut down the Fisher effect. In some cases, these effects are quantitatively large.

- Factors on the asset side of banks' balance sheets – how much credit is extended and at what terms – are important for understanding economic fluctuations, but we find that factors on the liability side of bank balance sheets are less important. Shocks to liquidity preferences and to the banking technology for providing transactions services contribute substantially to the fluctuations in M1, M3 and bank reserves. But, they are not important impulses to the fluctuations of other variables. Still, we document that the features that we incorporate on the liability side of bank balance sheets improve our model's out of sample fit for inflation, output, and investment in the EA. Furthermore, propagation

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

in our baseline model where banks have access to an inside money creation technology to finance credit is somewhat different than it is in the BGG model. The BGG model abstracts from the inside money on the liability side of bank balance sheets that appear in the baseline model.

- We assess the contribution of different parts of our model to econometric fit by using out-of-sample RMSEs for fourteen variables and for the various versions of the baseline model. To evaluate all the financial frictions at once, we compare CEE with our baseline model. In addition, we can separately evaluate the financial frictions stemming from asymmetric information and from inside money creation by comparing the performance of BGG against CEE and the baseline model. We find that the various models perform roughly equally well on the variables they are designed to address. In particular, they achieve the same high standards that were reported for standard models in Smets and Wouters (2003,2007).

The plan of the paper is as follows. The next two sections describe the model and the estimation results. After that, we describe our results. Technical details and some additional results appear in Christiano, Motto and Rostagno (2008). 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 Y_t can be converted into consumption goods one-for-one. One unit of final output can be converted into $\mu_{\Upsilon,t}\Upsilon^t$ investment goods, where $\Upsilon > 1$ is the trend rate of investment-specific technical change, and $\mu_{\Upsilon,t}$ is a stationary stochastic process. 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 good 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 Φz_t^* is a fixed cost and K_{jt} and l_{jt} denote the services of capital and homogeneous labor. Fixed costs are modeled as growing with the exogenous variable, z_t^* :

$$z_t^* = z_t \Upsilon^{\left(\frac{\alpha}{1-\alpha} t\right)}, \ \Upsilon > 1, \tag{3}$$

where the growth rate of z_t^* corresponds to the growth rate of output in steady state.

In (2), the persistent component of technology, z_t, has the following time series representation:

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

where $\mu_{z,t}$ is a stochastic process. The variable, ϵ_t, is a stationary shock to technology.

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

$$l_t = \left[\int_0^1 (h_{t,i})^{\frac{1}{\lambda_w}} \, di \right]^{\lambda_w}, \; 1 \leq \lambda_w. \tag{4}$$

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

Intermediate-goods firms are competitive in factor markets, where they confront a rental rate, $P_t \tilde{r}_t^k$, on capital services and a wage rate, W_t, on labor services. Each of these factor prices is expressed in nominal units. Each firm must finance fractions, ψ_k and ψ_l, of its capital and labor services bills, respectively, in advance. The gross rate of interest faced by the firm for this type of working-capital loan is denoted R_t.

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

$$\tilde{\pi}_t = \left(\pi_t^{target} \right)^{\iota} \left(\pi_{t-1} \right)^{1-\iota}. \tag{5}$$

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 investment goods, I_t, and installed physical capital, x, that has been used in period t. The capital producer uses these inputs to produce new installed capital, x', using the following production technology:

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

Here, S is a function with the property that in nonstochastic steady state, $S = S' = 0$, and $S'' > 0$. Given our linearization-based estimation strategy, the only feature of S about which we can draw inference from data is S''. Also, $\zeta_{i,t}$ is a shock to the marginal efficiency of investment. 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:

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

The capital producer solves:

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

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. The aggregate stock of physical capital evolves as follows

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

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. 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 capures 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 utilization cost function:

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

where a is increasing and convex. 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. 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 $Q_{\bar{K},t+1}$. Total receipts in period $t+1$, in currency units, received by an entrepreneur with idiosyncratic productivity, ω, is:

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

We find it convenient to express the latter as follows:

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

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

$$1+R_{t+1}^{k}\equiv\frac{\left[u_{t+1}\tilde{r}_{t+1}^{k}-\Upsilon^{-(t+1)}\tau_{t+1}^{oil}a(u_{t+1})\right]P_{t+1}+(1-\delta)Q_{\bar{K},t+1}}{Q_{\bar{K},t}}.$$

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:

$$\bar{\omega}_{t+1}\left(1+R_{t+1}^{k}\right)Q_{\bar{K},t}\bar{K}_{t+1}=Z_{t+1}B_{t}, \tag{6}$$

where $B_t=Q_{\bar{K},t}\bar{K}_{t+1}-N_{t+1}$ denotes the quantity of currency borrowed by the entrepreneur. Entrepreneurs with $\omega<\bar{\omega}_{t+1}$ cannot fully repay their bank loan. Bankrupt entrepreneurs are monitored and then must turn over everything they have 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:[6]

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

The object on the right of the equality is the quantity of funds the bank must pay to households. The first part of the quantity on the left is the number of non-bankrupt entrepreneurs,

[6] 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.

$1-F_t(\bar{\omega}_{t+1})$, 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 $N_{t+1}/(1+R_t)$ and taking into account the definition of $\bar{\omega}_{t+1}$, we obtain:

$$\frac{[\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})]\left(1+R^k_{t+1}\right)(\varrho_t+1)}{1+R_t}=\varrho_t, \tag{7}$$

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, $\left(1+R^k_{t+1}\right)Q_{\bar{K},t}\bar{K}_{t+1}$, 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 entrepreneurial earnings kept 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:

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

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, (7), and the first order necessary condition associated with the optimization problem. After substituting out the multiplier and rearranging, the latter reduces to:

$$\begin{aligned}
&E_t\{[1-\Gamma_t(\bar{\omega}_{t+1})]\frac{1+R^k_{t+1}}{1+R_t} \\
&+\frac{1-F_t(\bar{\omega}_{t+1})}{1-F_t(\bar{\omega}_{t+1})-\mu\bar{\omega}_{t+1}F_t'(\bar{\omega}_{t+1})}\left[\frac{1+R^k_{t+1}}{1+R_t}\left(\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})\right)-1\right]\} = 0.
\end{aligned} \tag{8}$$

To gain insight into the properties of the standard debt contract, we consider (6), (7) and (8), taking as given R_{t+1}^{k} and R_t.[7] We loosely refer to (7) as the 'supply' of credit by banks. Because (8) 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, (8) 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 tradeoff between Z_{t+1} and ϱ_t that is implied by (6).

To understand how the standard debt contract works, consider Figure 2. The positively sloped curves display the tradeoff between the external finance premium, $Z_{t+1} - (1 + R_t)$, 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 (8) 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 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 $\left(1 + R^k\right) / (1 + R)$ 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

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

survives to continue another period with probability γ_{t+1}. 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:

$$\bar{N}_{t+1} = \gamma_t \{ \left(1 + R_t^k\right) Q_{\bar{K}',t-1} \bar{K}_t - \left[1 + R_t^e \; + \; \overbrace{\mu \frac{\int_0^{\bar{\omega}_t} \omega dF_t(\omega) \left(1 + R_t^k\right) Q_{\bar{K}',t-1} \bar{K}_t}{Q_{\bar{K}',t-1} \bar{K}_t - \bar{N}_t}}^{\text{external finance premium}} \right] \tag{9}$$
$$\times \left(Q_{\bar{K}',t-1} \bar{K}_t - \bar{N}_t\right) \} + W_t^e.$$

The object in braces in (9) 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, $\bar{\omega}_t$.

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

2.4 Financial Sector

The financial sector is composed of 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 $B_{t+1} R_{t+1}^e$, where R_{t+1}^e 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:

$$D^m_{t+1} + T_t = B_{t+1}. \tag{10}$$

Household savings deposits pay interest, R^m_{t+1}, in period $t+1$ and they also generate some transactions 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.

In period t, banks make working capital loans, S^w_t, to intermediate goods producers and to other banks. Working capital loans are for the purpose of financing wage payments and capital rental costs:

$$S^w_t = \psi_l W_t l_t + \psi_k P_t \tilde{r}^k_t K_t.$$

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^h_t. These liabilities are issued in exchange for receiving A_t units of high-powered money from the households, so that

$$D^h_t = A_t. \tag{11}$$

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

$$D^f_t = S^w_t. \tag{12}$$

Total demand deposits, D_t, are:

$$D_t = D^h_t + D^f_t. \tag{13}$$

Demand deposits pay interest, R^a_t. 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 $R_t + R^a_t$. Since firms receive interest, R^a_t, on deposits, net interest on working capital loans is R_t.

The bank has a technology for converting homogeneous labor, l^b_t, capital services, K^b_t, and excess reserves, E^r_t, into transactions services:

$$\frac{D_t + \varsigma D_t^m}{P_t} = x_t^b \left(\left(K_t^b\right)^\alpha \left(z_t l_t^b\right)^{1-\alpha} \right)^{\xi_t} \left(\frac{E_t^r}{P_t} \right)^{1-\xi_t} \tag{14}$$

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. In addition, $\xi_t \in (0,1)$ 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:

$$E_t^r = A_t - \tau D_t, \tag{15}$$

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:

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

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 (10), (**??**), (11), (12), (13), (14) and (15). The equilibrium conditions associated with the bank problem are derived in the Appendix.

Our model has implications for various monetary aggregates: currency, M_1 (currency plus demand deposits), M_3 (M_1 plus savings deposits), high powered money (currency plus bank reserves) and bank reserves. The reason we assume banks finance loans to entrepreneurs by issuing two types of liabilities rather than one, is that this allows us to match the M_3 velocity growth.[8] If banks issued only one type of liability and this were included in M_3,

[8] In Christiano, Motto and Rostagno (2003), banks finance entrepreneurial loans with only one type of liability.

then the velocity of M_3 would be low compared to its empirical counterpart. This is because the quantity of debt to entrepreneurs is high in our calibrated model.

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:

$$E_t^j \sum_{l=0}^{\infty} \beta^l \zeta_{c,t+l} \{ u(C_{t+l} - bC_{t+l-1}) - \psi_L \frac{h_{j,t+l}^{1+\sigma_L}}{1+\sigma_L} - H\left(\frac{\frac{M_{t+l}}{P_{t+l}}}{\frac{M_{t+l-1}}{P_{t+l-1}}} \right) \tag{16}$$
$$- \upsilon \frac{\left[\left(\frac{(1+\tau^c)P_{t+l}C_{t+l}}{M_{t+l}} \right)^{(1-\chi_{t+l})\theta} \left(\frac{(1+\tau^c)P_{t+l}C_{t+l}}{D_{t+l}^h} \right)^{(1-\chi_{t+l})(1-\theta)} \left(\frac{(1+\tau^c)P_{t+l}C_{t+l}}{D_{t+l}^m b} \right)^{\chi_{t+l}} \right]^{1-\sigma_q}}{1-\sigma_q} \},$$

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 $b > 0$, (16) 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:

$$M_t^b - (M_t + A_t) \geq 0. \tag{17}$$

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:

$$\begin{aligned} & (1+R_t^a)\left(M_t^b - M_t\right) + X_t - T_t - D_{t+1}^m \\ & -(1+\tau^c) P_t C_t + (1-\Theta)(1-\gamma_t) V_t - W_t^e + Lump_t \\ & -B_{t+40}^{long} + \sigma_t^{long}(1+\left[1-\tau_t^D\right] R_t^{long}) B_t^{long} + \left(1+R_t^T\right) T_{t-1} + (1+R_t^m) D_t^m \\ & + \left(1-\tau^l\right) W_{j,t} h_{j,t} + M_t + \Pi_t + A_{j,t} \geq M_{t+1}^b > 0. \end{aligned} \tag{18}$$

Equation (18) 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:

$$h_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{\frac{\lambda_w}{1-\lambda_w}} l_t, \ 1 \leq \lambda_w, \tag{19}$$

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, (4). 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

$$\tilde{\pi}_{w,t} \equiv \left(\pi_t^{target}\right)^{\iota_w} \left(\pi_{t-1}\right)^{1-\iota_w}, \ 0 < \iota_w < 1. \tag{20}$$

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

The household's problem is to maximize (16) subject to the various non-negativity constraints, the demand for labor, the Calvo wage-setting frictions, and (18). 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:

$$\mu \int_0^{\bar{\omega}_t} \omega dF(\omega) \left(1+R_t^k\right) \frac{Q_{\bar{K}',t-1}\bar{K}_t}{P_t} + \frac{\tau_t^{oil} a(u_t)}{\Upsilon^t} \bar{K}_t + \frac{\Theta(1-\gamma_t)V_t}{P_t} + G_t + C_t + \left(\frac{1}{\Upsilon^t \mu_{\Upsilon,t}}\right) I_t \leq Y_t. \tag{21}$$

The first object in (21) represents final output used up in bank monitoring. The second term captures capital utilization costs.[9] 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

[9] 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 appendix, we develop a scaled version of the resource constraint. In addition, we follow 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

For monetary policy, we adopt a flexible representation of the Taylor rule. We adopt the following standard notation. If we have a variable, x_t, whose steady state is x, then

$$\hat{x}_t \equiv \frac{x_t - x}{x} \simeq \log \frac{x_t}{x}, \tag{22}$$

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.

Denote the target interest rate of the monetary authority by R^{target} :

$$\begin{aligned} \hat{R}_t^e &= \rho_i \hat{R}_{t-1}^e + (1-\rho_i)\alpha_\pi \frac{\pi}{R^e}\left[E_t\left(\hat{\pi}_{t+1}\right) - \hat{\pi}_t^{target}\right] \qquad (23) \\ &+ (1-\rho_i)\frac{\alpha_y}{4R^e}\log\left(\frac{GDP_t}{\mu_{z^*}GDP_{t-1}}\right) + (1-\rho_i)\alpha_{d\pi}\frac{\pi}{R^e}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + (1-\rho_i)\frac{\alpha_b}{4R^e}\log\left(\frac{B_{t+1}}{\mu_{z^*}B_t}\right)\frac{1}{400R^e}\varepsilon_t \end{aligned}$$

where π_t^{target} has the time series representation described in the next section. We set the response to total credit, α_b, to zero in the model for the US. The inclusion of credit in the model for the euro area tries to capture some of the features of the euro area monetary policy strategy. The inclusion of the growth rate of output and of the change in inflation in (23) is motivated by the findings of Smets and Wouters (2003). Finally, ε_t in (23) denotes the monetary policy shock.

2.8 Fundamental Shocks

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

$$\left(\begin{array}{cccccccccccccccc} \hat{x}_t^b & \hat{\mu}_{\Upsilon,t} & \hat{\chi}_t & \hat{g}_t & \hat{\mu}_{z^*,t} & \hat{\gamma}_t & \hat{\epsilon}_t & \varepsilon_t & \hat{\sigma}_t & \hat{\zeta}_{c,t} & \hat{\zeta}_{i,t} & \hat{\tau}_t^{oil} & \hat{\lambda}_{f,t} & \hat{\sigma}_{long,t} & \hat{\xi}_t & \hat{\pi}_t^{target} \end{array}\right), \tag{24}$$

where a hat over a variable means (22). Also,

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

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 we had difficulty compiling bank reserves data 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 riskiness shock, $\hat{\sigma}_t$, has a first order autoregressive representation, we assume that agents acquire advance information about the realization of the univariate innovation. In particular, we suppose that $\hat{\sigma}_t$ evolves as follows:

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

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, $\left\{\xi_{\sigma,t}^0, \xi_{\sigma,t-1}^1, ..., \xi_{\sigma,t-p}^p\right\}$, has a diagonal covariance matrix and is *iid* over time. In addition, we assume

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

In practice, we restrict $\sigma_1^2 = \sigma_2^2 = ... = \sigma_p^2$.

