Inflation indicators in a sticky price framework*

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Abstract

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1 Introduction

The basic New Keynesian model has become the standard tool for analyzing monetary policy, see for example Galí (2002) and Woodford (2003). The main feature of this framework is the integration of imperfect competition and price stickiness into a dynamic general equilibrium model. This means that inflation depends on real marginal costs and not directly on a traditional output gap measure (such as actual output minus a measure of detrended output). However, real marginal costs can be related to a flexible-price output gap; that is, actual output minus flexible-price output. Neiss and Nelson (2005) argue that the flexible-price output gap is a more reliable indicator of future inflation than traditional output gaps.

Furthermore, the flexible-price real interest rate gap, defined as the difference between the actual real interest rate and the flexible-price real interest rate, has received increased attention among central banks as a measure of the monetary policy stance and as a useful indicator of future inflation rates. Neiss and Nelson (2003) show that the real interest rate gap can be measured with less uncertainty than the output gap, which makes it a more reliable indicator for inflation.

Analyses based on the basic New Keynesian model usually only include one nominal friction; that is, price stickiness, and they lack capital accumulation. Hence, an important drawback with these models will be that they are unlikely to be empirically relevant except for a very few number of variables. For this reason, we extend the basic New Keynesian model with a number frictions and shocks that are necessary to account for the main properties of the data, following Smets and Wouters (2003), Christiano, Eichenbaum and Evans (2005), and Adolfson et al. (2005a). The results should therefore be of relevance for giving monetary policy advice in practice.

We ask to what degree the results based on the basic New Keynesian model also hold in more general specifications that include a large number of frictions and shocks. The focus is on the relationships between inflation and a number of inflation indicators, or measures of economic activity, that have been proposed in the New Keynesian literature. Specifically, we consider four different inflation indicators: (i) the trend-adjusted output gap (ii) the flexible-price output gap (iii) the flexible-price real interest rate gap and (iv) the real marginal cost. To capture the open economy aspects of the relationships we look at two measures of inflation; that is, the CPI and the domestic inflation rates.

We specify four different models each with a different sets of frictions. This enables us to identify what frictions matters quantitatively for the relationships. The first model, $\mathcal{M}_0$, is the benchmark model and includes sticky wages, habit formation, variable capacity utilization and an open economy sector. In the next model, $\mathcal{M}_1$, we assume away wage stickiness. In model $\mathcal{M}_2$ we assume away, in addition to wage stickiness, habit formation and variable capacity utilization. In the final model, $\mathcal{M}_3$, we consider a closed economy version, where we shut down the open economy sector in addition to wage stickiness, habit formation and variable capacity utilization. Each model is estimated with Bayesian methods on Swedish data from 1980 to 2005.

Moreover, in addition to different specifications of the frictions, the indicator properties depend on the different shocks that hit the economy. To this end, we calculate the correlations between inflation and the indicator variables for each one of the shocks in the model. To account for the aggregate fluctuations in the data we allow for a large number shocks, namely four types of technology shocks, two types of preference shocks, four types of mark up shocks, two different monetary policy shocks, a risk premium shock, fiscal policy shocks and foreign shocks.

Finally, we provide results from a variance decomposition where we quantify what shocks are important in driving the aggregate fluctuations in the inflation rates and the indicator variables. Based on this information we make a historical decomposition with the most important shocks and show the development from 1986 to 2005.

The key findings are the following. The flexible-price real interest rate gap (the real interest rate gap for short) is a reliable indicator of the CPI and the domestic inflation rates in all models. It has a clear and significant negative relationship with both inflation measures. On the other hand, the indicator properties of the flexible-price output gap depends to a large extent on the open economy sector. In our benchmark economy the correlation between the flexible-price output gap and inflation is very low. Furthermore, the trend-adjusted output gap shows little or no relation to inflation in the models.

Generally the relationships between endogenous variables depend on the shocks that hit the economy. However, for virtually all the shocks in the model the relationship between the real interest rate gap and the inflation rate turns out to be negative. On the other hand, the relationship between the flexible-price output gap and the inflation rate varies much more depending on the type of shock. For example, different technology shocks give rise to a positive relationship, while other shocks like the labor supply shock and the risk premium shock give rise to a negative relationship. This means that when accounting for all shocks the relationship becomes weak. A similar story explains the weak relationship between the trend adjusted output gap and inflation.

The flexible-price output gap is generally an unreliable measure of the marginal cost. This is due to both nominal wage stickiness and the open economy sector. In the benchmark model the flexible-price output gap is only weakly correlated with the firm's real marginal cost.

To summarize the quantitative importance of the frictions we found that habit formation and variable capacity utilization have small effects on the indicator properties while wage stickiness and the open economy sector are quantitatively important.

Related studies include Smets and Wouters (2003) who calculate the flexible-price output gap and real interest rate gap for the Euro area. Lam and Tkacz (2004) study the indicator properties of the real interest rate gap in a dynamic general equilibrium model calibrated to fit the Canadian data. They find that the real interest rate gap is a good predictor for output growth but the results for the inflation rate are less supportive. In a study based on Euro data Giammarioli and Valla (2003) have investigated the benefits of including a time varying natural interest rate in a Taylor rule. The improvement in terms of stabilization was found to be small. Edge, Kiley and Laforte (2005) generate a flexible-price output gap series for the United States in a multi-sector framework. Their output gap series is appealing in the sense that it captures the business cycle fluctuations in a way that is consistent with the NBER dated recessions and the FRB/US model. However, the flexible-price real interest rate they obtain is very volatile. A result they attribute to the presence of habit formation.

The paper proceeds as follows. In section 2 we present the dynamic general equilibrium model and in section 3 the model is estimated on Swedish data. Section 4 reports the quantitative results. Finally, section 5 concludes.

2 Economic environment

Following Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003) our benchmark model includes a number frictions that generate intrinsic persistence in the propagation of shocks. The nominal frictions include staggered nominal price and wage contracts with partial indexation, cash-in-advance on the wage bill and money in the utility function. The real frictions include habit formation in consumption, investment adjustment costs and variable capacity utilization. Furthermore the model includes a large number exogenous disturbances in order to account for the variations in the data.

The benchmark model $\mathcal{M}_0$ is described in some detail. The other three models, $\mathcal{M}_1$, $\mathcal{M}_2$ and $\mathcal{M}_3$ are subsets of this model where one or a number of the frictions have been deleted.

2.1 Households

The economy is inhabited by a continuum of j households distributed on the unit interval $[0,1]$. Households are identical, except for the differentiated labor service they supply. Time is discrete $t = 0, 1, .., \infty$. Formally, each household j solves

$$\max_{\{C_t, H_{j,t}, M_{t+1}, B^*_{t+1}, K_{t+1}, I_t, Q_t, U_t\}_{t=0}^{\infty}} \mathrm{E} \sum_{t=0}^{\infty} \beta^t \mathcal{U}\left(C_t, C_{t-1}, H_{j,t}, Q_t; \varsigma_t^c, \varsigma_t^h\right), \tag{1}$$

where $C_t, H_{j,t}$ and Q_t denote composite consumption, specialized labor supply and nominal cash holdings, respectively, while ς_t^c and ς_t^h denote two exogenous preference shocks, and $\beta \in (0,1)$ is a parameter denoting the subjective discount factor.

The period utility index takes the standard iso-elastic form

$$\mathcal{U}\left(C_t, H_{j,t}, Q_t; \varsigma_t^c, \varsigma_t^h\right) = \varsigma_t^c \ln\left(C_t - bC_{t-1}\right) + A_q \frac{\left(Q_t/P_t/z_t\right)^{1-\sigma_q}}{1-\sigma_q} - \varsigma_t^h A_L \frac{\left(H_{j,t}\right)^{1+\sigma_L}}{1+\sigma_L}, \tag{2}$$

where z_t denotes an exogenous "unit-root" technology process, $b \in [0,1)$ is a parameter measuring the degree of habit formation, A_q and A_L are parameters measuring the weight on cash balances and the disutility of work, respectively, σ_q and σ_L are parameters measuring the elasticity of substitution.

Aggregate consumption is assumed to be given by a CES index of domestically produced goods, C_t^d, and imported goods, C_t^m, according to

$$C_t = \left[(1-\omega_c)^{\frac{1}{\eta_c}} \left(C_t^d\right)^{\frac{\eta_c - 1}{\eta_c}} + \omega_c^{\frac{1}{\eta_c}} \left(C_t^m\right)^{\frac{\eta_c - 1}{\eta_c}}\right]^{\frac{\eta_c}{\eta_c - 1}}, \tag{3}$$

where ω_c is a parameter measuring the weight on imported consumption goods and η_c is a parameter measuring the elasticity of substitution between domestic and imported consumption goods.

The household objective is maximized subject to three constraints. The first is the law of motion for the (physical) capital stock, K_{t+1}, that is

$$K_{t+1} = (1-\delta) K_t + \Upsilon_t \left(1 - \mathcal{S}\left(I_t/I_{t-1}\right)\right) I_t$$

where I_t denotes aggregate investment, Υ_t an exogenous investment-specific technology shock and δ is a parameter denoting the depreciation rate of physical capital. The function $\mathcal{S}$ introduces investment adjustment costs. The function is assumed, in steady state, to satisfy $\mathcal{S} = \mathcal{S}' = 0$ and $\mathcal{S}'' > 0$.

Aggregate investment is given by a CES index of domestically produced goods, I_t^d, and imported goods, I_t^m, according to

$$I_t = \left[(1 - \omega_i)^{\frac{1}{\eta_i}} \left(I_t^d \right)^{\frac{\eta_i - 1}{\eta_i}} + \omega_i^{\frac{1}{\eta_i}} \left(I_t^m \right)^{\frac{\eta_i - 1}{\eta_i}} \right]^{\frac{\eta_i}{\eta_i - 1}}, \tag{4}$$

where ω_i is a parameter measuring the weight on imported investment goods and η_i is a parameter measuring the elasticity of substitution across investment goods.

Households supply differentiated labour services in monopolistically competitive labor markets, which imply some market power on their own labor market. Each household is thus a wage-setter but is constrained by its labor demand equation

$$H_{j,t} = \left(\frac{W_{j,t}}{W_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} H_t, \tag{5}$$

where W_t, $W_{j,t}$, H_t denote the aggregate nominal wage level, the individual nominal wage and the composite labor supply, respectively, and $\lambda_w/(1-\lambda_w) > 1$ measures the elasticity of substitution between differentiated labor inputs while λ_w is the wage markup.

Finally, maximization is subject to an intertemporal budget constraint

$$\begin{aligned} & (1 + \tau_t^c) P_t^c C_t + P_t^i I_t + P_t \mathcal{A}(U_t) K_t + M_{t+1} + S_t B_{t+1}^* \qquad (6) \\ = & \left(1 - \tau_t^h\right) W_t H_{j,t} + R_t^k U_t K_t + R_{t-1}(M_t - Q_t) + Q_t \\ & + R_{t-1}^* \mathcal{G}(\cdot) S_t B_t^* + \Pi_t + TR_t, \end{aligned}$$

where τ_t^h denotes the labor income tax, τ_t^c the consumption tax, M_{t+1} the stock of money, Q_t nominal cash balances, the difference $M_t - Q_t$ is thus deposited with the financial intermediary where it earns a nominal interest rate R_{t-1}, R_t^k denotes the nominal rental rate of capital, the capital stock is related to capital services, K_t^s, through the relationship $K_t^s = U_t K_t$, where U_t denotes the utilization rate of capital, the function $\mathcal{A}(U_t) K_t$ measures the cost of setting the utilization rate to U_t and satisfies: $U = 1$, $\mathcal{A}(1) = 0$ and $\mathcal{A}' = R^k$ in steady state and $\mathcal{A}''(U_t) \geq 0$, S_t denotes the nominal exchange rate defined as foreign currency per unit of domestic currency, B_t^* nominal foreign bonds, the function $\mathcal{G}(\cdot)$ represents the risk premium on foreign bonds, R_{t-1}^* denotes the nominal interest rate on foreign bonds, TR_t a lump-sum transfer from the government including seigniorage, and Π_t profits from firms producing intermediate inputs.

The risk premium on the foreign bond holdings depends on the net foreign asset position and the expected change in the exchange rate in the following way

$$\mathcal{G}(A_t, S_{t+1}, S_{t-1}; \tilde{\phi}_t) = \exp\left(-\tilde{\phi}_a (A_t - \bar{A}) - \tilde{\phi}_s \left(\mathrm{E}_t \frac{S_{t+1}}{S_{t-1}} - 1\right) + \tilde{\phi}_t\right),$$

where A_t denotes the net foreign assets of the domestic households, $\tilde{\phi}_t$ an exogenous shock to the risk premium while $\tilde{\phi}_a$ and $\tilde{\phi}_s$ are parameters. The somewhat *ad hoc* inclusion of the term $\mathrm{E}_t S_{t+1}/S_{t-1}$ is motivated by the work of Adolfson et al. (2005a) and Duarte and Stockman (2005). In order to ensure a well defined steady state it is assumed that the premium on foreign bond holdings depends on the net foreign asset position, see Schmitt-Grohé and Uribe (2001).

Wage setting is subject to nominal rigidities à la Calvo (1983) and Erceg, Henderson and Levin (2000). In each period a fraction of households, ξ^w, are unable to re-adjust wages. These households index their wage rate to last period's CPI inflation rate, the inflation target, $\bar{\pi}_{t+1}^c$, as follows

$$W_{j,t+1} = (\pi_t^c)^{\kappa_w} \left(\bar{\pi}_{t+1}^c\right)^{(1-\kappa_w)} \mu_{z,t+1} W_{j,t}^{new}, \tag{7}$$

where $\mu_{z,t+1} = z_{t+1}/z_t$ and κ_w is an indexation parameter.

For those households that are allowed to reoptimize their wage rate it is convenient to formulate the wage setting problem in the following way

$$\max_{W_{j,t}^{new}} \quad \mathrm{E}\sum_{s=0}^{\infty} (\beta\xi_w)^s \,\mathcal{U}\left(C_t, H_{j,t}, Q_t; \varsigma_t^c, \varsigma_t^h\right), \tag{8}$$
$$\text{s.t.} \quad (5), (6) \text{ and } (7).$$

2.2 Intermediate domestic good producing firms

Intermediate goods producing firms act as monopolists and face the demand function $Y_{i,t}$ for good i. Each good is produced by a single firm. The firms take the wage rate, the rental rate of capital and the prices of the other firms as given when choosing prices, labor and capital to maximize profits. There is no entry or exit and potential profits are allocated to the households. The intermediate good firms minimize costs

$$\min_{H_{i,t}, K_{i,t}} W_t R_t^f H_{i,t} + R_t^k K_{i,t}^s \tag{9}$$

subject to the increasing returns to scale production technology

$$Y_{i,t} = \epsilon_t z_t^{1-\alpha} \left(K_{i,t}^s\right)^{\alpha} \left(H_{i,t}\right)^{1-\alpha} - z_t\phi, \tag{10}$$

where $K_{i,t}^s$ denotes capital services, which may differ from physical capital since we allow for variable capital utilization, ϵ_t denotes an exogenous temporary technology shock, ϕ is a parameter that measures the fixed cost in production, and α is a parameter measuring capital's share in production. The inclusion of R_t^f reflects a working capital assumption. That is, we assume that a fraction, ν, of the firm's wage bill has to be financed in advance by loans from the financial intermediary. The labor costs for the firms are thus $W_t R_t^f H_{i,t}$ and R_t^f is defined as

$$R_t^f = \nu R_{t-1} + 1 - \nu. \tag{11}$$

Each intermediate firm faces a random probability $(1 - \xi_d)$ that makes it possible to reoptimize its price in any period, following Calvo (1983). This price is denoted $P_t^{d,new}$. The firms that are not allowed to optimize their price simply update their prices according to

$$P_{t+1}^{d} = \left(\pi_{t}^{d}\right)^{\kappa_d} \left(\bar{\pi}_{t+1}^{c}\right)^{1-\kappa_d} P_{t}^{d,new} \tag{12}$$

where κ_d is a parameter determining the weight given to domestic inflation, π_t^d. Firm i solves the following optimization problem when setting its price

$$\begin{aligned} \max_{P_t^{d,new}} \mathrm{E}\sum_{s=0}^{\infty} \left(\beta\xi_d\right)^s \upsilon_{t+s}[(\left(\pi_t^d\pi_{t+1}^d...\pi_{t+s-1}^d\right)^{\kappa_d} \left(\bar{\pi}_{t+1}^c\bar{\pi}_{t+2}^c...\bar{\pi}_{t+s}^c\right)^{1-\kappa_d} P_t^{d,new})Y_{i,t+s} \\ -MC_{i,t+s}^d(Y_{i,t+s} + z_{t+s}\phi^j)], \end{aligned} \tag{13}$$

where υ_{t+s} denotes the marginal utility of nominal income in period $t+s$ and $MC_{i,t+s}^d$ the firm's nominal marginal cost.