In the case of the EA, we also adopt the above signal structure on the γ_t shock. We did not apply this in the case of the US because we found that the signal variances were estimated to be zero.

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 discuss the steady state parameters in the first subsection below. The second set of parameters is estimated using the Bayesian procedures in An and Schorfheide (2005), Schorfheide (2000) and SW. The parameters estimated here include the ones that characterize monetary policy, wage and price frictions, the shock processes, capital utilization and investment adjustment costs. We discuss these parameters in the second subsection below. After that, we briefly discuss the estimated shocks and apply RMSE tests for model fit.

3.1 Parameters Governing Steady State

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.[10] We then computed a weighted average of the tax rates, based on each country's share in GDP. The result, 45 percent, is reported in Table 1. The tax rate on capital is taken from Eurostat and refers to the EA implicit tax rate on capital over the period 1995-2001.

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

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 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.[11] 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

[11] 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%.

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 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).[12] 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.

[12]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.

3.2 Parameters Governing Dynamics

In the case of the US, we use the following 16 variables to estimate the model parameters that do not influence steady state:

$$X_t = \left(\begin{array}{c} \Delta \log \left(\frac{N_{t+1}}{P_t} \right) \\ \pi_t \\ \log \left(\text{per capita hours}_t \right) \\ \Delta \log \left(\frac{\text{per capita credit}_t}{P_t} \right) \\ \Delta \log \left(\text{per capita GDP}_t \right) \\ \Delta \log \left(\frac{W_t}{P_t} \right) \\ \Delta \log \left(\text{per capita } I_t \right) \\ \Delta \log \left(\frac{\text{per capita } M1_t}{P_t} \right) \\ \Delta \log \left(\frac{\text{per capita } M3_t}{P_t} \right) \\ \Delta \log \left(\text{per capita consumption}_t \right) \\ \text{External Finance Premium}_t \\ R_t^{long} - R_t^e \\ R_t^e \\ \Delta \log P_{I,t} \\ \Delta \log \text{real oil price}_t \\ \Delta \log (\frac{\text{per capita Bank Reserves}_t}{P_t}) \end{array} \right), \tag{25}$$

where 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. Details about our data sources are provided in Appendix A. The sample period used in the estimation is 1985Q1-2007Q2.[13] We use this rather short sample because of data limitations in the EA and 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 occured in the early 1980s.[14] Finally, prior to estimation, we remove the sample mean from the data, X_t, 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.

[13] 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 1985Q1-2007Q2.

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

We adopt the following functional form for the costs of capital utilization:

$$a(u) = 0.5b\sigma_a u^2 + b(1-\sigma_a)u + b((\sigma_a/2) - 1).$$

Here, b is selected to ensure $u = 1$ in steady state and $\sigma_a \geq 0$ is a parameter that controls the degree of convexity of costs. We adopt the following specification of investment adjustment costs:

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

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 with respect to x, in steady state. Note that S and its first derivative are both zero in steady state.

Prior and posterior distributions of the parameters that do not control steady state are displayed in Table 4.[15] We allow for the presence of *iid* measurement error on the financial and monetary variables used in our analysis, and the corresponding estimates appear in Table 5. 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.

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. [16]

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

[15] 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.

[16] 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.

investment flows:

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

Five parameters pertain to the monetary policy rule, (23):

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

The priors and posteriors of the above parameters are displayed in Figure 3a and are also reported in Table 4. In the case of the Calvo parameters, ξ_p, ξ_w, our priors 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. The posteriors on ξ_p and ξ_w for the US are shifted substantially to the right, relative to our priors. 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 each of prices and wages are reoptimized every 3.2 quarters.[17] Our estimate of the degree of price stickiness for the US is considerably less than those reported by Levin, Onatski, Williams and Williams ( ) (LOWW) and Primiceri, Schaumburg and Tambalotti (2006) (PST), 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.[18] Prices in our US model are only a little less flexible than these studies suggest.

[17]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.

[18]For example, in calibrating their model to the micro data, Golosov and Lucas (2003, Table 1, page 20) select parameters to ensure that firms re-optimize prices on average once every 1.5 quarters.

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 PST and SW.

Our estimates imply a high cost of varying capital utilization. This is consistent with the findings in Altig, Christiano, Eichenbaum and Linde (2004) (ACEL), who report a similar result for US data only, using a very different estimation strategy. LOWW report 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.

We now turn to the parameters of the monetary policy rule, (23). 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). 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.[19] The estimated policy rules in PST, LOWW and SW are consistent with our results in that they also imply strong response of monetary policy to inflation and a high degree of intertia. Finally, the standard deviation of the monetary policy shock in the Taylor rule is 48 and 50 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 other parameters are displayed in Figures 3b and 3c, and reported in Table 5.

For comparison, we also estimated two special versions of our model. The 'simple model' is the version of our model without the banking system, without the financial frictions and

[19] 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.

without money (i.e., υ set to zero in (16)). This corresponds closely to the model in CEE or SW. The 'BGGFinancial accelerator model' introduces the BGG financial frictions into the simple model. Alternatively, it is the version of our model without money and a detailed liability side of the financial intermediaries. These alternative models and the posterior modes of their parameters are reported in Tables A.1 and A.2.

3.3 Selected Second Moment Implications of the Estimated Models

Tables 6a and 6b displays the second moment implications of the EA and US estimated models, respectively. In addition, the table displays the corresponding second moments in the data. With some exceptions, the estimated models overstate volatility. The baseline EA and US models both overstate the standard deviation of output growth by about 50 percent. In the case of the EA, the baseline model overstates the volatility of inflation by a similar amount, 30 percent. There is cause for concern in the US model because it overstates inflation volatility by nearly a factor of 3. Both models overstate the volatility of consumption growth by about 70 percent, and the volatility of investment is also overstated. Given the importance of the external finance premium in our analysis, it is disappointing that its overstated factors of 3 and 12, respectively, in the EA and US. The volatility implications of the CEE and BGG models are roughly similar to those of the baseline model. Interestingly, the EA model does well in terms of the volatility of the stock market, while the US model understates it by about 35 percent. In future work, we plan to investigate the reasons for the overstatement of volatility.

3.4 Estimated Shocks

We briefly examine a subset of the shocks emerging from model estimation. Figures 4a and 4b display the (demeaned) EA and US data used in the analysis, together with the associated two-sided smoothed estimates from the model, computed at the mode of the posterior distribution of the parameters. Data and smoothed estimates almost exactly coincide, with the vertical differences corresponding to the estimated measurement error. It is evident from the figures that measurement errors play a very minor role, with the (slight) exception of the stock market. The smoothed estimate of the data can equivalently be thought of as being the simulation of the model in response to the estimated (by two-sided Kalman smoothing) economic shocks. The similarity between raw data and model predicted data shows that we have a nearly exact decomposition of the historical data into economic shocks.

The shocks are graphed in Figures 5a-5d. 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.

Note the pronounced downward trend in the inflation target in both the EA and US. That down trend corresponds to the down trend in actual inflation in our two data sets.

The banking reserve demand parameter, ξ, displays sharp spikes in the US in 1984 and in late 2001 (the latter corresponds to a huge jump in reserves on September 11). These spikes represent our model's explanation of the spikes in the non-borrowed reserves data in Figure 4b.

We isolate several shocks for special attention in the next section, $\sigma_{long,t}$, γ_t, σ_t and $\zeta_{i,t}$. 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^e and the absence of a trend in the term premium in Figures 4a and 4b.) 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 7a and 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 target shock.

3.5 RMSE Tests of Model Fit

In this section, we evaluate our model's fit by comparing its out of sample forecasting performance with 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.[20]

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

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

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 6a and 6b for the EA and US, respectively. Our first forecast is computed in 2001Q3, when we compute 1, 2, ..., 8 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 CEE and BGG models. 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 forcast.

The grey area in Figures 6a and 6b represent classical 95 percent confidence intervals about the BVAR RMSEs. To understand these, let $RMSE^{BVAR}$ and $RMSE^{CMR}$ denote the RMSEs from the BVAR and baseline models, respectively, for some forecast horizon. The technical appendix shows that, for T large,

$$RMSE^{BVAR} - RMSE^{CMR}\tilde{}N(0, \frac{V}{T}),$$

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 6a and 6b represent:

$$RMSE^{BVAR} \pm 1.96\sqrt{\frac{\hat{V}}{T}}.$$

So, if $RMSE^{CMR}$ 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.

Consider the forecasts of GDP growth in the EA first. Note that the baseline model significantly outperforms CEE. The baseline model also outperforms BGG, BVAR and the random walk model, though not statistically significantly so. Turning to inflation, note that the baseline model appears to dominate CEE signicantly and it also dominates the random walk model. The BVAR model slightly outperforms the baseline model, though not significantly so. In the case of investment growth, the baseline model dominates CEE and BGG, and significantly so at the 3 quarter ahead horizon. The baseline model does about as well as the BVAR model. Turning to the spread and to the stock market, note that the baseline model outperforms the others 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 BGG at the longer horizons, but does significantly worse than BVAR at the short horizons. In one deviation from the overall pattern, CEE does a little better than the baseline model at all horizons. Finally, it is somewhat disappointing that the baseline and simple accelerator models do poorly forecasting the external finance premium ('risk premium'). In the introduction, the risk premium played a key role in our intuition about why our empirical analysis finds the risk shock is important.

Now consider the results for the US in Figure 6b. 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.

SW 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 SW: 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 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.

3.6 Diagnosing the Importance of Model Features Using the Marginal Likelihood

The log-marginal likelihood of our baseline model for the EA and US is, 4,698.5 and 4,397.5, respectively.[21] In this section, we evaluate the contribution to model fit of signals on σ_t and of the Fisher effect. The results for the signals appear in Tables 8a and 8b for the EA and the US, respectively. Table 8 makes it clear that the data overwhelmingly favor the signal specification. For example, the posterior odds in favor of 8 lags of signals over 7 is 2.3 to 1. The posterior odds of 8 lags over 6 or 4 is in each case enormous.

The marginal likelihood also favors the Fisher effect against an alternative. As an alternative we considered a model specification in which the household's interest payments are non-state contingent in real terms rather than nominal terms. The log, marginal likelihoods for the EA and the US are 4,648.9 and 4,369.1, respectively. Thus, the posterior odds favor the Fisher effect specification overwhelmingly. .

[21] Marginal likelihoods were computed using the Laplace approximation.

4 Key Economic Implications of the Model

This section discusses the economic implications of our model. We start with a description of the channels through which two key structural features of our baseline model can account for some fundamental co-movements of asset prices and macroeconomic quantities over the business cycle. We then turn to the dynamic properties of our model and compare them with those of two reduced-scale versions of the model, its CEE and the BGG components. The former is estimated without financial frictions. The latter is estimated without the banking sector.

4.1 Variance Decompositions

Tables 9 and 10 displays our models' implications for the variance decompositions of various variables at business cycle frequencies for the EA and US models, respectively. As 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). Part 'a' of each table corresponds to standard business cycle quantities, while part 'b' corresponds to financial variables.[22]

There are several things worth noting in these tables. We begin by considering the variance decomposition of standard variables, reported in Tables 9a and 10a for the EA and US, respectively. First, note that the price markup plays a rather large role in the variance of inflation. In the EA, the fraction of business cycle variance in inflation is 36 percent, while in the US (Table 10), the corresponding number is 23 percent. This finding is consistent with other analyses, such as those of JPT and SW.[23] Second, the money demand shocks emerging from the banking sectors and from households have virtually no impact on any of the usual quantity variables (see the rows corresponding to σ_{x^b} - the banking technology shock, and corresponding to σ_{χ} - the money demand shock). Not surprisingly, these shocks do have a large impact on $M1$ and $M3$ (see tables 9b and 10b).

Third, our two financial shocks have a large impact on the variance of output, and the primary role in this is played by advance information on the risk shock. Financial shocks account for 23 percent of the business cycle variance in output, in each of the EA and US (add over the columns corresponding to σ_{γ} and σ_{σ} in Tables 9a and 10a). The risk shock is by far the most important of the two financial shocks. In both the EA and the US, advance information on the risk shock accounts for roughly 20 percent of the business cycle variance

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

[23] Though it is well known, this result is rather disconcerting because of the effort made in the model construction on the setting of prices. Despite this effort, the estimation results imply that a large fraction of the fluctuation in prices is unexplained exogenous variation.

of output.[24] That is, advance information on the risk shock accounts for over 85 percent of the contribution to variance of all the financial shocks in each of the EA and US. Fourth, advance information on the risk shock accounts for over 10 percent of the business cycle variance of investment, hours worked, labor productivity in the EA and US.

There are several interesting things to note about the variance decompositions of financial variables, reported in Tables 9b and 10b. First, the financial shocks account for over 3/4 of the business cycle variance in the stock market, credit flows and the external finance premium. Second, the external finance premium largely reflects the risk shock (see 'premium'). This shock accounts for over 95 percent of the business cycle variance of the external finance premium in each of the EA and US. Third, a surprisingly large fraction of the variance of slope of the term structure of interest rates is explained by the economic shocks of the model. To a first approximation, the model's implications for the term structure corresponds to the 'expectations hypothesis': that long rates are the expected value of future short rates. We capture the deviation of the data from the term structure hypothesis with the shock, σ_{long}, included in the household's budget constraint, (18). According to Tables 9b and 10b, this shock only accounts for 36 and 22 percent of the variance of the term structure in the EA and US, respectively. That is, 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).

[the remainder of the empirical results have yet to be written up. However, they are summarized in the introduction.]

[24]The rows marked $\sigma_{\sigma^{signal}}$ in Tables 9-10 report the sum of the percent of variance due to information j periods in the past, $j = 1, ..., 8$.

[9] Benigno, Pierpaolo, and Michael Woodford, 2004, 'Optimal Stabilization Policy When Wages and Prices are Sticky: The Case of a Distorted Steady State', July 21.

[10] Bernanke, B., 2005, "The Global Saving Glut and the U.S. Current Account Deficit," Speech delivered at the Homer Jones Lecture, St. Louis, Missouri (April 14).

[11] Bernanke, Ben S. and Gertler, Mark**,** 1989, "Agency Costs, Net Worth, and Business Fluctuations.", *American Economic Review,* March, 79(1), pp. 14–31.

[12] Bernanke, Ben, Mark Gertler and Simon Gilchrist, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework." Handbook of Macroeconomics, edited by John B. Taylor and Michael Woodford, pp. 1341-93. Amsterdam, New York and Oxford: Elsevier Science, North-Holland.

[13] Bils, Mark, and Pete Klenow. 2004. "Some Evidence on the Importance of Sticky Prices." *Journal of Political Economy.* 112 (October): 947-985.

[14] Blanchard, Olivier Jean, 1993, 'Consumption and the Recession of 1990-1991,' *American Economic Review*, May; 83(2): 270-74

[15] Blinder, Alan S., and Ricardo Reis, 2005, 'Understanding the Greenspan Standard,' Prepared for the Federal Reserve Bank of Kansas City symposium, *The Greenspan Era: Lessons for the Future*, Jackson Hole, Wyoming, August 25-27.

[16] Blinder, A. and J. Yellen, 2001, *The Fabulous Decade: Macroeconomic Lessons from the 1990s*, New York, Century Foundation Press.

[17] Boldrin, Michele, Lawrence Christiano and Jonas Fisher, 2001, 'Habit Persistence, Asset Returns, and the Business Cycle,' *American Economic Review*.

[18] Carlstrom, Charles, and Timothy Fuerst, 1997, 'Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis,' *The American Economic Review*, vol. 87, no. 5 (December), 893-910.

[19] Chari, V.V., Lawrence J. Christiano, and Martin Eichenbaum, 1995, "Inside Money, Outside Money and Short Term Interest Rates." Journal of Money, Credit and Banking 27, 1354-86.

[20] Christiano, Lawrence J., 1989, 'P*: Not the Inflation Forecaster's Holy Grail,' Federal Reserve Bank of Minneapolis *Quarterly Review*.

[21] Christiano, Lawrence J., 2002, 'Solving Dynamic Equilibrium Models by a Method of Undetermined Coefficients', *Computational Economics*, October, Volume 20, Issue 1-2.

[22] Christiano, Lawrence J., 2007, Comment on Del Negro, Schorfheide, Smets and Wouters, "On the Fit of New Keynesian Models," *Journal of Business & Economic Statistics*, 25(2), 2007.

[23] Christiano, Lawrence J. and Joshua Davis, 2007, 'Two Flaws In Business Cycle Accounting,' National Bureau of Economic Research Working paper 12647.

[24] Christiano, Lawrence J., Martin Eichenbaum and Charles Evans, 1999. "Monetary Policy Shocks: What Have We Learned and to What End?," in John Taylor and Michael Woodford, editors, *Handbook of Macroeconomics*.

[25] Christiano, Lawrence J., Martin Eichenbaum and Charles Evans, 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*.

[26] Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno, 2003, "The Great Depression and the Friedman-Schwartz Hypothesis," *Journal of Money, Credit and Banking*. 35, no. 6, pt. 2 (December): 1119-1198.

[27] Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno. 2007, 'Shocks, Structures or Policies? The Euro Area and the US After 2001,' *Journal of Economic Dynamics and Control*.

[28] Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno, 2008, 'Technical Appendix for "Financial Factors in Economic Fluctuations"', manuscript.

[29] Cooley, Thomas, Ramon Marimon, and Vincenzo Quadrini, 2004, "Aggregate Consequences of Limited Contract Enforceability," *Journal of Political Economy*, 112, 817-847.

[30] Covas, Francisco, and Wouter den Haan, 2007, "The Role of Debt and Equity Finance over the Business Cycle," manuscript, University of Amsterdam, January.

[31] Davis, Josh, 2008, 'On the Presence of News in a Hybrid Model of the Yield Curve,' manuscript, Northwestern University.

[32] Davis, Josh, 2008a, 'News and the Term Structure in General Equilibrium,' manuscript, Northwestern University.

[33] De Fiore, Fiorella and Harald Uhlig, 2005, 'Bank finance versus bond finance: what explains the differences between US and Europe?,' manuscript, August.

[34] De Graeve, Ferre, 2007, "The External Finance Premium and the Macroeconomy: US post-WWII Evidence," manuscript, Ghent University.

[35] Del Negro, Marco, Frank Schorfheide, Frank Smets and Raf Wouters, 2007, "On the Fit of New Keynesian Models," *Journal of Business & Economic Statistics*, 25(2), 2007, 143-162.

[36] Erceg, Christopher J., Henderson, Dale, W. and Andrew T. Levin, 2000, 'Optimal Monetary Policy with Staggered Wage and Price Contracts,' *Journal of Monetary Economics*, 46(2), October, pages 281-313.

[37] Field, Alexander, 2004, 'The Most Technologically Progressive Decade of the Century,' *American Economic Review*, September, 2003, vol. 93, no. 4.

[38] Fisher, Irving, 1933, "The Debt-Deflation Theory of Great Depressions." *Econometrica* 1, 337-357.

[39] Fisher, Jonas D. M., 1999, 'Credit Market Imperfections and the Heterogeneous Response of Firms to Monetary Shocks," *Journal of Money, Credit and Banking*, May, pp. 187-211.

[40] Fuerst, Timothy, 1995, "Money and Financial Interactions in the Business Cycle," *Journal of Money, Credit, and Banking*, 27, 1321-1338.

[41] Gale, Douglas, and Martin Hellwig, 1985, "Incentive-Compatible Debt Contracts: The One-Period Problem," *Review of Economic Studies*, 52, 647-663.

[42] Golosov, Mikhail, and Robert E. Lucas, Jr.. 2007. "Menu Costs and Phillips Curves," *Journal of Political Economy*, 115 (2): 117-199

[43] Gerlach, Stefan and Lars Svensson, 2001, 'Money and Inflation in the Euro Area: A case for Monetary Indicators?', BIS Working Paper No. 98.

[44] Gertler, Mark, and Lown, C., 1999, "The Information in the High-yield Bond Spread for the Business Cycle: Evidence and some Implications," *Oxford Review of Economic Policy* 15, 132-150.

[45] Goodfriend, Marvin, 1998, 'Using the Term Structure of Interest Rates for Monetary Policy,' Federal Reserve Bank of Richmond *Quarterly Review*, volume 84/3 Summer.

[46] Guerron, Pablo, 2005, 'Time-Dependent Portfolio Adjustment and the Short- and Long-Run Dynamics of Money Demand,' manuscript, Northwestern University.

[47] Hamilton, James B, 1994, Time Series Analysis. Princeton: Princeton University Press.

[48] Hopenhayne, Hugo and Ivan Werning, 2008, 'Equilibrium Default,' manuscript.

[49] Iacoviello, Matteo, 2005, "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle," *American Economic Review*, June, pp. 739-764.

[50] Justiniano, A., and G. E. Primiceri, 2005, "The Time Varying Volatility of Macroeconomic Fluctuations," mimeo, Northwestern University.

[51] Justiniano, A., G. E. Primiceri and A. Tambalotti, 2008, 'Investment Shocks and the Business Cycle', manuscipt.

[52] Kiyotaki, Nobu, and John H. Moore, 1997, "Credit Cycles," *Journal of Political Economy*, 105, 211-248.

[53] Klenow, Peter, and Oleg Kryvtsov. 2004. "State-Dependent or Time-Dependent Pricing: Does it Matter for Recent U.S. Inflation." manuscript, Stanford University.

[54] Kim, C. J. and C. R. Nelson, 1999, "Has the US Economy Become More Stable? A Bayesian Approach Based on a Markov-Switching Model of the Business Cycle," *The Review of Ecvonomics and Statistics* 81, 608-616.

[55] Kohn, Don, 2003, "Productivity and Monetary Policy," Remarks offered at the Federal Reserve Bank Philadelphia Monetary Seminar, Philadelphia, September 24.

[56] Kwark, N. S., 2002, "Default Risks, Interest Rate Spreads, and Business Cycles: Explaining the Interest Rate Spread as a Leading Indicator," *Journal of Economic Dynamics and Control*, 26, 271-302.

[57] Kydland, Finn, and Edward C. Prescott, 1990, 'Business Cycles: Real Facts and a Monetary Myth,' *Federal Reserve Bank of Minneapolis Quarterly Review*, Spring, (Vol. 14 No. 2).

[58] Levin, Andrew T., Fabio M. Natalucci and Egon Zakrajsek, 2004, "The Magnitude and Cyclical Behavior of Financial Market Frictions," manuscript, Board of Governors of the Federal Reserve System, October.

[59] Levin, Andrew, Onatski, John Williams and Noah Williams,

[60] McGrattan, Ellen and Edward Prescott, 2004, "Taxes, Regulations and the value of US and UK corporations," Federal Reserve bank of Minneapolis, Research Department Staff Report 309.

[61] McConnell, M.M. and G. Perez-Quiros, 2000, "Output Fluctuations in the United States: What Has Changed Since the Early 1980s?,' *American Economic Review*, Vol. 90, No. 5, 1464-1476.

[62] Mendoza, Enrique, A. Razin and Linda Tesar, 1994, "Effective tax rates in macroeconomics. Cross-country estimates of tax rates on factor income and consumption," *Journal of Monetary Economics* 34, 297-323.

[63] Mills, Frederick C., 1934, 'Changes in Prices, Manufacturing Costs and Industrial Productivity, 1929-1934,' National Bureau of Economic Research, Bulletin 53, December 22. This may be found at http://www.nber.org/newsbulletin/newsbulletin/dec22_1934.pdf.

[64] Mody, A., Taylor, M.P., 2003, "The High-Yield Spread as a Predictor of Real Economic Activity: Evidence of a Financial Accelerator for the United States," *International Monetary Fund Staff Papers* 50, 373-402.

[65] Mulligan, Casey, 2002, "Capital tax incidence: first impressions from the time series," NBER WP 9374.

[66] Prescott, Edward, 2002, 'Prosperity and Depression: 2002 Richard T. Ely Lecture,' *The American Economic Review*, Volume 92, Number 2, 1, May, pp. 1-15(15)

[67] Prescott, Edward, 2003, 'Why Do Americans Work so Much More than Europeans?,' Federal Reserve Bank of Minneapolis Research Department Staff Report 321.

[68] Primiceri, Giorgio, Enrst Schaumburg and Andrea Tambalotti, 2006, 'Intertemporal Disturbances,' manuscript, Northwestern University, April.

[69] Queijo, Virginia, 2005, "How Important are Financial Frictions in the US and the Euro Area?", Seminar paper no. 738, Institute for International Economic Studies, Stockholm University, August.

[70] Reifschneider, D.L., D.J. Stockton and D.W. Wilcox, 1997, 'Econometric Models and the Monetary Policy Process,' *Carnegie-Rochester Conference Series on Public Policy* 47, 1-37.

[71] Rudebusch, Glenn, and Eric Swanson, 2007, 'Examining the Bond Premium Puzzle,' Federal Reserve Bank of San Francisco Working Paper 2007-25, October.

[72] with a DSGE Model

[73] Schorfheide, Frank, 2005, "Learning and Monetary Policy Shifts," *Review of Economic Dynamics*, 8, 392-419.

[74] Smets, Frank and Raf Wouters, 2003, 'An Estimated Stochastic General Equilibrium Model of the Euro Area,' *Journal of the European Economic Association*, 1, 1123-75.

[75] Smets, Frank and Raf Wouters, 2005, "Comparing shocks and frictions in US and euro area business cycles: a Bayesian DSGE approach," *Journal of Applied Econometrics*, 20(1), January.

[76] Smets, Frank and Raf Wouters, 2007, American Economic Review.

[77] Stock J.H. and M.W. Watson, 2003a, "Has the Business Cycle Changed and Why?" *NBER Macroeconomics Annual* 2002.

[78] Stock J.H. and M.W. Watson, 2003b, "Has the Business Cycle Changed? Evidence and Explanations," Mimeo, August.

[79] Taylor, John B, 1993, "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy*, 39(0): 195–214.

[80] Taylor, John B, 2007, 'Housing and Monetary Policy,' Presented at the 2007 Jackson Hole Conference, August.

[81] Timmer, Marcel P., Gerard Ypma and Bart van Ark, 2005, 'IT in the European Union: Driving Productivity Divergence?', GGDC Research Memorandum GD-67, University of Groningen, Appendix Tables, original draft, 2003, updated June. See also http://www.ggdc.net/dseries/growth-accounting.html.

[82] Townsend, Rob, 1979, "Optimal Contracts and Competitive Markets with Costly State Verification," *Journal of Economic Theory*, 21, 265-293.

[83] Townsend, Rob, 1988, "Information Constrained Insurance: The Revelation Principle Extended," *Journal of Monetary Economics*, 21, 411-450.

[84] Yun, Tack, 1996, 'Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles,' *Journal of Monetary Economics,* 37(2): 345 - 370.

7 Appendix A: 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.[29] The interest rate, R_t^e, is measured for the US by the Federal Funds rate and for the EA it

[29] In the case of the US the bond is issued by the US Federal government and in the case of the EA, the bond corresponds to a weighted average of member country government bonds.

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.

8 Appendix B: 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::

$$x_t = \rho_1 x_{t-1} + \rho_2 x_{t-2} + \varepsilon_t + \xi_{t-1}^1 + \xi_{t-2}^2 + ... + \xi_{t-p}^p, \tag{29}$$

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:

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

Note that the presence of news does not alter the fact that (29) 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,

$$x_t = \rho_1 x_{t-1} + \rho_2 x_{t-2} + \varepsilon_t + \xi^1_{t-1} + \xi^2_{t-2}. \tag{30}$$

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

$$\begin{bmatrix} x_t \\ u^2_t \\ u^1_t \end{bmatrix} = \begin{bmatrix} \rho & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_{t-1} \\ u^2_{t-1} \\ u^1_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \xi^2_t \\ \xi^1_t \end{bmatrix}. \tag{31}$$

It is easy to confirm that this is the same as (30). Write the first equation:

$$x_t = \rho x_{t-1} + u^1_{t-1} + \varepsilon_t. \tag{32}$$

To determine u^1_{t-1} evaluate (31) at the previous date:

$$\begin{aligned} u^2_{t-1} &= \xi^2_{t-1} \\ u^1_{t-1} &= u^2_{t-2} + \xi^1_{t-1}. \end{aligned}$$

The second of the above two expressions indicates that we must evaluate (31) at an earlier date:

$$\begin{aligned} u^2_{t-2} &= \xi^2_{t-2} \\ u^1_{t-2} &= u^2_{t-3} + \xi^1_{t-2}. \end{aligned}$$

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

$$u^1_{t-1} = \xi^2_{t-2} + \xi^1_{t-1}.$$

Substituting this into (32), we obtain (30), which is the result we sought. We can refer to u^1_{t-1} as the "state of signals about x_t as of $t-1$". We can refer to ξ^2_{t-2} as the "signal about x_t that arrives at time $t-2$". We can refer to ξ^1_{t-1} as the "signal about x_t that arrives at time $t-1$".