2.3 Final domestic good firms

There is a continuum of final goods firms on the unit interval $i \in [0,1]$ that buy differentiated goods from the intermediate goods firms and produce the final composite good using a CES production technology. The maximization problem is formally given by

$$\max_{Y_{i,t},Y_t} \left[P_tY_t - \int_0^1 P_{i,t}Y_{i,t}di\right] \tag{14}$$

subject to the following CES production function

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{1}{\lambda_{d,t}}} di\right]^{\lambda_{d,t}}, \tag{15}$$

where $\lambda_{d,t}$ is an exogenous time-varying markup shock in the domestic goods market.

2.4 Importing and exporting firms

A continuum of importing consumption and investment firms purchase a homogenous good at price P_t^* in the world market, and differentiate this good by brand naming. The nominal marginal cost of the importing firms is thus $S_tP_t^*$. The differentiated import goods are subsequently aggregated by an import consumption and investment packer, so that the final import goods are each a CES composite according to

$$C_t^m = \left[\int_0^1 \left(C_{i,t}^m \right)^{\frac{1}{\lambda_{mc,t}}} di \right]^{\lambda_{mc,t}}, \quad I_t^m = \left[\int_0^1 \left(I_{i,t}^m \right)^{\frac{1}{\lambda_{mi,t}}} di \right]^{\lambda_{mi,t}}, \tag{16}$$

where $\lambda_{mc,t}$ and $\lambda_{mi,t}$ are the exogenous time-varying markup shocks in the import consumption, mc, and import investment, mi, sectors.

We assume that the consumption and investment importers invoice in the domestic currency. In order to allow for short-run incomplete exchange rate pass-through to import prices we introduce nominal rigidities in the local currency price. This is modeled through the same type of Calvo setup as for the intermediate goods producers, as described above.

The exporting firms buy the (homogenous) domestic final good at price P_t^d and turn this into a differentiated export good through the same type of brand naming technology as the importers. The nominal marginal cost of the exporting firms are thus P_t^d/S_t. The differentiated export good is subsequently aggregated by an export packer in the following way

$$X_t = \left[\int_0^1 \left(X_{i,t} \right)^{\frac{1}{\lambda_{x,t}}} di \right]^{\lambda_{x,t}}, \tag{17}$$

where X_t denotes aggregate exports and $\lambda_{x,t}$ is an exogenous time-varying markup shock.

The exporters are assumed to invoice in the foreign currency. To model short-run incomplete exchange rate pass-through to export prices we introduce nominal rigidities in the local currency price. As was the case for the importers we model this through the Calvo setup. The price setting problem of the exporting firms is thus analogous to that of the domestic and importing firms.

Finally, foreign demand for domestic goods is given by

$$X_t = \left(\frac{P_t^x}{P_t^*} \right)^{-\eta_f} Y_t^* \tilde{z}_t^* \tag{18}$$

where P_t^x denotes the export price (in foreign currency), P_t^* the foreign price level, Y_t^* foreign output, η_f the elasticity of substitution between export and foreign goods, and $\tilde{z}_t^*$ a stationary technology shock measuring the relative technological progress in the domestic economy versus the foreign economy.

2.5 Monetary and fiscal authorities

The monetary authority's conduct of monetary policy is approximated with a generalized Taylor (1993) rule, which in its log-linearized form is given by

$$\begin{aligned} \widehat{R}_t &= \rho_R \widehat{R}_{t-1} + (1-\rho_R)\left(\widehat{\bar{\pi}}_t^c + r_\pi\left(\hat{\pi}_{t-1}^c - \widehat{\bar{\pi}}_t^c\right) + r_y \hat{Y}_{t-1} + r_x \hat{X}_{t-1}\right) \\ &\quad + r_{\Delta\pi}\Delta\hat{\pi}_t^c + r_{\Delta y}\Delta\hat{Y}_t + \hat{\varrho}_t, \end{aligned} \tag{19}$$

where $\hat{\pi}_t^c$ denotes the CPI inflation rate index,[1] $\widehat{\bar{\pi}}_t^c$ an exogenous time-varying inflation target shock, $\hat{Y}_{t-1}$ the output gap measured as deviation of actual output from trend output, $\hat{X}_{t-1}$ the real exchange rate, $\hat{\varrho}_t$ an exogenous monetary policy shock, while ρ_R, $r_\pi, r_y, r_x, r_{\Delta\pi}$, and $r_{\Delta y}$ are parameters.

The government's budget constraint in nominal terms is given by

$$P_t G_t + TR_t = R_{t-1}\left(M_{t+1} - M_t\right) + \tau_t^c P_t^c C_t + \tau_t^h W_t H_t \tag{20}$$

where G_t denotes government consumption, which is exogenously given. Hence, the transfers are endogenous and has the interpretation of a budget deficit since there is no government debt. The tax-rates and government consumption are estimated in a simple VAR-model.

2.6 Exogenous shock processes

The following exogenous shock processes are in their log-linearized form given by

$$\hat{\Theta}_t = \rho\hat{\Theta}_{t-1} + \varepsilon_t, \qquad \varepsilon_t \sim N(0, \sigma^2) \tag{21}$$

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[1] Formally $\hat{\pi}_t^c = \left((1-\omega_c)\left(\gamma^{d,c}\right)^{1-\eta_c}\right)\widehat{\pi}_t^d + \left((\omega_c)\left(\gamma^{mc,c}\right)^{(1-\eta_c)}\right)\widehat{\pi}_t^{m,c}$

where $\Theta_t = \left\{ \epsilon_t, \mu_{z,t}, \Upsilon_t, \tilde{z}_t^*, \varsigma_t^c, \varsigma_t^h, \varrho_t, \bar{\pi}_t^c, \widetilde{\phi}_t, \lambda_{d,t}, \lambda_{mc,t}, \lambda_{mi,t}, \lambda_{x,t} \right\}$, $0 < \rho < 1$, and $\sigma \geq 0$.

Tax-rates and government expenditures are modelled as an exogenous vector process. This process is estimated as a VAR model. The following VAR model is estimated

$$\Gamma_0 \tau_t = \Gamma(L) \tau_{t-1} + \varepsilon_{\tau,t}, \qquad \varepsilon_{\tau,t} \sim N(0, \Sigma_\tau) \tag{22}$$

where $\tau_t = \begin{pmatrix} \hat{\tau}_t^h & \hat{\tau}_t^c & \tilde{G}_t \end{pmatrix}'$, and $\tilde{G}_t$ denotes detrended (HP-filtered) government expenditures.

The foreign economy is modelled in a separate VAR model

$$F_0 X_t^* = F(L) X_{t-1}^* + \varepsilon_{x^*,t}, \qquad \varepsilon_{x^*,t} \sim N(0, \Sigma_{x^*}). \tag{23}$$

where $X_t^* = \begin{pmatrix} \pi_t^* & \hat{y}_t^* & R_t^* \end{pmatrix}'$, π_t^* denotes the foreign inflation rate, R_t^* the foreign interest rate and $\hat{y}_t^*$ the foreign HP-filtered output.

2.7 Equilibrium

We assume a symmetric and competitive equilibrium in which behavior is identical across households and across firms. This allows us to treat the economy as comprising of a representative household and a representative firm.

In addition to aggregate consistency, all markets clear. This implies, among other things, that the aggregate resource constraint holds

$$C_t^d + I_t^d + G_t + X_t = \epsilon_t z_t^{1-\alpha} \left(K_{i,t}^s\right)^\alpha \left(H_{i,t}\right)^{1-\alpha} - z_t \phi - \mathcal{A}(U_t) K_t, \tag{24}$$

the accumulation of foreign assets follows

$$S_t B_{t+1}^* = S_t P_t^x X_t - S_t P_t^* \left(C_t^m + I_t^m\right) + R_{t-1}^* \mathcal{G}(\cdot) S_t B_t^*, \tag{25}$$

and the loan market equilibrium condition holds

$$\nu W_t H_t = M_{t+1} - Q_t. \tag{26}$$

To ensure the existence of a time-invariant decision rule, all variables need to be stationary. Hence, the real variables are detrended with the real growth rate and nominal variables with the nominal price level; that is, we assume that real money balances are stationary. The set of equations that characterize the equilibrium can be found in Adolfson et al. (2005a). To find the decision rules, we use a numerical algorithm suggested by Anderson and Moore (1985). In order to calculate the flexible-price economy we extend the state space representation of the model with "flexible-price-and-wage" variables. These variables are the same as in the standard version of the model but are solved under the assumption of flexible-prices and wages and no markup shocks.