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

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

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:

$$\begin{bmatrix} x_t \\ x_{t-1} \\ u_t^p \\ u_t^{p-1} \\ \vdots \\ u_t^2 \\ u_t^1 \end{bmatrix} = \begin{bmatrix} \rho_1 & \rho_2 & 0 & 0 & \cdots & 0 & 1 \\ 1 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix} \begin{bmatrix} x_{t-1} \\ x_{t-2} \\ u_{t-1}^p \\ u_{t-1}^{p-1} \\ \vdots \\ u_{t-1}^2 \\ u_{t-1}^1 \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ 0 \\ \xi_t^p \\ \xi_t^{p-1} \\ \vdots \\ \xi_t^2 \\ \xi_t^1 \end{bmatrix}$$

We can write this in compact notation as follows:

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

where

$$\begin{aligned} \Psi_{x,t} &= \begin{bmatrix} x_t \\ x_{t-1} \\ u_t^p \\ u_t^{p-1} \\ \vdots \\ u_t^2 \\ u_t^1 \end{bmatrix}, \ P_x = \begin{bmatrix} \rho_1 & \rho_2 & 0 & 0 & \cdots & 0 & 1 \\ 1 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix}, \ \varepsilon_{x,t} = \begin{bmatrix} \varepsilon_t \\ 0 \\ \xi_t^p \\ \xi_t^{p-1} \\ \vdots \\ \xi_t^2 \\ \xi_t^1 \end{bmatrix}, \\ E\varepsilon_{x,t}\varepsilon_{x,t}' &= \begin{bmatrix} \sigma_\varepsilon^2 & 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & \sigma_1^2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & \sigma_p^2 \end{bmatrix}. \end{aligned}$$

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,

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

9 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:

$$X_t = \left(\begin{array}{c} \Delta \log \left(\frac{N_{t+1}}{P_t} \right) \\ \pi_t \\ \log\left(\text{per capita hours}_t\right) \\ \Delta \log \left(\frac{\text{per capita credit}_t}{P_t} \right) \\ \Delta \log\left(\text{per capita GDP}_t\right) \\ \Delta \log \left(\frac{W_t}{P_t} \right) \\ \Delta \log\left(\text{per capita } I_t\right) \\ \Delta \log \left(\frac{\text{per capita } M1_t}{P_t} \right) \\ \Delta \log \left(\frac{\text{per capita } M3_t}{P_t} \right) \\ \Delta \log\left(\text{per capita consumption}_t\right) \\ \text{External Finance Premium}_t \\ R_t^{long} - R_t^e \\ R_t^e \\ \Delta \log P_{I,t} \\ \Delta \log \text{real oil price}_t \\ \Delta \log \left(\frac{\text{per capita Bank Reserves}_t}{P_t} \right) \end{array} \right), \tag{33}$$

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:

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

The observer system is:

$$X_t = H\xi_t + w_t, \; E w_t w_t' = R,$$

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:

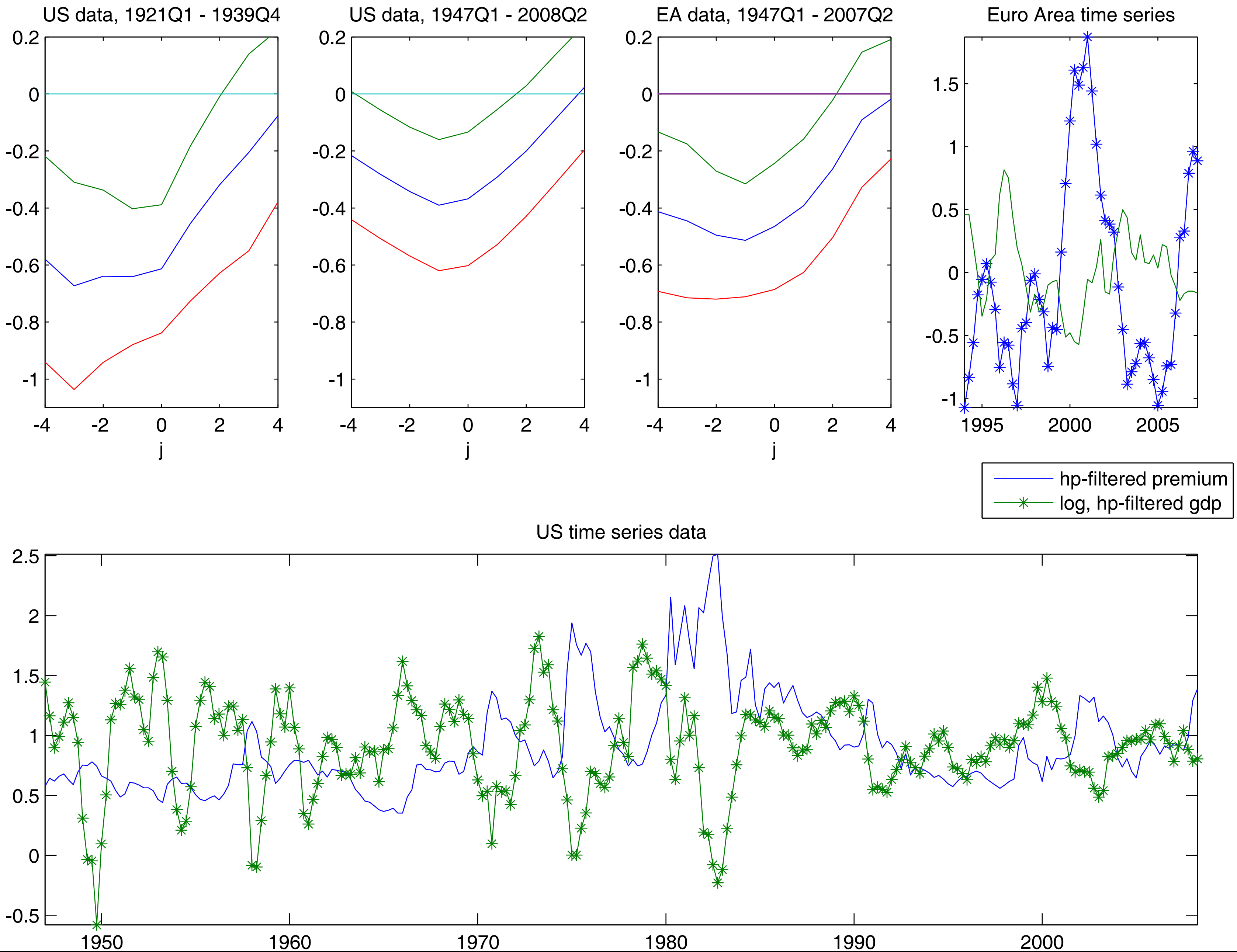
$$\begin{bmatrix} \Delta \log GDP_t \\ \Delta \log C_t \\ \Delta \log I_t \\ \Delta \log h_t \\ \log \pi_t \\ \Delta \log \left(\frac{N_{t+1}}{P_t} \right) \\ \Delta \log \left(\frac{\text{credit}_t}{P_t} \right) \\ Z_t - R_t^e \\ \Delta \log \frac{GDP_t}{h_t} \\ R_t^{long} - R_t^e \\ R_t^e \\ \Delta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

where

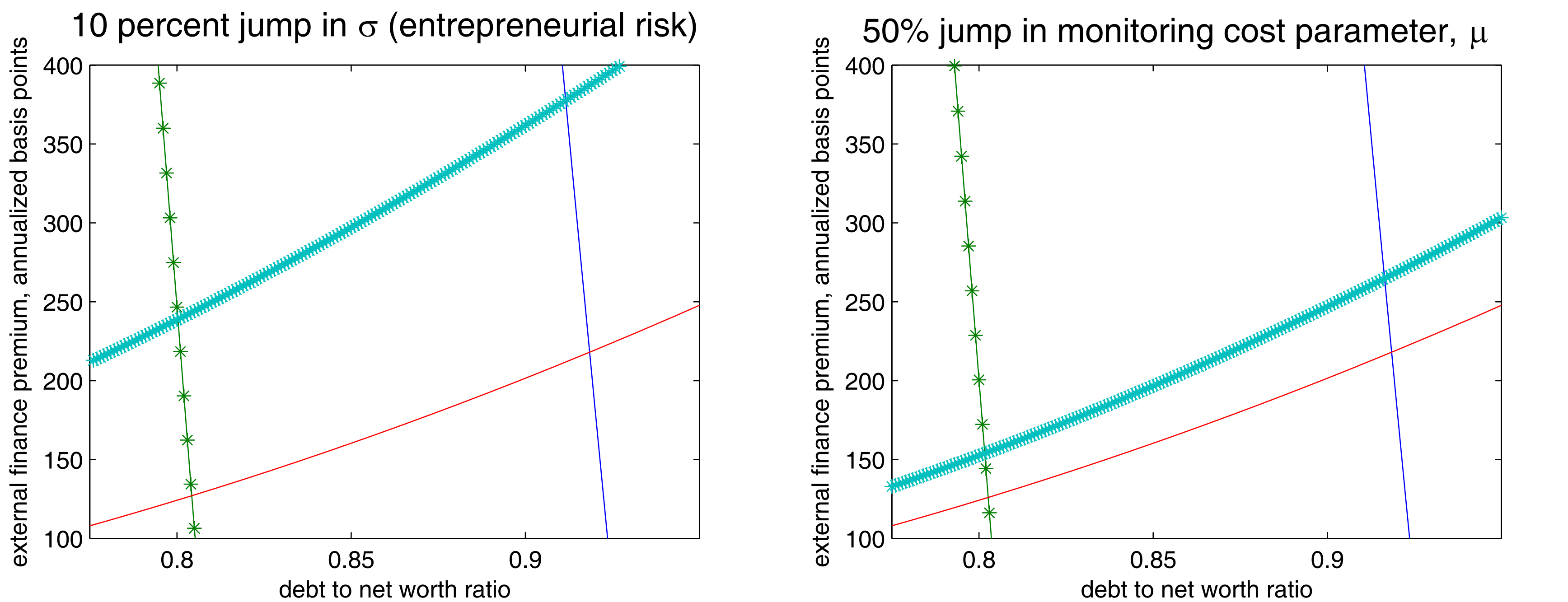
$$J = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1-L & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0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

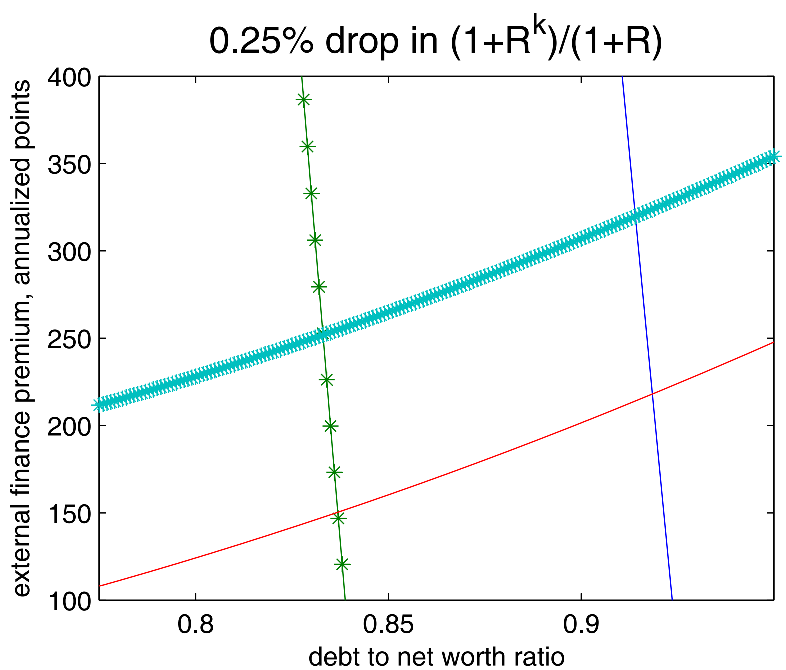
In the case of the US, there is an additional column and row composed of zeroes, except the 16^{th} element, which contains unity.

Figure 1: Correlation(finance premium (t),output (t-j)), HP filtered data, 95% confidence interval



Notes: Premium is measured by the difference between the yield on the lowest rated corporate bonds (Baa) and the highest rated corporate bonds (Aaa). Bond rate data obtained from St. Louis Fed website. GDP data obtained from Balke and Gordon (1986). Filtered output data are scaled so that their standard deviation coincide with that of the premium data.





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 3.a: Priors and Posteriors (US - thick line, EA - thin line) Model Paramters

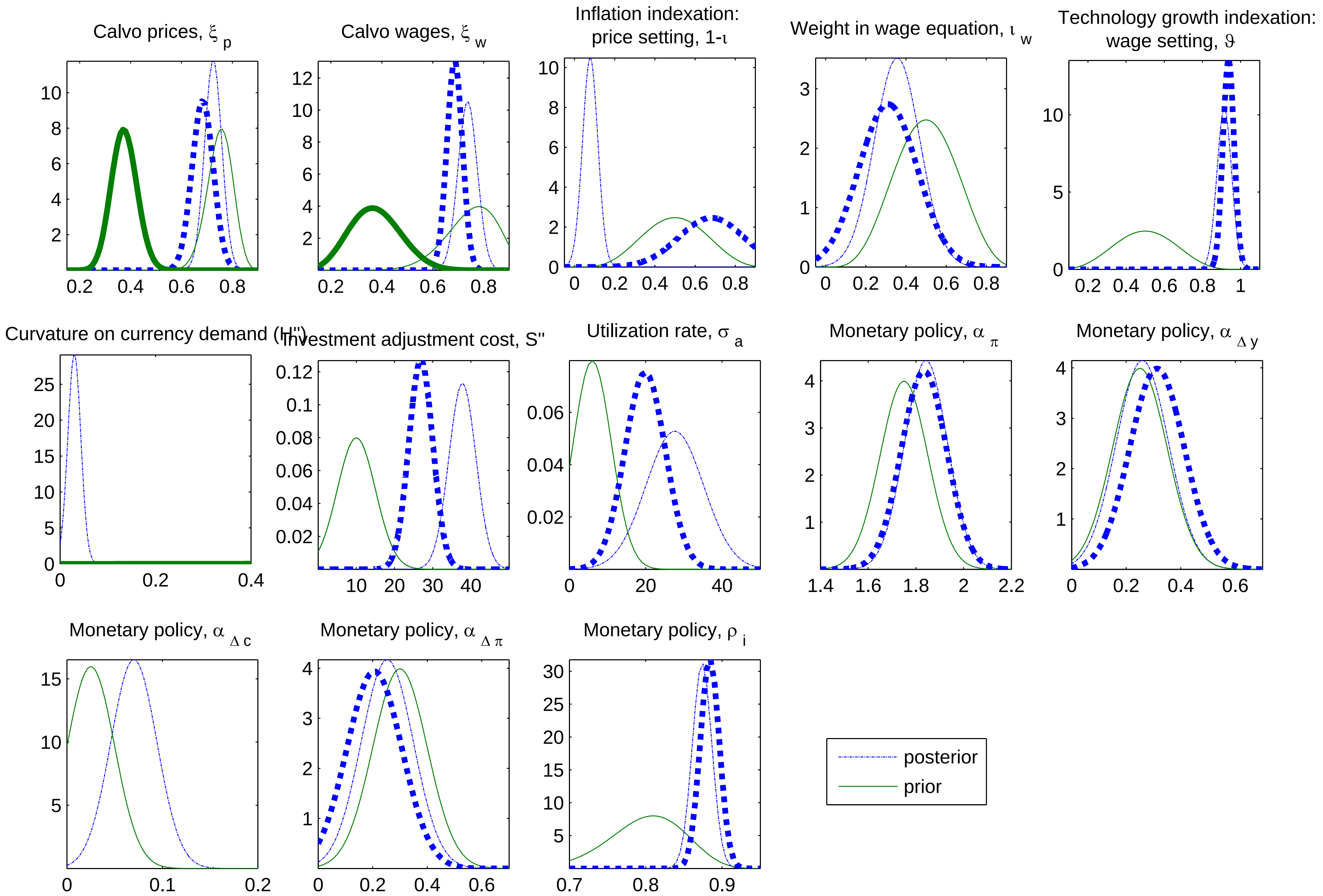


Figure 3.b: Priors and Posteriors (US - thick line, EA - thin line) Autoregressive coefficients