2.8 Definitions of the output gaps, the real marginal cost, and the real interest rate gap

Nominal marginal costs for intermediate goods producing firms is given by

$$MC_t^d = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \frac{1}{\epsilon_t {z_t}^{1-\alpha}} (R_t^k)^\alpha \left(W_t R_t^f \right)^{1-\alpha}, \tag{27}$$

and real marginal costs are thus given by

$$mc_t = \frac{MC_t^d}{P_t^d}. \tag{28}$$

We consider two definitions of the output gap. The first gap is defined as deviations of output from detrended output

$$\hat{y}_t = \ln Y_t - \ln \bar{Y}. \tag{29}$$

This trend-adjusted output gap is intended to capture traditional definitions where potential output follows a smooth trend. The second gap is defined as deviations of output from its flexible-price counterpart

$$y_t^{fp} = \ln Y_t - \ln Y_t^{flex}, \tag{30}$$

where the flexible-price output is defined as the level that would prevail in the absence of price and wage stickiness and markup shocks. This definition has become standard in the New Keynesian literature, see Smets and Wouters (2003) and Edge, Kiley, and Laforte (2005).

The real interest is calculated as

$$r_t = R_t - E_t \pi_{t+1}, \tag{31}$$

which implies that the real interest rate gap is given by

$$rr_t = r_t - r_t^{flex}. \tag{32}$$

3 Bayesian estimation

The model is estimated applying Bayesian techniques advanced by Schorfheide (2000) and Smets and Wouters (2003). This involves a two-step procedure involving calibration and Bayesian methods. In practice we impose a prior distribution on the structural parameters. A posterior density function is then generated by combining the prior with the likelihood function. To form the likelihood function we rewrite the reduced form solution of the model in state-space form. A measurement equation maps the unobserved state variables to the observed variables. We then apply the Kalman filter to calculate the likelihood function of the observed variables. The joint posterior distribution of all estimated parameters is obtained in two steps. First, the posterior mode and Hessian matrix evaluated at the mode is computed using standard numerical optimization routines. Second, the Hessian matrix is used in the Metropolis-Hastings algorithm to generate a sample from the posterior distribution. We use a sample of 500,000 post burn-in draws from the posterior distribution.

A number of parameters are calibrated since they are (i) "deep" parameters relating to preferences and technology and (ii) affect only steady state ratios and are therefore not identified.

A time period is taken to be one quarter. The depreciation rate, δ, is set to 0.01 and the capital share in production, α, is set to 0.25 in order to match the investment-output ratio and the labor income-output ratio. The discount factor, β, is set to 0.999, which arguably is a relatively high value. However, this high value is necessary in order to match a nominal risk-free interest rate of about 4 percent annually. The labour supply elasticity, σ_L, as well as the share of the wage bill financed by loans, ν, is set to 1, following Christiano; Eichenbaum and Evans (2005). The money growth is set to 4.25 percent which together with the (estimated) steady state growth rate of productivity yields an inflation rate close to 2 percent annually.

The following variables are set to their sample averages: the labour income and consumption taxes; that is, $\tau^h = 0.30$ and $\tau^c = 0.24$, respectively; the government expenditures-output ratio is set to 0.30 and the share of imports in consumption and investment; that is, $\omega_c = 0.40$ and $\omega_i = 0.70$, respectively.

In selecting the prior distributions we follow the practice of assuming the inverse gamma distribution for the parameters bounded to be positive, the beta distribution for the parameters bounded between zero and one, and the normal or the truncated normal distributions for the remaining parameters. The prior distribution of the estimated parameters corresponds to those in Adolfson et al. (2005a). A difference is the prior for the capital utilization parameter σ_a, though, which in this paper is assumed to be 2. Note also that the monetary policy shock, the labor supply shock, and the four markup shocks are assumed to be iid. Table 1 shows the prior distribution of the estimated parameters together with the posterior distribution. The marginal likelihood of the four models are also reported in Table 1.

4 Indicator properties

The prior distribution play an important role in the Bayesian estimation framework. It is therefore informative to also report the implications of the priors. Unconditional and conditional second moments are used as measures of the indicator properties. Note that since we are studying relationships between various endogenous variables, it is not possible to discuss causality.

The aim of the exercises is to evaluate how the indicator properties depend on real and nominal frictions as well as the shocks that hit the economy. In subsection 4.1 the focus is on the frictions, while subsection 4.2 focuses on the shocks.

4.1 Unconditional second moments

Figure 1 shows correlations and autocorrelations for the benchmark model $\mathcal{M}_0$. The dashed black line shows the results from the prior distribution and the solid red line the results from the posterior distribution. The probability intervals contain 90% of the sample draws. In general, the correlations and autocorrelations from the prior and the posterior distributions are not identical although they are qualitatively similar. The probability intervals are smaller in the posterior distribution, which indicates that there is information in the data for the parameter estimates.

There is a clear and significant negative relationship between the real interest rate gap and the CPI as well as the domestic inflation rate. This extends the results in Neiss and Nelson (2003) to an empirically relevant framework that include nominal wage stickiness, a greater number of real frictions and a formal open economy sector. Moreover, the flexible-price output gap has a positive but weak relationship with both inflation measures, while the trend adjusted output gap has no relation. This suggests that the real interest rate gap is a more reliable indicator of inflation than the output gap.

Real marginal costs are the fundamental determinant of the inflation rate in the New Keynesian model. However, there is not a one-to-one relationship between real marginal costs and the inflation rate. This relationship, as any other relationship in the model, depends on the frictions and the shocks that hit the economy. Still, there is a positive relationship between the domestic inflation rate and the real marginal cost; accounting for the probability intervals the contemporaneous correlation coefficient lies in the range 0.2 to 0.3. Note that the correlation between the expected domestic inflation rate and real marginal costs is stronger. This is due to the Calvo contracts. If a large portion of the firms are not able to change their prices in the current period in response to a rise in real marginal costs the effect on the aggregate inflation rate will be small. However, expected inflation rises since firms are be able to change their prices in future periods. A similar pattern also holds for the relationship between the CPI and the real marginal cost.

The real interest rate gap is only weakly related to the flexible-price output gap and has no relation to the trend-adjusted output gap. On the other hand, it is strongly related to real marginal costs and domestic inflation expectations. The traditional view of the transmission mechanism is assumed to work through the output gap which in turn affects the inflation rate. The benchmark model gives only weak quantitative support for this view. The channel that works through inflation expectations and real marginal costs is quantitatively more important.

To summarize: many of the qualitative findings from the basic New Keynesian model also hold in the benchmark model but quantitatively the strength of the relationships are weaker. This is particularly the case for the indicator value of the flexible-price output gap. On the other hand, the real interest rate gap is a reliable indicator of both the CPI and the domestic inflation rates.

Figure 2 displays the results for model $\mathcal{M}_1$. These results can be compared to those from $\mathcal{M}_0$

in order to quantify how nominal wage stickiness affects the indicator properties. Generally the correlations in the two models are qualitatively and quantitatively similar. That is, the CPI and the domestic inflation rates show a clear negative correlation with the real interest rate gap and a positive correlation with the real marginal cost. The relationships are stronger for expected inflation rates than for actual rates. Finally, the indicator properties for both measures of the output gap are weak. In particular, the trend adjusted output gap has no relation to inflation.

An important issue in the New Keynesian literature is the relation between real marginal costs and the flexible-price output gap. In the basic New Keynesian model there is a one-to-one relation. Nominal wage stickiness is a friction that formally breaks this relationship. However, it is a quantitative matter to what extent the relationship is broken. In the simulation based on the prior distribution there is an almost one-to-one relationship between real marginal costs and the flexible-price output gap in $\mathcal{M}_1$. In model $\mathcal{M}_0$, on the other hand, the correlation is only about 0.4. This quantifies the effect of nominal wage stickiness. Note that the results from the posterior distribution show a different story, namely that the relationship is about the same in both models. Hence, the data support a weak relation between the flexible-price output gap and the firm's real marginal cost.

Figure 3 presents the results from model $\mathcal{M}_2$. Compared to model $\mathcal{M}_1$ there is no habit formation nor variable capacity utilization in $\mathcal{M}_2$. The effect of these frictions on the various correlations is in general very small. This is the case for the results from the prior distribution as well as the the posterior distribution.

Results from model $\mathcal{M}_3$ are reported in Figure 4. In this model, we have shut down, in addition to wage stickiness, habit formation and variable capacity utilization, the open economy sector. This implies that a number of shocks have been shut down; that is, the markup shocks on imported consumption and investment goods and exported goods, the risk premium shock, the asymmetric technology shock, and the foreign shocks. Another implication is that the difference between the CPI and the domestic inflation rate disappears. This model is very close to the basic New Keynesian model. The differences consist of capital accumulation and a number of shocks that are usually not accounted for in the basic New Keynesian framework, that is, two preference shocks, a markup shock and fiscal policy shocks.

In general the correlations and autocorrelations from the prior and the posterior distributions are very close. But more interestingly, there is an almost one-to-one relationship between real marginal costs and the flexible-price output gap. Furthermore, the flexible-price output gap is a good inflation indicator. In particular, it has a strong relationship with expected inflation.

4.2 Conditional second moments

The relationships between inflation and the indicator variables depend on the frictions in the model as we have seen. They also depend on the shocks that hit the economy. Table 2 provides results for various correlations conditional on one specific shock in model $\mathcal{M}_0$. A first observation is that the correlation between any two variables can be positive, negative or zero depending on the type of shock. Hence, in order to predict, for example, future inflation rates it is necessary to identify what type of shock that has hit the economy.

Moreover, these results also explain why the real interest rate gap is a good inflation indicator, while the flexible-price output gap is not. For virtually all the shocks in the model the relationship between the real interest rate gap and the inflation rate is clearly negative. A notable exception is the risk premium shock, though, which gives rise to a basically zero correlation. The relationship between the flexible-price output gap and the inflation rate is much more dependent on the type of shock that hits the economy. For example, the four technology shocks give rise to a clear and positive relationship. On the other hand, the labor supply shock, the inflation target shock, the risk premium shock and the markup shock on imported investment goods all give rise to a clear negative relationship. This means that when accounting for all shocks the relationship becomes weak. A similar story explains the weak relationship between the trend adjusted output gap and inflation.

5 What shocks drive inflation and the indicators?

In this section, we first quantify the contribution of each shock to the forecast error variance in inflation and the indicator variables. In the next step, we plot the smoothed estimates of inflation, the indicator variables, and technology and monetary shocks from 1986 to 2005. Finally, we report results from a historical decomposition. The results in this section refers to the empirically most relevant model; that is, $\mathcal{M}_0$.

5.1 Variance decomposition

Table 3 reports the variance decomposition for 1, 8 and 20 quarters for inflation and the indicator variables.

Fluctuations in the CPI and the domestic inflation rates are primarily driven by markup shocks in the very short run. This seems to be a typical result in this class of models, see for example Smets and Wouters (2003). On longer horizons the inflation target shock is the primarily determinant.

The domestic markup shock together with technology and labor supply shocks account for most of the variations in real marginal costs in the very short run. On a two-year horizon the risk premium shock becomes the main determinant. Note also that this shock accounts for a significant part of the variations in the real interest rate gap, the flexible-price output gap as well as the trend-adjusted output gap.

Let us now turn to the three gap measures. For the shortest horizon, fluctuations in the real interest rate gap is mainly accounted for by the labor supply shock. The fluctuations in the flexible-price output gap is mainly explained by the inflation target, the stationary technology and the risk premium shocks while fluctuations in the trend-adjusted output gap are mainly explained by the three price markup shocks; that is, domestic, export and imported consumption markups.

For the 8 quarter horizon the risk premium shock is important for all three gaps as noted above. Also, the monetary policy shock is a key shock for the two the flexible-price gaps while the investment specific and the stationary technology shocks are important determinants for the detrended output gap. Note that these two shocks have little impact on the two flexible-price gaps, which indicates that they affect the sticky and the flexible-price equilibrium in a similar way for the medium term horizon. This is to expected since wage and price stickiness have the largest effects in the very short run.

Finally, beyond the two-year horizon the gap measures are mainly driven by the imported investment markup. The flexible-price gaps are, in addition, also explained by the risk premium and the foreign shocks.

5.2 Historical decomposition

Figures 5a and 5b plot the Kalman-smoothed estimates for the indicator variables and inflation, respectively, from 1986 to 2005. Since the observed values are in growth rates, the estimated levels are uncertain. The actual levels should therefore be interpreted with some caution.

Four things are worth noting. First, the two output gaps identifies the recession in the beginning of 1990's and the boom around 2000. However, the confidence band around the trend adjusted output gap is quite large. In fact, it is hardly different from zero over the sample period. Because of the high uncertainty the trend adjusted output gap may be a poor indicator for monetary policy.

Second, the real interest rate gap, a measure of the monetary policy stance, was stimulative at the economic boom in 1990 and contractive at the recession a couple of years later. On the other hand, during the lead up to the boom in 2000 the monetary policy stance was contractive and stimulative in the recession that followed.

Third, the probability band around the real interest rate gap is small, in particular from 1995 and on. Smets and Wouters (2003) estimate a fairly large probability band and conclude that the interest rate gap may be a poor guide for monetary policy. A possible explanation for the different results may be the treatment of the observed variables. The observed real variables are in growth rates in our set up while Smets and Wouters (2003) detrend the real variables by a linear trend. Hence, they exclude trend uncertainty in the estimation, see Sims (2003) for a discussion about this.

Fourth, it is illustrative to compare the real interest rate gap and the expected inflation rate from the beginning of 1990. The period 1990 to 2000 was a period with a positive real interest rate gap and low inflation expectations. At 2000 there is a sharp easing of the monetary policy stance together with higher inflation expectations. A couple of years later monetary policy tightens and inflation expectations falls.

In Figure 6 the smoothed estimates of the stationary, nonstationary and investment specific technology shocks, the monetary policy shock, the inflation target shock and the risk premium shock are displayed. The investment specific technology shock were quite large during the 1990 boom. During the subsequent recession all three technology shocks where low. Quite interestingly, neither the stationary nor the investment specific technology shocks were particularly high during the boom in 2000. The nonstationary technology shock where above average but still not extremely high. Hence, the economic boom in 2000 can only to a small extent be attributed to unusually high improvements in technology.

Figures 7a and 7b display the historical contribution of the three technology shocks to inflation and the indicator variables. In general, technology shocks have had a small impact on the flexible-price output gap. In particular, they account for practically nothing of the deep recession in the early nineties. However, from 2000 and on all three technology shocks have contributed negatively to the flexible-price output gap. The picture is somewhat different if we look at the trend adjusted output gap. According to this measure the investment specific shock contributes significantly both to the downturn in the early nineties as well as to the development during the last five years. It is also notable that the stationary technology shock is a predominant factor behind the boom in the late nineties.

In Figures 8a and 8b we show the historical contributions of the monetary policy, the inflation target and the risk premium shocks. All three shocks have contributed negatively to the two output gaps from 1985 to 2000. From 2000 and on they contribute positively, though. These shocks have a negligible effect on the real marginal cost, which is consistent with the results from the variance decomposition.

Regarding the CPI and the domestic inflation rates the inflation target shock explains the high inflation rates in the late 1980's as expected.

6 Concluding remarks

To be written.

Appendix

Data

This appendix describes the data used to estimate the model. We use quarterly Swedish data for the period 1980Q1 - 2005Q4.[2] All data were obtained from Statistics Sweden, except the repo rate and the real exchange rate which were obtained from Sveriges Riksbank. The foreign variables on output, the interest rate and inflation are weighted together across Sweden's 20 largest trading partners in 1991 using weights from the IMF. We match the following 15 variables: domestic inflation - measured by the UNDINHX index, the real wage, consumption, investment, the real exchange rate, the short-run interest rate, hours worked per capita, GDP, exports, imports, the consumer price index (CPI) - measured with the UND1X index, the investment deflator, foreign output, foreign inflation and the foreign interest rate. The foreign variables are necessary to include because they enable identification of the asymmetric technology shock. The unit root technology shock induces a common stochastic trend in the real variables of the model and to make these variables stationary we use first differences and derive the state space representation for the following vector of observed variables.

$$\mathbf{y}_t = \begin{array}{ccccccccc} [& \pi_t^d & \Delta\ln(W_t/P_t) & \Delta\ln C_t & \Delta\ln I_t & \hat{x}_t & R_t & \hat{H}_t & \Delta\ln Y_t ... \\ & \Delta\ln\tilde{X}_t & \Delta\ln\tilde{M}_t & \pi_t^{cpi,c} & \pi_t^{def,i} & \Delta\ln Y_t^* & \pi_t^* & R_t^* &]'. \end{array} \tag{33}$$

The growth rates are computed as quarter to quarter log-differences, while the inflation and interest rate series are measured as annualized quarterly rates. The share of import and export to output are increasing from about 0.25 to 0.40 and from 0.21 to 0.50 respectively during the sample period. In the model, import and export are assumed to grow at the same rate as output. Hence, we decided to remove the excessive trend of import and export in the data, to render the

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[2] We use the period 1980:1-1985:4 to compute a prior of the state for the unobserved variables, and then use the period 1986:1-2005:4 for inference. The benchmark sample period is restricted to 1986Q1 - 2005Q4 due to gradually deregulated financial markets and recurrent devaluations during the 1970's and beginning of the 1980's.

export and import shares stationary. It should be noted that the stationary variables $\hat{x}_t$ and $\hat{H}_t$ are measured as deviations around the mean, i.e. $\hat{x}_t = (x_t - x)/x$ and $\hat{H}_t = (H_t - H)/H$, respectively. The variables to the exogenous fiscal VAR model include the income tax rate, the consumption tax rate and government expenditures. The income tax rate, $\hat{\tau}_t^h$, is defined as direct taxes on households over disposable income and the consumption tax rate, $\hat{\tau}_t^c$, is defined as indirect taxes on households over consumption expenditures. Both are measured as deviations around the mean. Finally, the government expenditures, $\hat{g}_t$, is detrended with the HP filter.