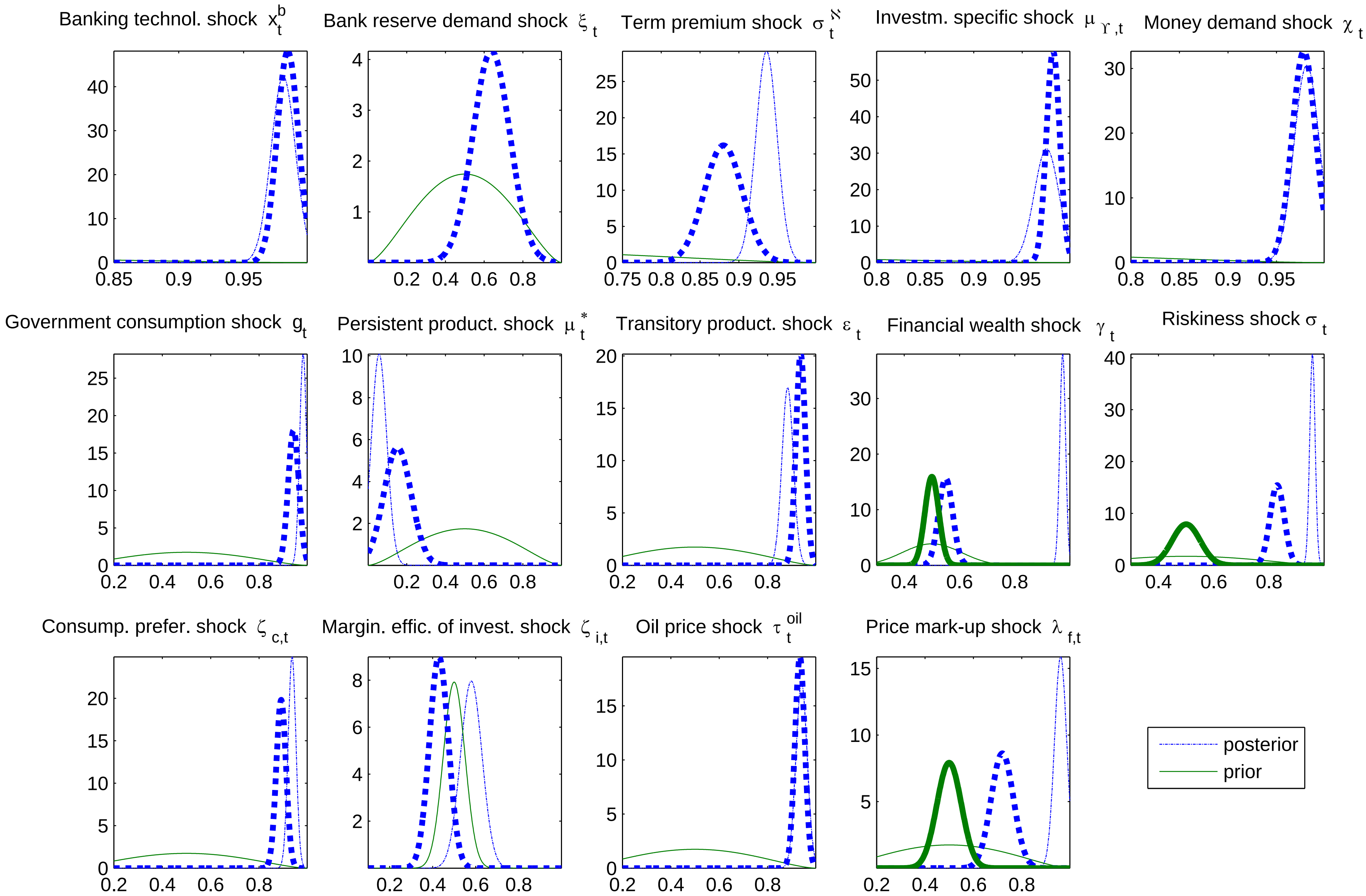


Figure 3.c: Priors and Posteriors (US - thick line, EA - thin line) Innovation std deviations

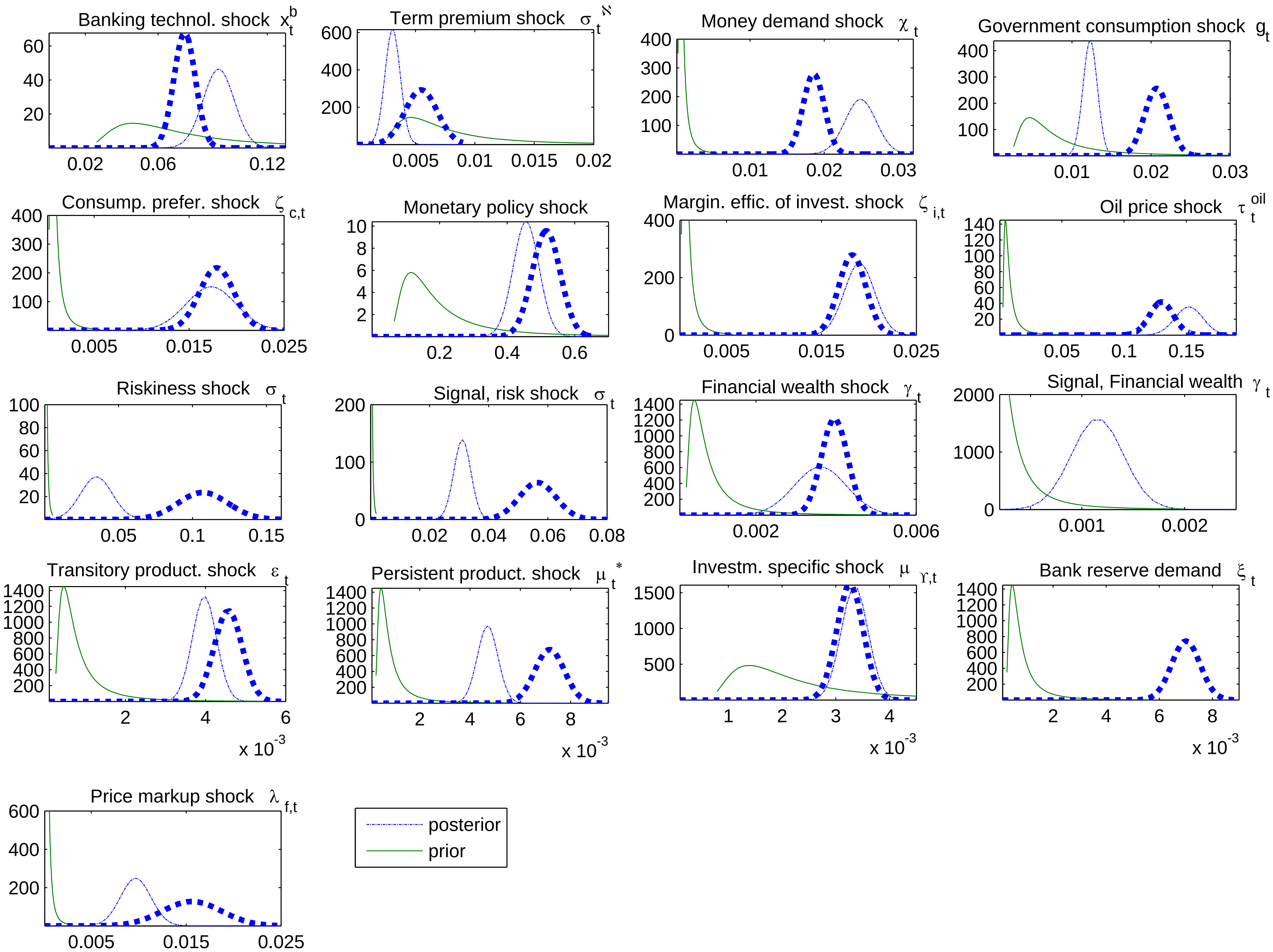


Figure 4.a: EA, Actual (solid line) and Fitted (dotted line) Data

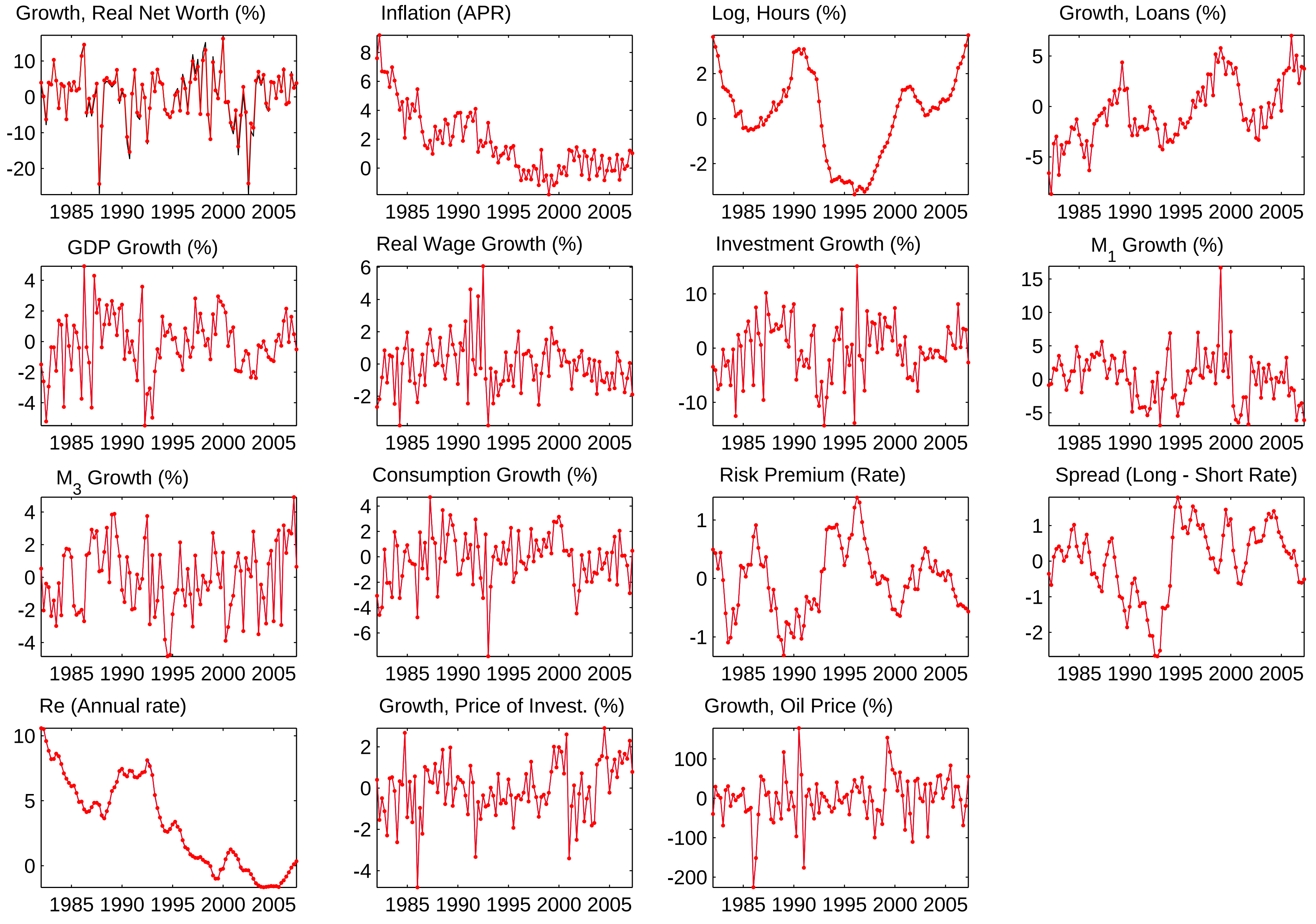


Figure 4.b: US, Actual (solid line) and Fitted (dotted line) Data

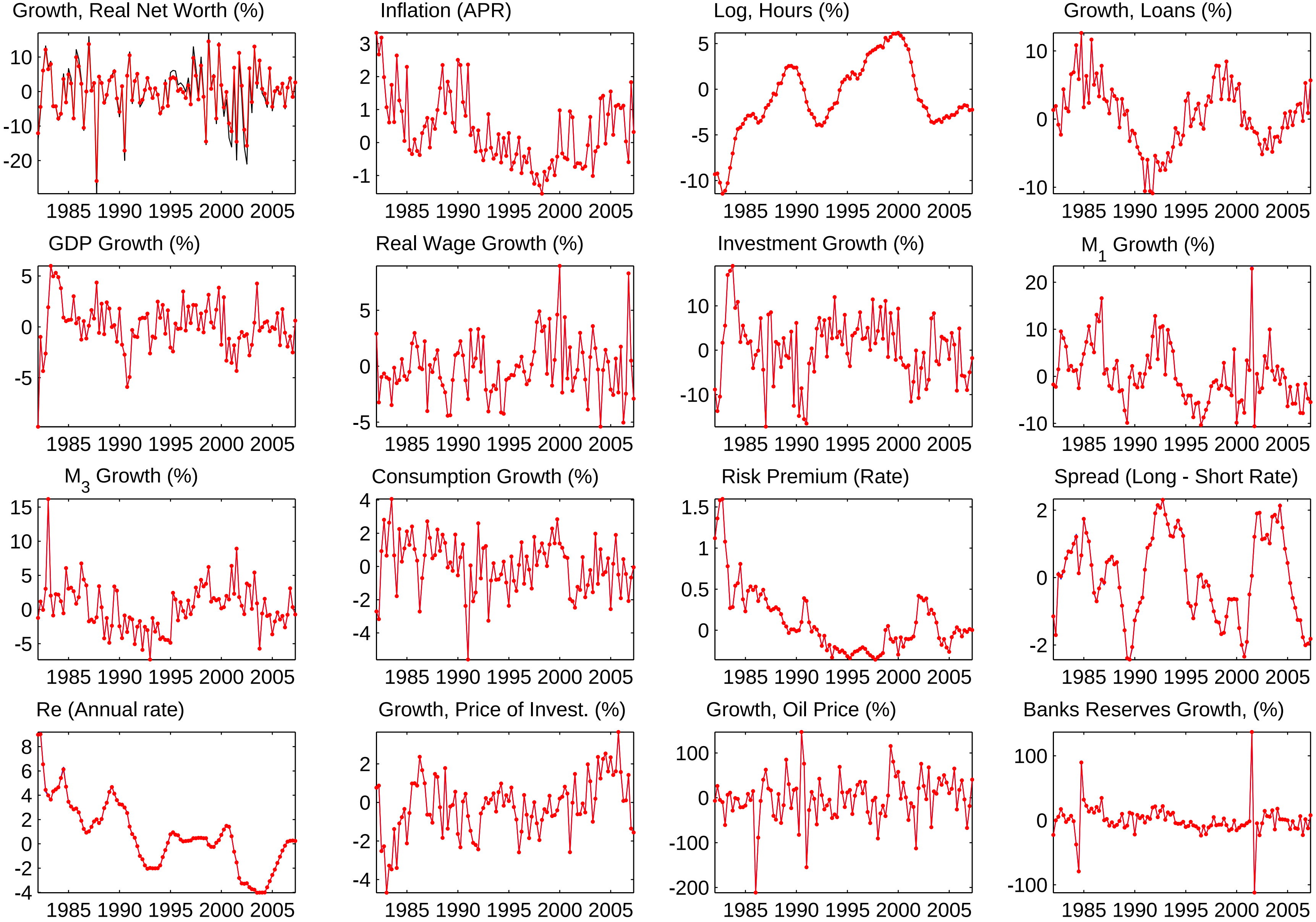
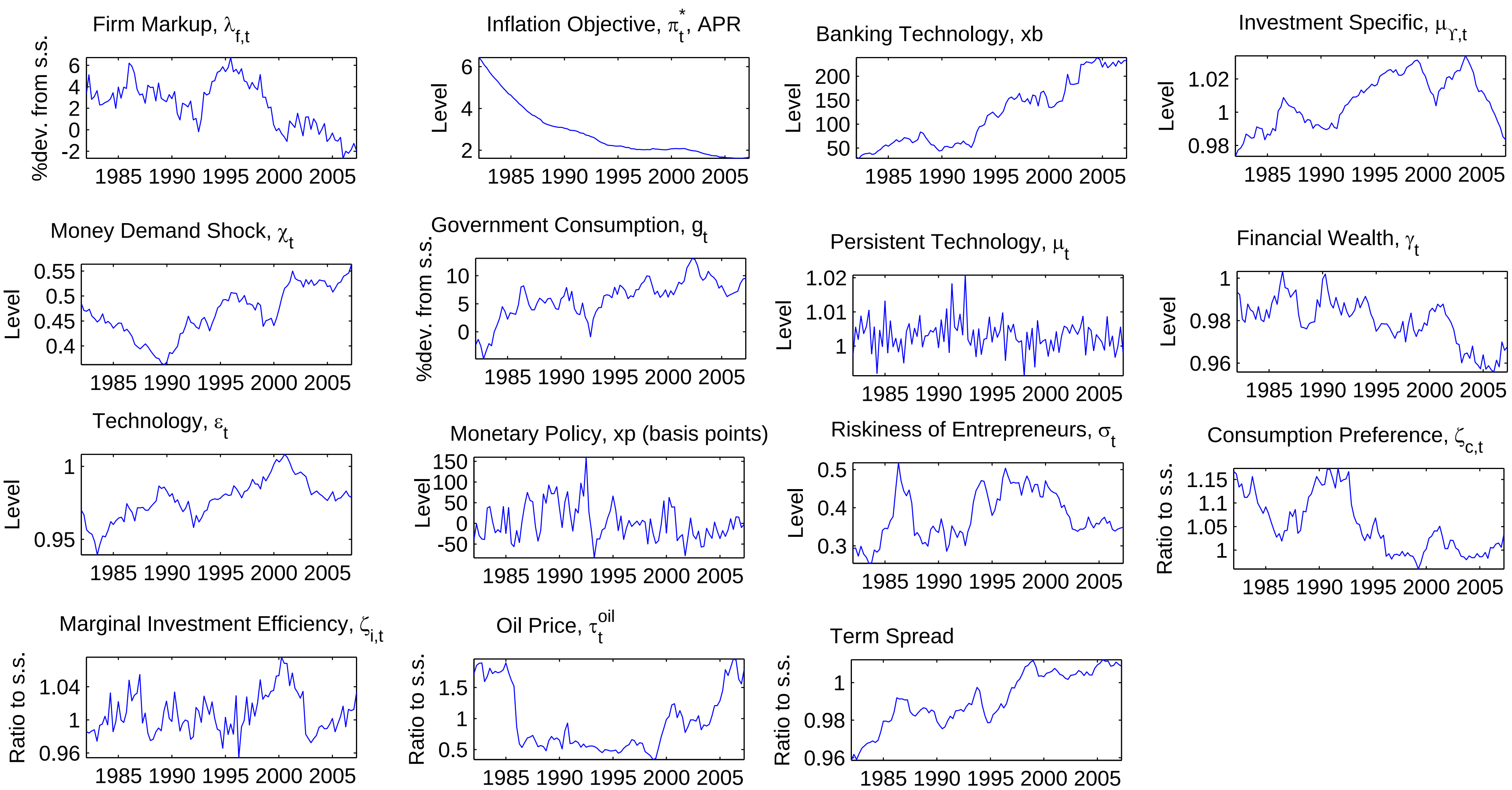