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Table 1: DSGE Model's parameter estimates (Part I)

	Prior $\mathcal{M}0$			*Posterior*							
				$\mathcal{M}0$		$\mathcal{M}1$		$\mathcal{M}2$		$\mathcal{M}3$	
Parameter	*Distr*	$P(1)$	$P(2)$	$P(1)$	*Interval*	$P(1)$	*Interval*	$P(1)$	*Interval*	$P(1)$	*Interval*
ξ_d	$\mathcal{B}$	0.75	0.05	0.751	$[0.686, 0.805]$	0.666	$[0.577, 0.712]$	0.681	$[0.611, 0.742]$	0.710	$[0.638, 0.773]$
$\xi_{m,c}$	$\mathcal{B}$	0.75	0.05	0.914	$[0.896, 0.933]$	0.909	$[0.887, 0.923]$	0.904	$[0.885, 0.921]$		
$\xi_{m,i}$	$\mathcal{B}$	0.75	0.05	0.943	$[0.926, 0.957]$	0.942	$[0.922, 0.953]$	0.938	$[0.921, 0.953]$		
ξ_x	$\mathcal{B}$	0.75	0.05	0.869	$[0.829, 0.899]$	0.867	$[0.828, 0.897]$	0.859	$[0.821, 0.893]$		
ξ_w	$\mathcal{B}$	0.75	0.05	0.677	$[0.619, 0.772]$						
κ^d	$\mathcal{B}$	0.5	0.15	0.286	$[0.143, 0.529]$	0.275	$[0.142, 0.529]$	0.301	$[0.143, 0.524]$	0.315	$[0.153, 0.533]$
κ^{mc}	$\mathcal{B}$	0.5	0.15	0.213	$[0.119, 0.433]$	0.230	$[0.131, 0.449]$	0.228	$[0.112, 0.392]$		
κ^{mi}	$\mathcal{B}$	0.5	0.15	0.224	$[0.146, 0.471]$	0.275	$[0.151, 0.475]$	0.295	$[0.159, 0.470]$		
κ^x	$\mathcal{B}$	0.5	0.15	0.389	$[0.216, 0.588]$	0.348	$[0.191, 0.553]$	0.384	$[0.218, 0.579]$		
κ^w	$\mathcal{B}$	0.5	0.15	0.584	$[0.356, 0.821]$						
λ_d	$\mathcal{TN}$	1.2	0.05	1.218	$[1.158, 1.316]$	1.225	$[1.141, 1.299]$	1.202	$[1.123, 1.282]$	1.242	$[1.163, 1.321]$
$\lambda_{m,c}$	$\mathcal{TN}$	1.2	0.05	1.111	$[1.079, 1.155]$	1.126	$[1.090, 1.163]$	1.120	$[1.084, 1.158]$		
$\lambda_{m,i}$	$\mathcal{TN}$	1.2	0.05	1.388	$[1.323, 1.463]$	1.397	$[1.329, 1.466]$	1.377	$[1.311, 1.447]$		
$\mathcal{A}''$	$\mathcal{TN}$	2.0	1	3.490	$[2.266, 4.752]$	3.505	$[2.400, 4.873]$				
S''	$\mathcal{N}$	7.694	1.5	7.653	$[5.595, 10.137]$	7.775	$[5.555, 10.137]$	7.901	$[5.686, 10.181]$	6.320	$[3.733, 8.838]$
b	$\mathcal{B}$	0.65	0.1	0.534	$[0.489, 0.716]$	0.471	$[0.371, 0.599]$				
η_ι	$\mathcal{IG}$	1.5	4	1.445	$[1.337, 1.729]$	1.475	$[1.347, 1.759]$	1.533	$[1.355, 1.790]$		
η_f	$\mathcal{IG}$	1.5	4	1.482	$[1.348, 1.879]$	1.502	$[1.357, 1.895]$	1.560	$[1.362, 1.902]$		
μ_z	$\mathcal{TN}$	1.0055	0.0005	1.0049	$[1.0045, 1.0052]$	1.0049	$[1.0045, 1.0052]$	1.0048	$[1.0045, 1.0052]$	1.0049	$[1.0042, 1.0056]$
$\tilde{\phi}$	$\mathcal{IG}$	0.01	2	0.0317	$[0.017, 0.097]$	0.0558	$[0.033, 0.169]$	0.0952	$[0.045, 0.206]$		
$\tilde{\phi}_s$	$\mathcal{B}$	0.5	0.15	0.463	$[0.414, 0.569]$	0.462	$[0.413, 0.558]$	0.481	$[0.413, 0.553]$		
ρ_{μ_z}	$\mathcal{B}$	0.85	0.1	0.872	$[0.618, 0.924]$	0.818	$[0.615, 0.904]$	0.769	$[0.590, 0.880]$	0.756	$[0.575, 0.883]$
ρ_ε	$\mathcal{B}$	0.85	0.1	0.969	$[0.951, 0.979]$	0.968	$[0.950, 0.980]$	0.968	$[0.954, 0.980]$	0.952	$[0.909, 0.977]$
ρ_Υ	$\mathcal{B}$	0.85	0.1	0.749	$[0.637, 0.920]$	0.825	$[0.685, 0.926]$	0.765	$[0.635, 0.892]$	0.521	$[0.375, 0.657]$
$\rho_{\tilde{z}^*}$	$\mathcal{B}$	0.85	0.1	0.729	$[0.769, 0.984]$	0.965	$[0.861, 0.985]$	0.966	$[0.929, 0.988]$		
ρ_{ζ^c}	$\mathcal{B}$	0.85	0.1	0.978	$[0.738, 0.981]$	0.935	$[0.787, 0.974]$	0.971	$[0.933, 0.993]$	0.954	$[0.855, 0.987]$
$\rho_{\tilde{\phi}}$	$\mathcal{B}$	0.85	0.1	0.919	$[0.719, 0.945]$	0.924	$[0.841, 0.951]$	0.921	$[0.8480, 0.953]$		

Notes: $\mathcal{B}$ is the Beta distribution, $\mathcal{IG}$ is the Inverse Gamma, $\mathcal{N}$ is the Normal-distribution, $\mathcal{TN}$ is the Truncated Normal. $P(1)$ and $P(2)$ denotes means and standard deviations. All probability intervals are 90% credible intervals. Estimation is based on the sample period $Q1:1986 - Q4:2005$.

Table 1: DSGE Model's parameter estimates (Part II)

	Prior $\mathcal{M}0$			*Posterior*							
				$\mathcal{M}0$		$\mathcal{M}1$		$\mathcal{M}2$		$\mathcal{M}3$	
Parameter	*Distr.*	$P(1)$	$P(2)$	$P(1)$	*Interval*	$P(1)$	*Interval*	$P(1)$	*Interval*	$P(1)$	*Interval*
σ_{μ_z}	$\mathcal{IG}$	0.2	2	0.124	$[0.097, 0.179]$	0.119	$[0.094, 0.173]$	0.126	$[0.094, 0.171]$	0.169	$[0.111, 0.264]$
σ_{ε}	$\mathcal{IG}$	0.7	2	0.444	$[0.384, 0.582]$	0.491	$[0.419, 0.626]$	0.509	$[0.417, 0.620]$	0.554	$[0.451, 0.677]$
σ_{Υ}	$\mathcal{IG}$	0.2	2	0.679	$[0.491, 0.845]$	0.584	$[0.484, 0.791]$	0.682	$[0.535, 0.877]$	0.950	$[0.775, 1.159]$
$\sigma_{\tilde{z}^*}$	$\mathcal{IG}$	0.4	2	0.179	$[0.151, 0.240]$	0.187	$[0.152, 0.242]$	0.192	$[0.152, 0.243]$		
σ_{ζ^c}	$\mathcal{IG}$	0.2	2	0.173	$[0.154, 0.364]$	0.286	$[0.208, 0.392]$	0.686	$[0.487, 0.908]$	0.488	$[0.252, 0.715]$
σ_{ζ^h}	$\mathcal{IG}$	1.0	2	0.424	$[0.376, 0.528]$	0.654	$[0.509, 0.897]$	0.629	$[0.483, 0.814]$	0.680	$[0.529, 0.868]$
$\sigma_{\tilde{\phi}}$	$\mathcal{IG}$	0.05	2	0.301	$[0.264, 0.626]$	0.339	$[0.288, 0.601]$	0.416	$[0.306, 0.589]$		
σ_{λ_d}	$\mathcal{IG}$	1.0	2	0.415	$[0.364, 0.507]$	0.462	$[0.401, 0.569]$	0.473	$[0.400, 0.572]$	0.464	$[0.392, 0.558]$
$\sigma_{\lambda_{m,c}}$	$\mathcal{IG}$	1.0	2	0.619	$[0.536, 0.749]$	0.629	$[0.545, 0.767]$	0.647	$[0.550, 0.773]$		
$\sigma_{\lambda_{m,i}}$	$\mathcal{IG}$	1.0	2	1.226	$[1.071, 1.514]$	1.248	$[1.088, 1.544]$	1.289	$[1.089, 1.546]$		
σ_{λ_x}	$\mathcal{IG}$	1.0	2	0.871	$[0.667, 1.071]$	0.864	$[0.665, 1.067]$	0.854	$[0.670, 1.077]$		
ρ_R	$\mathcal{B}$	0.8	0.05	0.859	$[0.808, 0.896]$	0.779	$[0.722, 0.821]$	0.765	$[0.715, 0.811]$	0.786	$[0.740, 0.826]$
r_{π}	$\mathcal{N}$	1.7	0.1	1.667	$[1.532, 1.857]$	1.697	$[1.562, 1.878]$	1.703	$[1.548, 1.862]$	1.749	$[1.600, 1.901]$
$r_{\Delta\pi}$	$\mathcal{N}$	0.3	0.1	0.175	$[0.093, 0.272]$	0.243	$[0.164, 0.346]$	0.271	$[0.181, 0.364]$	0.300	$[0.212, 0.393]$
r_x	$\mathcal{N}$	0.0	0.05	-0.050	$[-0.074, -0.017]$	-0.052	$[-0.077, -0.032]$	-0.046	$[-0.067, -0.026]$		
r_y	$\mathcal{N}$	0.125	0.05	0.121	$[0.005, 0.149]$	0.0616	$[0.008, 0.109]$	0.0506	$[0.004, 0.102]$	0.0615	$[0.019, 0.108]$
$r_{\Delta y}$	$\mathcal{N}$	0.063	0.05	0.123	$[0.074, 0.185]$	0.073	$[0.013, 0.127]$	0.071	$[0.014, 0.129]$	0.089	$[0.033, 0.148]$
σ_R	$\mathcal{IG}$	0.15	2	0.193	$[0.167, 0.244]$	0.211	$[0.181, 0.264]$	0.227	$[0.187, 0.276]$	0.261	$[0.214, 0.317]$
$\sigma_{\bar{\pi}^c}$	$\mathcal{IG}$	0.05	2	0.237	$[0.078, 0.294]$	0.171	$[0.118, 0.238]$	0.155	$[0.113, 0.208]$	0.098	$[0.0540, 0.152]$
Log. Marg. Like.				-2201.9		-2224.3		-2220.4		-941.9	

Notes: $\mathcal{B}$ is the Beta distribution, $\mathcal{IG}$ is the Inverse Gamma, $\mathcal{N}$ is the Normal-distribution, $\mathcal{TN}$ is the Truncated Normal. $P(1)$ and $P(2)$ denotes means and standard deviations. All probability intervals are 90% credible intervals. Estimation is based on the sample period $Q1:1986 - Q4:2005$.

Table 2. Conditional correlations.

Moment	All	ϵ_t	$\hat{\Upsilon}_t$	$\mu_{z,t}$	$\tilde{z}^*_t$	$\hat{\varsigma}^c_t$	$\hat{\varsigma}^h_t$	ϱ_t	$\widehat{\bar{\pi}}^c_t$	$\widehat{\widetilde{\phi}}_t$	$\lambda_{d,t}$	$\lambda_{mc,t}$	$\lambda_{mi,t}$	$\lambda_{x,t}$
$\rho\left(\pi^d_t, mc_t\right)$	0.23	0.82	0.39	0.87	0.79	0.80	0.98	0.65	-0.40	-0.04	-0.56	0.24	0.61	0.30
$\rho\left(\mathrm{E}_t\pi^d_{t+1}, mc_t\right)$	0.34	0.81	0.25	0.85	0.75	0.79	0.99	0.56	-0.40	-0.27	0.53	-0.00	0.55	0.04
$\rho\left(\pi^c_t, mc_t\right)$	0.17	0.67	0.19	0.70	0.67	0.78	0.93	0.55	-0.46	-0.22	-0.63	0.02	-0.09	-0.37
$\rho\left(\mathrm{E}_t\pi^c_{t+1}, mc_t\right)$	0.22	0.66	0.12	0.70	0.64	0.77	0.93	0.48	-0.46	-0.39	0.31	-0.41	-0.12	-0.51
$\rho\left(\pi^d_t, rr_t\right)$	-0.48	-0.74	-0.65	-0.69	-0.85	-0.68	-0.79	-0.95	-0.59	-0.17	-0.28	-0.39	-0.31	-0.51
$\rho\left(\mathrm{E}_t\pi^d_{t+1}, rr_t\right)$	-0.50	-0.71	-0.59	-0.65	-0.81	-0.67	-0.86	-0.96	-0.57	0.06	-0.98	-0.57	-0.31	-0.70
$\rho\left(\pi^c_t, rr_t\right)$	-0.42	-0.56	-0.36	-0.54	-0.75	-0.63	-0.66	-0.96	-0.57	-0.08	-0.20	-0.04	-0.07	-0.92
$\rho\left(\mathrm{E}_t\pi^c_{t+1}, rr_t\right)$	-0.45	-0.54	-0.33	-0.53	-0.73	-0.62	-0.71	-0.94	-0.56	0.14	-0.90	-0.82	-0.12	-0.96
$\rho\left(\pi^d_t, \hat{y}_t\right)$	-0.11	-0.76	-0.68	-0.49	-0.68	-0.95	-0.48	0.92	-0.62	0.54	-0.35	0.87	-0.44	0.07
$\rho\left(\mathrm{E}_t\pi^d_{t+1}, \hat{y}_t\right)$	-0.08	-0.76	-0.63	-0.46	-0.66	-0.94	-0.40	0.89	0.76	0.39	0.68	0.80	-0.44	-0.17
$\rho\left(\pi^c_t, \hat{y}_t\right)$	-0.10	-0.88	-0.63	-0.63	-0.82	-0.97	-0.67	0.89	-0.66	0.42	-0.41	0.72	-0.46	-0.58
$\rho\left(\mathrm{E}_t\pi^c_{t+1}, \hat{y}_t\right)$	-0.11	-0.88	-0.63	-0.62	-0.82	-0.97	-0.64	0.84	-0.65	0.29	0.51	0.58	-0.51	-0.70
$\rho\left(\pi^d_t, y^{fp}_t\right)$	0.12	0.72	0.27	0.60	0.89	0.82	-0.33	0.94	-0.17	-0.43	-0.32	0.90	-0.34	0.19
$\rho\left(\mathrm{E}_t\pi^d_{t+1}, y^{fp}_t\right)$	0.15	0.73	0.29	0.62	0.90	0.84	-0.22	0.92	-0.16	-0.60	0.70	0.84	-0.36	-0.05
$\rho\left(\pi^c_t, y^{fp}_t\right)$	0.06	0.58	-0.08	0.36	0.74	0.78	-0.53	0.91	-0.24	-0.58	-0.38	0.71	-0.39	-0.46
$\rho\left(\mathrm{E}_t\pi^c_{t+1}, y^{fp}_t\right)$	0.05	0.57	-0.10	0.38	0.75	0.80	-0.48	0.87	-0.22	-0.69	0.58	0.58	-0.44	-0.58
$\rho\left(mc_t, rr_t\right)$	-0.58	-0.96	-0.58	-0.88	-0.78	-0.60	-0.87	-0.43	-0.06	-0.55	-0.63	0.72	-0.10	0.65
$\rho\left(mc_t, \hat{y}_t\right)$	0.07	-0.34	-0.52	-0.32	-0.31	-0.77	-0.45	0.71	0.14	0.63	0.91	0.40	0.04	0.94
$\rho\left(mc_t, y^{fp}_t\right)$	0.37	0.81	0.01	0.76	0.76	0.62	-0.28	0.71	0.89	0.85	0.89	0.40	0.11	0.94
$\rho\left(\hat{y}_t, rr_t\right)$	-0.05	0.21	0.64	0.37	0.52	0.50	0.05	-0.84	0.27	-0.33	-0.72	-0.07	0.86	0.80
$\rho\left(y^{fp}_t, rr_t\right)$	-0.22	-0.82	-0.10	-0.62	-0.80	-0.81	-0.15	-0.85	-0.22	-0.37	-0.74	-0.12	0.80	0.69

Table 3. Variance decomposition. Posterior model M0.