Figure 5.a: EA, Estimated Economic Shocks



these pictures need to be pulled apart using the fig file. there's some sort of bug in the suptitle program which causes the pictures to be badly arranged.

Figure 5.b: EA, Innovations to Shocks with Signal Representation

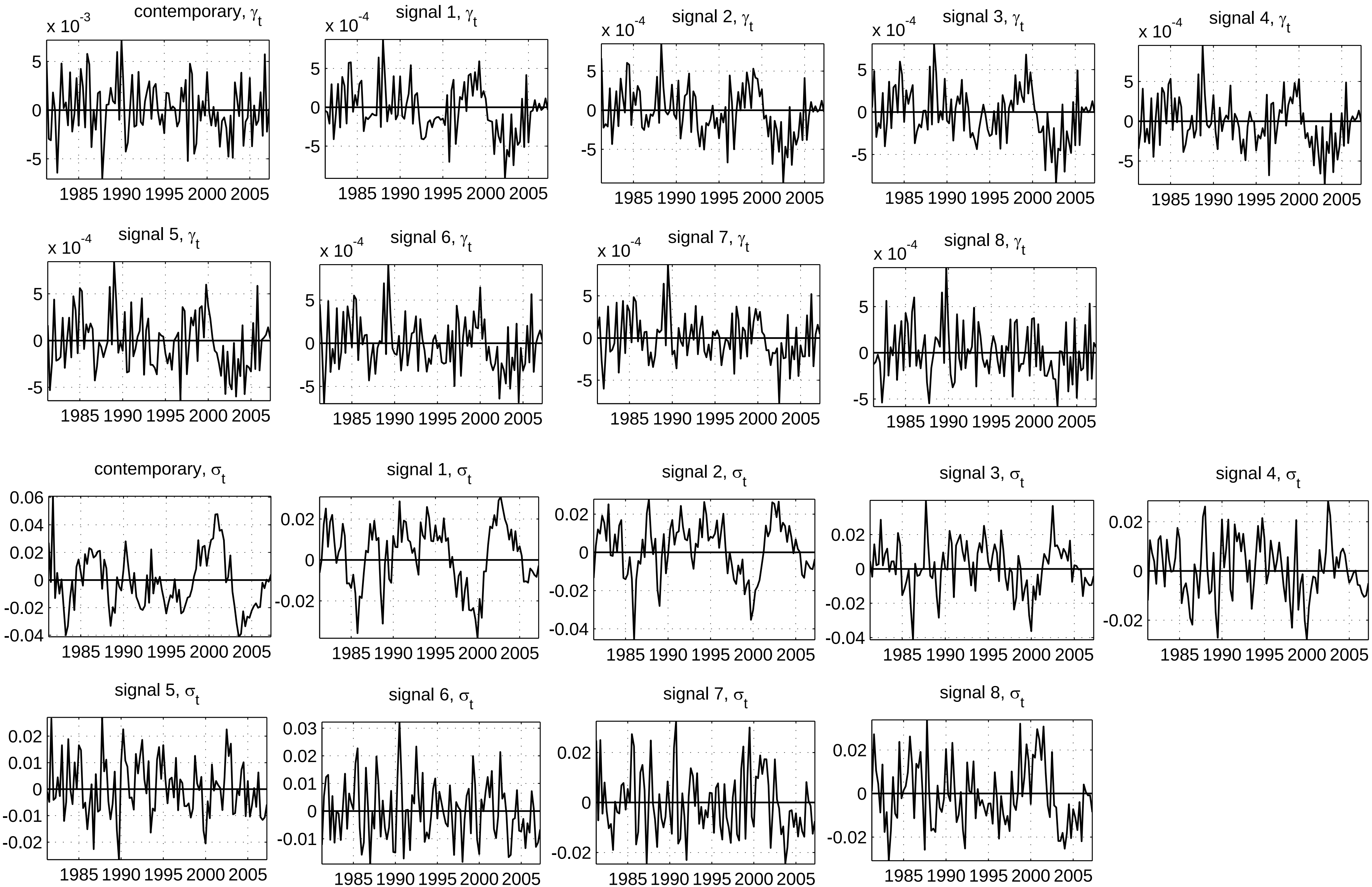
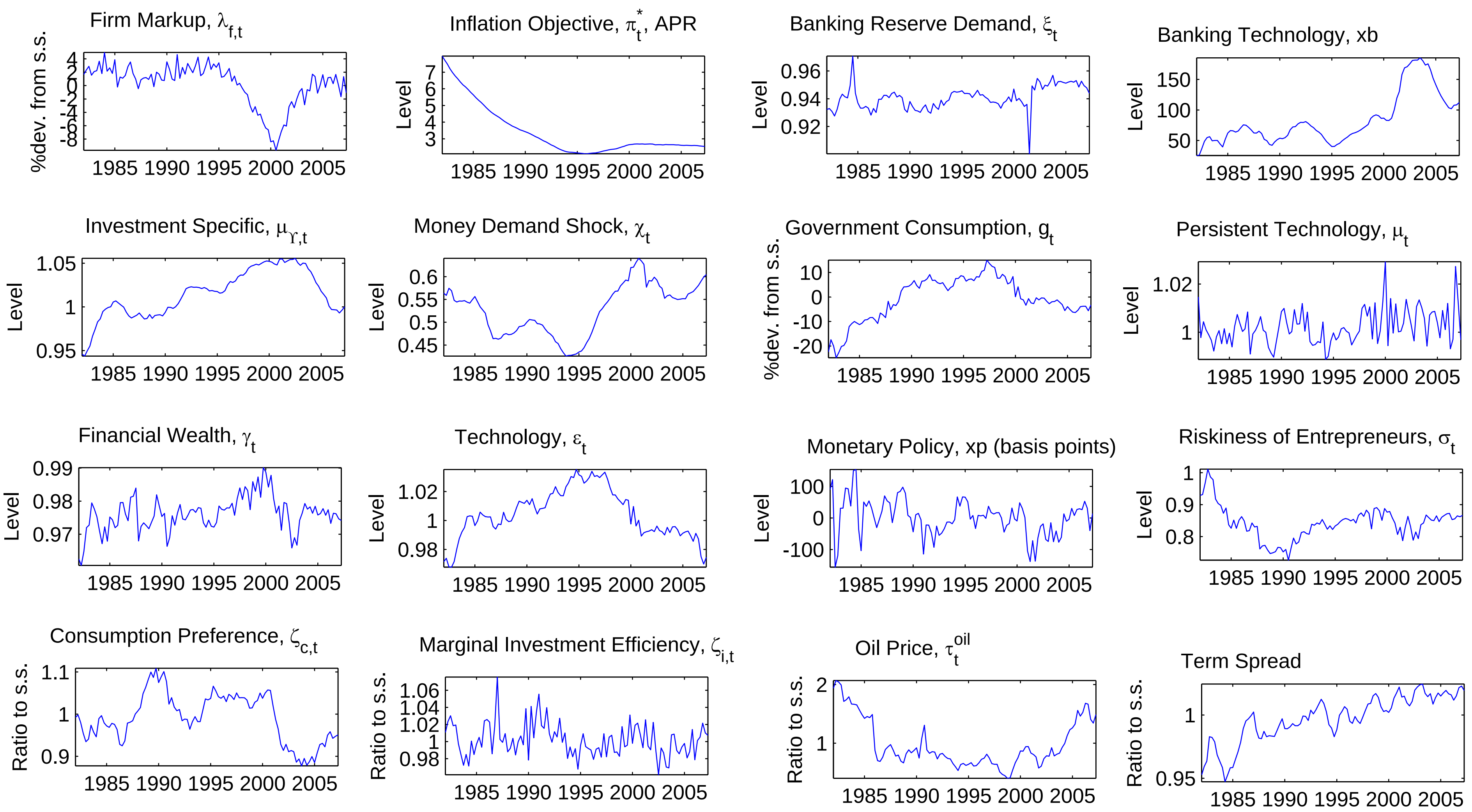


Figure 5.c: US, Estimated Economic Shocks



these pictures need to be pulled apart also, σ_{long,t} should be in the term spread header.

Figure 5.d: US, Innovations to Shocks with Signal Representation

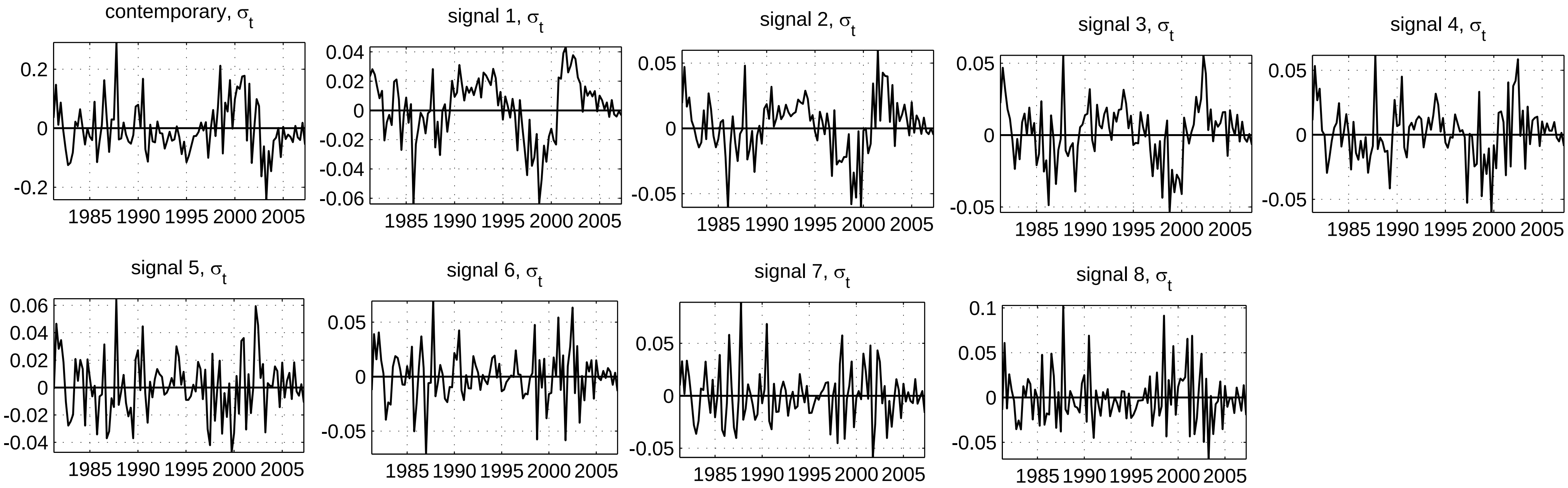


Figure 6.a. EA, RMSE: Confidence band represents 2 std and is centred around BVAR

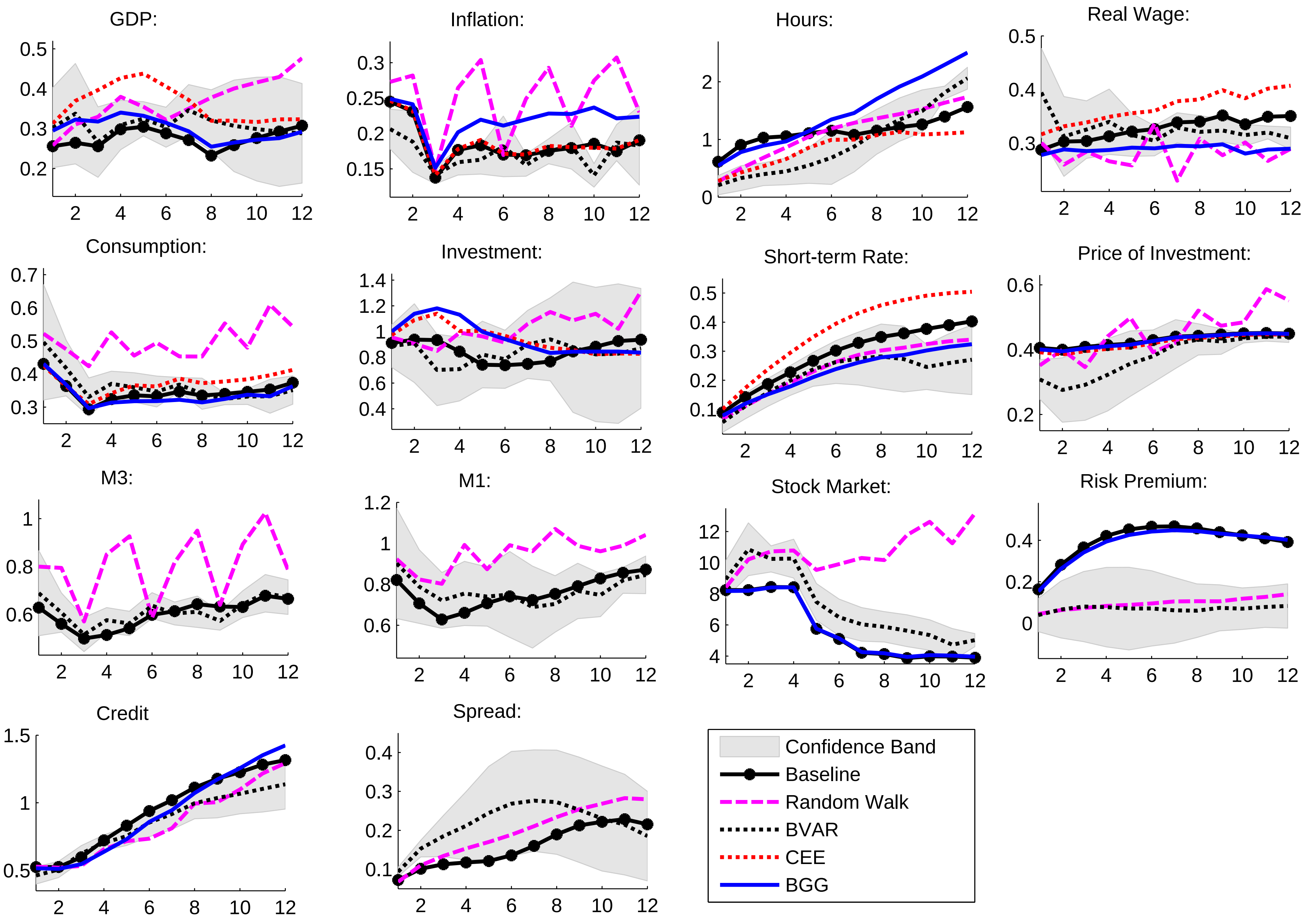


Figure 6.b: US, RMSE. Confidence band represents 2 std and is centred around BVAR (in percent)

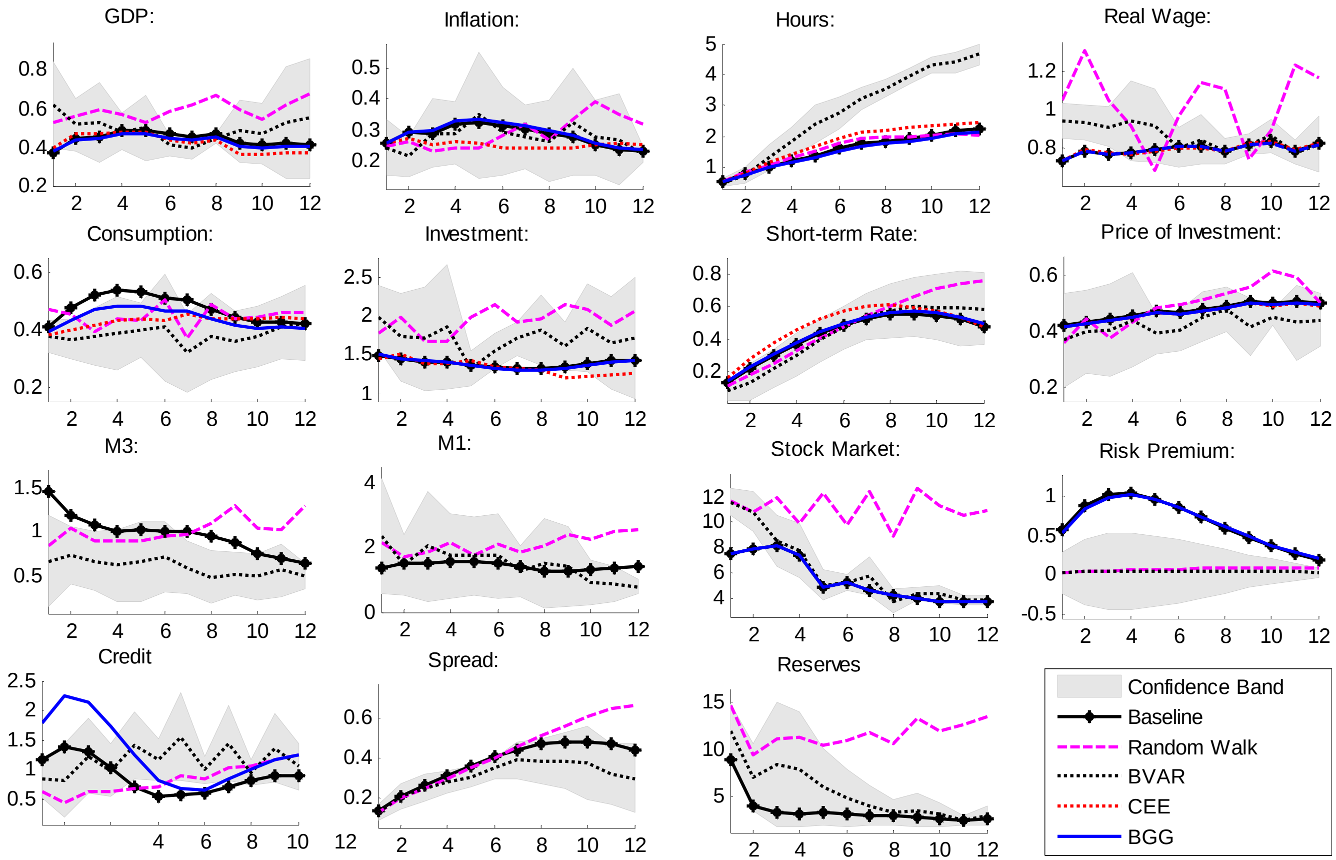


Table 1: Model Parameters, EA and US (Time unit of Model: quarterly)			
		Euro Area	US
Panel A: Household Sector			
β	Discount rate	0.999	0.9966
σ_L	Curvature on Disutility of Labor	1.00	1.00
υ	Weight on Utility of Money	0.001	0.001
σ_q	Curvature on Utility of Money	-6.00	-7.00
θ	Power on Currency in 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: Parameter Estimates, Baseline Model

		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	0.725	0.033	0.67-0.78	0.683	0.042	0.61-0.75
ξ_w	Calvo wages	Beta	0.75^* 0.375	0.1	0.737	0.038	0.68-0.80	0.686	0.030	0.64-0.74
H''	Curvature on currency demand**	Normal	2.0	2.0	0.030	0.014	0.01-0.05	/	/	/
ι	Weight on steady state inflation	Beta	0.5	0.15	0.922	0.038	0.86-0.98	0.319	0.160	0.05-0.58
ι_w	Weight on steady state inflation	Beta	0.5	0.15	0.645	0.113	0.46-0.83	0.689	0.145	0.45-0.93
ϑ	Weight on technology growth	Beta	0.5	0.15	0.914	0.039	0.85-0.98	0.937	0.029	0.89-0.99
S''	Investment adjust. cost	Normal	10.0	5	37.776	3.540	31.95-43.60	26.888	3.150	21.71-32.06
σ_a	Capacity utilization	Gamma	6	5	27.600	7.554	15.18-40.02	19.842	5.316	11.13-28.56
α_π	Weight on inflation in Taylor rule	Normal	1.75	0.1	1.842	0.090	1.69-1.99	1.834	0.095	1.68-1.99
α_y	Weight on output growth in Taylor rule	Normal	0.25	0.1	0.259	0.096	0.10-0.42	0.313	0.100	0.15-0.48
$\alpha_{d\pi}$	Weight on change in infl. in Taylor rule	Normal	0.3	0.1	0.253	0.096	0.10-0.41	0.206	0.101	0.04-0.37
α_C	Weight on credit groth in Taylor rule**	Normal	0.05	0.025	0.070	0.024	0.03-0.11	/	/	/
ρ_i	Coeff. on lagged interest rate	Beta	0.8	0.05	0.874	0.013	0.85-0.89	0.884	0.013	0.86-0.90
ρ	Banking technol. shock (x_t^b)	Beta	0.5	0.2	0.981	0.009	0.97-0.999	0.984	0.008	0.97-0.999
ρ	Bank reserve demand shock (ξ_t)***	Beta	0.5	0.2	/	/	/	0.638	0.096	0.48-0.80
ρ	Term premium shock ($\sigma_t^{\aleph}$)	Beta	0.5	0.2	0.936	0.014	0.91-0.96	0.880	0.025	0.84-0.92
ρ	Investm. specific shock ($\mu_{\Upsilon,t}$)	Beta	0.5	0.2	0.975	0.013	0.95-0.999	0.982	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	0.978	0.012	0.96-0.999
ρ	Government consumption shock (g_t)	Beta	0.5	0.2	0.982	0.014	0.96-0.999	0.943	0.022	0.91-0.98
ρ	Persistent product. shock ($\mu_{z,t}^*$)	Beta	0.5	0.2	0.057	0.040	0.01-0.12	0.152	0.070	0.04-0.27
ρ	Transitory product. shock (ϵ_t)	Beta	0.5	0.2	0.973	0.010	0.84-0.92	0.937	0.020	0.90-0.97
ρ	Financial wealth shock (γ_t)	Beta	0.5	0.1^{****}	0.883	0.024	0.96-0.99	0.550	0.026	0.51-0.59
ρ	Riskiness shock (σ_t)	Beta	0.5	0.2^{****}	0.957	0.010	0.94-0.97	0.829	0.026	0.79-0.87
ρ	Consump. prefer. shock ($\zeta_{c,t}$)	Beta	0.5	0.2	0.937	0.016	0.91-0.96	0.892	0.020	0.86-0.92
ρ	Margin. effic. of invest. shock ($\zeta_{i,t}$)	Beta	0.5	0.05	0.580	0.050	0.50-0.66	0.429	0.044	0.36-0.50
ρ	Oil price shock (τ_t^{oil})	Beta	0.5	0.2	0.940	0.023	0.90-0.98	0.934	0.020	0.90-0.97
ρ	Price mark-up shock ($\lambda_{f,t}$)	Beta	0.5	0.2^{****}	0.961	0.025	0.92-0.999	0.720	0.046	0.64-0.80

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	0.0932	0.0086	0.08-0.11	0.0750	0.0059	0.07-0.08
σ	Bank reserve demand shock (ξ_t)***	Inv. Gamma	0.01	5 d	/	/	/	0.0070	0.0005	0.006-0.009
σ	Term premium shock ($\sigma_t^{\aleph}$)	Inv. Gamma	0.01	5 d	0.0031	0.0006	0.001-0.004	0.0055	0.0014	0.003-0.010
σ	Investm. specific shock ($\mu_{\Upsilon,t}$)	Inv. Gamma	0.003	5 d	0.0034	0.0003	0.003-0.004	0.0033	0.0002	0.002-0.004
σ	Money demand shock (χ_t)	Inv. Gamma	0.001	5 d	0.0249	0.0021	0.020-0.030	0.0186	0.0014	0.016-0.021
σ	Government consumption shock (g_t)	Inv. Gamma	0.01	5 d	0.0123	0.0009	0.010-0.020	0.0207	0.0016	0.018-0.024
σ	Persistent product. shock ($\mu_{z,t}^*$)	Inv. Gamma	0.001	5 d	0.0047	0.0004	0.002-0.010	0.0072	0.0006	0.004-0.009
σ	Transitory product. shock (ϵ_t)	Inv. Gamma	0.001	5 d	0.0040	0.0003	0.003-0.005	0.0046	0.0003	0.003-0.005
σ	Financial wealth shock (γ_t)	Inv. Gamma	0.001	5 d	0.0036	0.0007	0.002-0.005	0.0042	0.0004	0.003-0.007
σ	Signal on Fin. wealth shock (γ_{signal})**	Inv. Gamma	$0.001/\sqrt[2]{8}$	5 d	0.0012	0.0003	0.007-0.002	/	/	/
σ	Riskiness shock (σ_t)	Inv. Gamma	0.001	5 d	0.0350	0.0108	0.02-0.05	0.0997	0.0164	0.08-0.13
σ	Signal on Riskiness shock (σ_{signal})	Inv. Gamma	$0.001/\sqrt[2]{8}$	5 d	0.0311	0.0029	0.03-0.04	0.0564	0.0062	0.05-0.07
σ	Consump. prefer. shock ($\zeta_{c,t}$)	Inv. Gamma	0.001	5 d	0.0173	0.0026	0.013-0.021	0.0179	0.0016	0.014-0.021
σ	Margin. effic. of invest. shock ($\zeta_{i,t}$)	Inv. Gamma	0.001	5 d	0.0190	0.0016	0.015-0.022	0.0194	0.0015	0.012-0.218
σ	Oil price shock (τ_t^{oil})	Inv. Gamma	0.01	5 d	0.1521	0.0113	0.13-0.17	0.1300	0.0096	0.11-0.15
σ	Monetary policy shock (ε_t)	Inv. Gamma	0.25	10 d	0.4560	0.0384	0.39-0.52	0.5157	0.0417	0.45-0.58
σ	Price markup shock ($\lambda_{f,t}$)	Inv. Gamma	0.0005	5 d	0.0097	0.0016	0.007-0.014	0.0156	0.0031	0.006-0.019

* 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.

** These parameters are 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. Baseline Model, Measurement Errors: Parameter Estimates

	Prior			Euro area Posterior		US Posterior	
	Type	Mode	b	Mode	St.error (Hessian)	Mode	St.error (Hessian)
Real Credit Growth	Weibull	0.00067 0.0095	5	0.0006	0.0001	0.00090	0.00020
Real M1 Growth	Weibull	0.00098 0.00151	5	0.0010	0.0002	0.00154	0.00031
Real M3 Growth	Weibull	0.00049 0.00074	5	0.0005	0.0001	0.00071	0.00016
Real Net Worth Growth	Weibull	0.00899 0.0090	5	0.0144	0.0011	0.01636	0.00081
External Finance Premium	Weibull	0.00010 0.00005	5	0.0001	0.00002	0.00005	0.00001
Short-term Nominal Interest Rate	Weibull	0.00023 0.00046	5	0.0003	0.00004	0.00023	0.00008
Spread (Long-Short Rate)	Weibull	0.00015 0.00034	5	0.0001	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.

should be Baseline, CEE and BGG models.

Table 6a: EA, Model-Implied Standard Deviation and Standard Deviation of the Corresponding Empirical Variables (in percent)															
	$\Delta(N/P)$	π	$Log,\ H$	$\Delta Loans$	ΔY	$\Delta(W/P)$	ΔI	$\Delta M1$	$\Delta M3$	ΔC	$Premium$	$Spread$	R	$Rel.\ \pi^I$	π^{oil}
Sample Data	8	0.4	1.9	0.72	0.48	0.39	1.3	0.97	0.54	0.49	0.14	0.26	0.77	0.34	15
Benchmark Model	8	0.52	4	1	0.75	0.54	2.4	1.6	3.1	0.79	0.4	0.48	0.51	0.34	15
Financial Accelerator	7.9	0.57	4	1.2	0.74	0.54	2.5	–	–	0.78	0.4	–	0.64	0.34	16
Simple Model	–	0.44	3.3	–	0.67	0.51	1.6	–	–	0.71	–	–	0.38	0.34	16

Table 6b: US, Model-Implied Standard Deviation and Standard Deviation of the Corresponding Empirical Variables (in percent)																
	$\Delta(N/P)$	π	$Log,\ H$	$\Delta Loans$	ΔY	$\Delta(W/P)$	ΔI	$\Delta M1$	$\Delta M3$	ΔC	$Premium$	$Spread$	R	$Rel.\ \pi^I$	π^{oil}	$Reserves$
Sample Data	8.2	0.24	3.1	1.1	0.48	0.67	1.6	1.6	0.79	0.38	0.062	0.33	0.55	0.33	13	5.6
Benchmark Model	5.4	0.68	2.8	3	0.76	0.76	1.9	2.8	4.1	0.72	0.77	0.45	0.5	0.33	13	8.9
Financial Accelerator	5.3	0.67	2.9	4.4	0.76	0.75	2	–	–	0.69	0.74	–	0.52	0.33	13	–
Simple Model	–	0.62	2.9	–	0.8	0.75	1.7	–	–	0.67	–	–	0.45	0.33	13	–

Table 7a: Properties of the Economic Shocks' Innovations in entr=1 Model												
		$\lambda_{f,t}$	π_t^*	ξ_t	xb_t	$\mu_{\Upsilon,t}$	χ_t	g_t	$\mu_{z,t}$	γ_t	ϵ_t	$Mon.Pol.$
Mean		-0.00058	-2.8e-005	0.00025	0.015	0.00036	-0.00017	0.0015	-0.00069	0.00036	0.00014	-0.039
Auto-Correlation		0.02	0.88	-0.26	0.68	0.5	0.42	-0.3	0.03	-0.01	-0.14	0.62
Cross-Correlation												
	$\lambda_{f,t}$	0.02	-0.4	0.12	-0.09	0	-0.13	0.22	-0.19	-0.18	0.22	-0.24
	π_t^*		0.01	0.18	0.14	0.09	0.54	-0.1	0.23	0.34	-0.17	-0.06
	ξ_t			0.01	-0.12	-0.04	0.55	-0.02	0.14	0.16	-0.09	-0.01
	xb_t				0.07	0.27	0.03	-0.07	0.22	0.15	-0.21	-0.67
	$\mu_{\Upsilon,t}$					0.01	0.23	0.13	0.03	0.19	0.1	-0.18
	χ_t						0.02	0.02	0.18	0.21	-0.13	0.2
	g_t							0.03	-0.45	-0.07	0.59	0.17
	$\mu_{z,t}$								0.01	0.05	-0.55	-0.24
	γ_t									0.01	-0.31	-0.08
	ϵ_t										0.01	0.19
	$Mon.Pol.$											0.5
	$patriot,\sigma_t$											
	$signal1,\sigma_t$											
	$signal2,\sigma_t$											
	$signal3,\sigma_t$											
	$signal4,\sigma_t$											
	$signal5,\sigma_t$											
	$signal6,\sigma_t$											
	$signal7,\sigma_t$											
	$signal8,\sigma_t$											
	$\zeta_{c,t}$											
	$\zeta_{i,t}$											
	τ_t^{oil}											
	$TermSpread$											

Note: figures refer to the smoothed innovations.

Table 7a: Properties of the Economic Shocks' Innovations in entr=1 Model, continued

	$patriot,\sigma_t$	$signal1,\sigma_t$	$signal2,\sigma_t$	$signal3,\sigma_t$	$signal4,\sigma_t$	$signal5,\sigma_t$	$signal6,\sigma_t$	$signal7,\sigma_t$	$signal8,\sigma_t$	$\zeta_{c,t}$	$\zeta_{i,t}$	τ_t^{oil}	$TermSpread$
	-0.0027	0.0014	0.001	0.00053	0.00027	0.0001	-1.6e-005	-0.00044	-0.00059	-0.0011	0.0012	-0.012	0.00082
	0.21	0.63	0.34	0.37	0.07	0.02	-0.15	-0.1	-0.38	0.2	-0.27	0.17	0.28
$\lambda_{f,t}$	-0.2	0.26	0.27	0.21	0.19	0.2	0.11	-0.05	-0.05	-0.18	0.07	-0.2	-0.19
π_t^*	0.12	-0.34	-0.3	-0.29	-0.23	-0.17	-0.12	-0.04	0.01	0.09	-0.08	0.2	-0.05
ξ_t	-0.25	0	-0.02	0.08	-0.08	0.02	-0.16	-0.22	-0.23	-0.08	-0.12	0.07	-0.17
xb_t	0.1	0.1	0.01	-0.02	-0.03	-0.01	0	-0.02	0.02	-0.51	0.02	-0.29	0.14
$\mu_{\Upsilon,t}$	0.05	-0.06	-0.04	-0.15	-0.11	-0.07	-0.05	-0.12	-0.04	0.07	-0.01	-0.12	-0.16
χ_t	0.12	-0.28	-0.24	-0.14	-0.08	0.02	-0.04	-0.02	0.03	0.27	-0.04	0.19	-0.11
g_t	-0.11	0.08	0.03	0.11	-0.05	0.06	-0.07	-0.05	-0.07	0.11	0.3	-0.1	-0.24
$\mu_{z,t}$	0.18	-0.06	0.04	0.03	0.15	0	0.15	0.05	0.16	-0.3	-0.02	-0.1	0.21
γ_t	-0.4	-0.48	-0.67	-0.63	-0.7	-0.75	-0.69	-0.7	-0.63	-0.06	0.23	-0.2	0.01
ϵ_t	0.1	0.18	0.21	0.31	0.16	0.28	0.15	0.23	0.17	0.27	-0.18	0.09	-0.34
$Mon.Pol.$	0.08	-0.38	-0.27	-0.17	-0.11	-0.07	-0.02	0.07	0.07	0.59	-0.01	0.2	-0.01
$patriot,\sigma_t$	0.09	0.07	0.24	0.27	0.44	0.54	0.68	0.79	0.88	0.18	-0.16	0.16	0.03
$signal1,\sigma_t$		0.03	0.75	0.71	0.61	0.52	0.38	0.32	0.19	-0.19	-0.07	0.14	-0.07
$signal2,\sigma_t$			0.03	0.75	0.74	0.66	0.58	0.47	0.41	-0.19	-0.19	0.15	-0.12
$signal3,\sigma_t$				0.03	0.71	0.68	0.59	0.51	0.41	-0.1	-0.18	0.08	-0.03
$signal4,\sigma_t$					0.03	0.74	0.73	0.65	0.6	-0.01	-0.25	0.2	0.06
$signal5,\sigma_t$						0.03	0.75	0.72	0.66	0	-0.27	0.13	-0.03
$signal6,\sigma_t$							0.03	0.78	0.78	-0.01	-0.34	0.14	-0.02
$signal7,\sigma_t$								0.03	0.83	0.19	-0.25	0.27	0.05
$signal8,\sigma_t$									0.04	0.15	-0.27	0.22	0.07
$\zeta_{c,t}$										0.02	0.13	0.35	0.01
$\zeta_{i,t}$											0.02	-0.09	0.21
τ_t^{oil}												0.14	-0.11
$TermSpread$													0.01

Note: figures refer to the smoothed innovations.

Table 8b: Log, Marginal Likelihood: News on About Risk, US Baseline Model

$$\hat{\sigma}_t = \rho_\sigma \hat{\sigma}_{t-1} + \xi^0_{\sigma,t} + \xi^1_{\sigma,t-1} + \xi^2_{\sigma,t-2} + ... + \xi^p_{\sigma,t-p}$$

p	log, marginal likelihood	odds, $p = 8$ versus indicated p
1	4325.584	$1.7{\times}10^{31}$
2	4359.521	$3.1{\times}10^{16}$
4	4384.980	$2.7{\times}10^{5}$
6	4394.025	31.9
7	4396.675	2.3
8 (baseline)	4397.487	1.0

Table 9a: Variance Decomposition, HP filtered data, EA (Baseline model)

				x			
shock	output	consumption	investment	hours	inflation	labor productivity	interest rate
σ_{λ_f}	15.02	23.05	2.63	16.37	35.74	1.40	20.46
σ_{x^b}	0.59	1.29	0.02	0.44	0.52	1.44	0.24
σ_{μ_Υ}	0.32	0.01	0.12	0.18	0.08	0.01	0.04
σ_χ	0.02	0.06	0.00	0.02	0.00	0.00	0.00
σ_g	3.26	3.11	0.00	3.34	0.87	0.21	0.48
$\sigma_{\mu_z^*}$	3.72	1.16	0.24	1.42	1.07	10.29	0.72
σ_γ	0.43	0.06	0.92	0.80	0.24	1.52	0.30
σ_ϵ	10.54	21.68	0.49	7.46	16.10	27.52	8.56
$\sigma_{\varepsilon^{\text{policy}}}$	6.22	11.27	1.01	4.14	5.40	0.10	33.15
σ_σ	2.88	0.19	5.11	6.57	0.88	13.17	1.08
$\sigma_{\sigma^{\text{signal}}}$	20.09	1.81	38.09	15.96	9.22	38.24	9.80
σ_σ and $\sigma_{\sigma^{\text{signal}}}$	22.96	2.00	43.20	22.53	10.09	51.41	10.88
σ_{ξ_c}	11.68	32.75	0.15	12.20	11.26	0.83	10.15
σ_{ξ_i}	24.57	1.72	51.14	30.69	10.17	5.22	11.56
$\sigma_{\tau^{\text{oil}}}$	0.42	1.39	0.03	0.24	2.21	0.04	1.32
σ_{long}	0.00	0.00	0.00	0.00	0.00	0.00	0.00
measurement error	0.00	0.00	0.00	0.00	0.00	0.00	1.26
inflation target	0.24	0.43	0.05	0.16	6.23	0.01	0.87
all shocks	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 9b: Variance Decomposition, HP filtered data, EA (Baseline model)

	x					
shock	stock market	credit	spread	term structure	real M1	real M3
σ_{λ_f}	1.83	13.15	0.16	12.36	44.28	1.82
σ_{x^b}	0.00	0.14	0.00	0.10	5.04	42.39
σ_{μ_Υ}	0.18	0.07	0.03	0.07	0.03	0.02
σ_χ	0.00	0.00	0.00	0.00	13.17	22.63
σ_g	0.03	0.10	0.01	0.07	0.44	0.02
$\sigma_{\mu_z^*}$	0.17	0.07	0.05	0.14	0.42	1.29
σ_γ	5.37	25.82	1.86	0.33	0.13	0.15
σ_ϵ	0.10	4.06	0.00	3.40	9.89	0.61
$\sigma_{\varepsilon^{\text{policy}}}$	4.89	1.81	0.99	25.76	13.15	1.58
σ_σ	13.94	5.07	20.58	0.97	1.39	0.76
$\sigma_{\sigma^{\text{signal}}}$	68.29	44.23	75.90	6.79	5.98	6.20
σ_σ and $\sigma_{\sigma^{\text{signal}}}$	82.22	49.30	96.48	7.76	7.38	6.96
σ_{ξ_c}	0.02	1.72	0.02	3.99	2.46	15.40
σ_{ξ_i}	1.90	2.54	0.27	8.77	1.18	6.17
$\sigma_{\tau^{\text{oil}}}$	0.14	0.94	0.05	0.56	1.87	0.15
σ_{long}	0.00	0.00	0.00	36.05	0.00	0.00
measurement error	2.89	0.19	0.02	0.32	0.21	0.02
inflation target	0.24	0.10	0.05	0.34	0.35	0.80
all shocks	100.00	100.00	100.00	100.00	100.00	100.00

Table 10a: Variance Decomposition, HP filtered data, US

				x			
shock	output	consumption	investment	hours	inflation	labor productivity	interest rate
σ_{λ_f}	11.88	18.67	3.74	12.39	23.26	3.28	12.85
ξ	0.00	0.00	0.00	0.01	0.00	0.01	0.00
σ_{x^b}	0.38	1.02	0.01	0.23	0.47	1.08	0.21
σ_{μ_Υ}	0.33	0.04	0.32	0.22	0.16	0.03	0.14
σ_χ	0.01	0.04	0.00	0.01	0.00	0.00	0.00
σ_g	11.13	3.09	0.03	10.22	4.24	1.79	3.22
$\sigma_{\mu_z^*}$	6.56	1.92	0.85	2.52	3.81	20.59	2.99
σ_γ	0.33	0.21	1.04	3.06	0.41	6.61	0.64
σ_ϵ	0.23	0.44	0.04	13.08	14.95	34.35	4.27
$\sigma_{\varepsilon^{\text{policy}}}$	4.02	9.37	0.26	3.71	4.80	0.68	22.04
σ_σ	2.32	0.56	3.56	1.34	0.38	4.14	0.48
$\sigma_{\sigma^{\text{signal}}}$	18.92	5.77	31.44	14.52	8.28	18.20	12.93
σ_σ and $\sigma_{\sigma^{\text{signal}}}$	21.24	6.34	35.00	15.87	8.67	22.34	13.42
σ_{ξ_c}	15.61	52.66	0.03	14.46	18.81	2.59	22.03
σ_{ξ_i}	27.57	3.49	58.57	23.93	11.78	6.43	14.51
$\sigma_{\tau^{\text{oil}}}$	0.58	2.41	0.10	0.17	3.83	0.20	2.34
σ_{long}	0.00	0.00	0.00	0.00	0.00	0.00	0.00
measurement error	0.00	0.00	0.00	0.00	0.00	0.00	0.55
inflation target	0.13	0.30	0.01	0.13	4.83	0.03	0.79
all shocks	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 10b: Variance Decomposition, HP filtered data, US

shock	stock market	credit	premium	term structure	real M1	real M3	nb reserves
				x			
σ_{λ_f}	1.39	1.71	0.01	12.96	30.12	5.61	7.62
ξ	0.00	0.00	0.00	0.00	0.21	0.08	53.31
σ_{x^b}	0.00	0.02	0.00	0.11	8.54	28.88	2.71
σ_{μ_Υ}	0.11	0.03	0.00	0.14	0.07	0.08	0.03
σ_χ	0.00	0.00	0.00	0.00	17.91	5.66	13.26
σ_g	0.05	0.19	0.02	1.59	0.93	1.40	1.05
$\sigma_{\mu_z^*}$	0.19	0.07	0.02	0.65	0.31	2.94	0.44
σ_γ	3.58	13.13	0.81	0.46	0.62	0.35	0.18
σ_ϵ	0.04	0.33	0.02	3.70	1.52	3.02	1.33
$\sigma_{\varepsilon^{\text{policy}}}$	1.26	0.14	0.02	15.70	21.42	8.25	8.44
σ_σ	19.96	10.00	36.23	0.67	0.46	0.30	0.14
$\sigma_{\sigma^{\text{signal}}}$	61.30	71.95	62.65	15.24	5.50	7.63	3.42
σ_σ and $\sigma_{\sigma^{\text{signal}}}$	81.26	81.94	98.88	15.92	5.96	7.92	3.57
σ_{ξ_c}	0.09	0.83	0.07	10.63	5.06	25.23	3.38
σ_{ξ_i}	2.30	1.24	0.12	13.51	3.26	9.19	3.43
$\sigma_{\tau^{\text{oil}}}$	0.08	0.32	0.02	1.11	3.36	0.71	1.07
σ_{long}	0.00	0.00	0.00	22.43	0.00	0.00	0.00
measurement error	9.59	0.03	0.00	0.88	0.34	0.02	0.01
inflation target	0.05	0.00	0.00	0.23	0.36	0.64	0.19
all shocks	100.00	100.00	100.00	100.00	100.00	100.00	100.00