1 quarter horizon	mc	rr	y^{fp}	$y^{TrendAdj}$	π^{d}	π^{CPI}
Stationary technology	**0.244**	0.090	**0.195**	0.018	0.080	0.046
Nonstationary technology	0.001	0.000	0.060	0.004	0.004	0.002
Consumtion preference	0.000	0.000	0.035	0.010	0.001	0.001
Labour supply	**0.451**	**0.829**	0.015	0.017	0.086	0.047
Markup in domestic goods market	**0.286**	0.002	0.087	**0.251**	**0.691**	**0.337**
Markup - import consumption goods	0.001	0.024	0.038	**0.112**	0.000	**0.337**
Markup - import investment goods	0.001	0.000	0.006	0.019	0.000	0.000
Risk premium shock	0.002	0.011	**0.109**	0.019	0.039	0.096
Investment specific technology	0.006	0.003	0.003	0.091	0.002	0.001
Asymmetric technology	0.000	0.000	0.001	0.004	0.000	0.000
Markup in export goods market	0.004	0.010	0.078	**0.227**	0.000	0.001
Monetary policy	0.003	0.008	0.070	0.098	0.007	0.017
Inflation target	0.000	0.013	**0.251**	0.053	0.070	0.068
Fiscal shocks	0.001	0.005	0.014	0.058	0.001	0.000
Foreign shocks	0.002	0.004	0.039	0.020	0.020	0.048
8 quarter horizon						
Stationary technology	0.033	0.000	0.011	**0.199**	0.043	0.056
Nonstationary technology	0.007	0.021	0.000	0.014	0.009	0.010
Consumtion preference	0.003	0.016	0.015	0.020	0.011	0.009
Labour supply	0.020	0.105	**0.219**	0.096	0.001	0.009
Markup in domestic goods market	0.089	0.041	0.000	0.000	0.008	0.000
Markup - import consumption goods	0.018	**0.107**	0.050	0.022	0.029	0.065
Markup - import investment goods	0.000	0.054	0.044	0.020	0.000	0.000
Risk premium shock	**0.445**	**0.123**	**0.369**	**0.159**	**0.215**	**0.181**
Investment specific technology	0.066	0.048	0.001	**0.297**	0.038	0.009
Asymmetric technology	0.000	0.000	0.000	0.000	0.000	0.000
Markup in export goods market	0.010	0.062	0.001	0.001	0.009	0.006
Monetary policy	**0.118**	**0.229**	**0.150**	0.071	0.038	0.031
Inflation target	0.003	0.100	0.002	0.018	**0.450**	**0.474**
Fiscal shocks	0.005	0.012	0.026	0.004	0.002	0.001
Foreign shocks	**0.183**	0.084	0.111	0.082	**0.148**	**0.147**
20 quarter horizon						
Stationary technology	0.001	0.005	0.001	**0.200**	0.075	0.091
Nonstationary technology	0.001	0.000	0.002	0.007	0.010	0.016
Consumtion preference	0.003	0.003	0.002	0.068	0.010	0.010
Labour supply	0.002	0.121	0.001	0.001	0.003	0.007
Markup in domestic goods market	0.010	0.002	0.007	0.004	0.001	0.000
Markup - import consumption goods	0.030	0.012	0.003	0.002	0.002	0.002
Markup - import investment goods	0.001	**0.280**	**0.275**	**0.158**	0.000	0.001
Risk premium shock	**0.201**	0.150	**0.258**	0.010	0.003	0.010
Investment specific technology	0.014	0.001	0.093	**0.499**	0.000	0.012
Asymmetric technology	0.000	0.000	0.000	0.000	0.000	0.000
Markup in export goods market	0.006	0.000	0.002	0.001	0.000	0.000
Monetary policy	0.001	0.011	0.023	0.014	0.000	0.000
Inflation target	**0.565**	0.092	**0.187**	0.031	**0.883**	**0.849**
Fiscal shocks	0.015	**0.171**	0.001	0.003	0.003	0.002
Foreign shocks	**0.151**	**0.152**	0.145	0.004	0.010	0.002

Figure 1. M0 Prior (dashed) vs M0 Posterior (red solid)

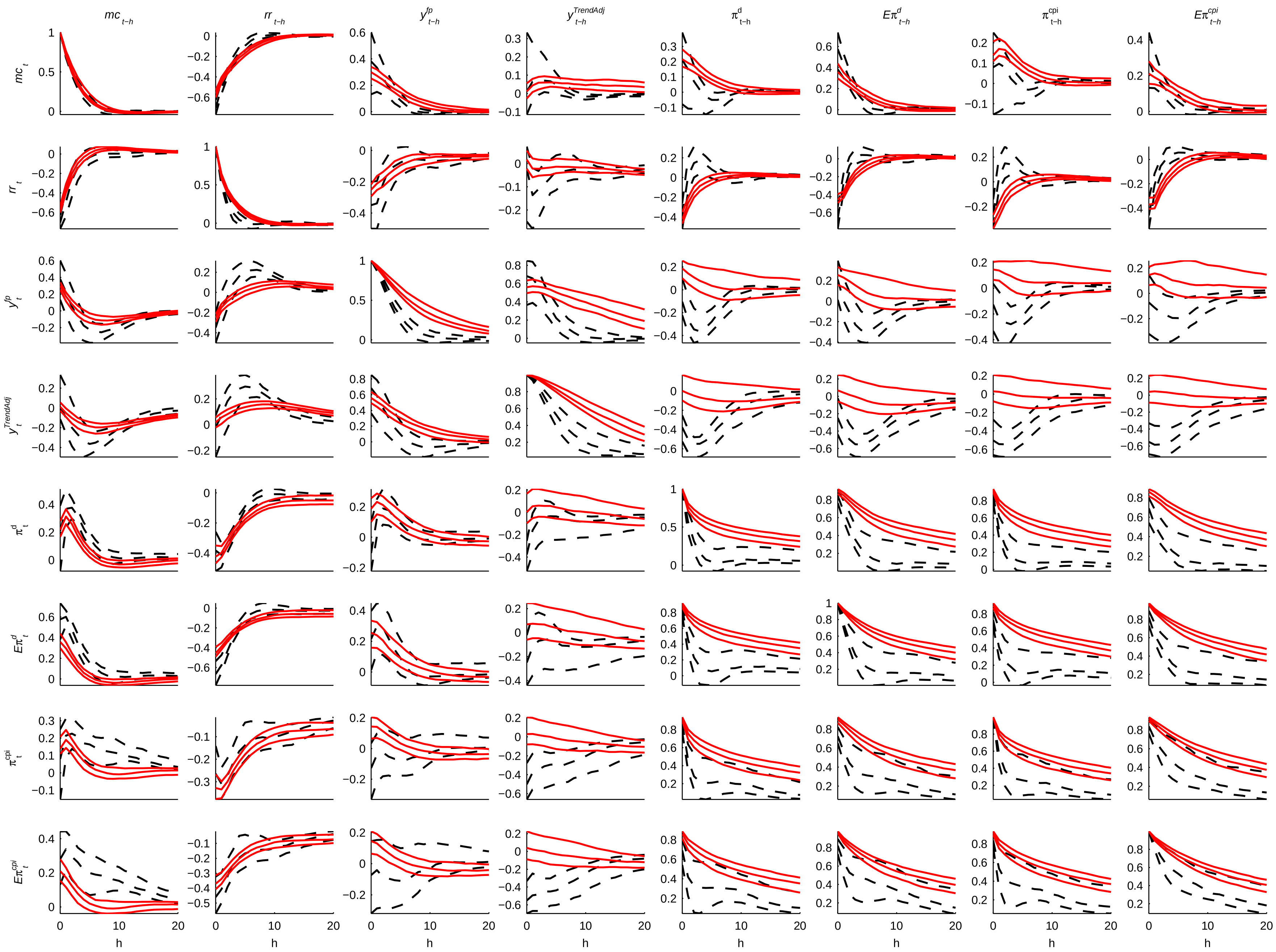


Figure 2. M1 Prior (dashed) vs M1 Posterior (red solid)

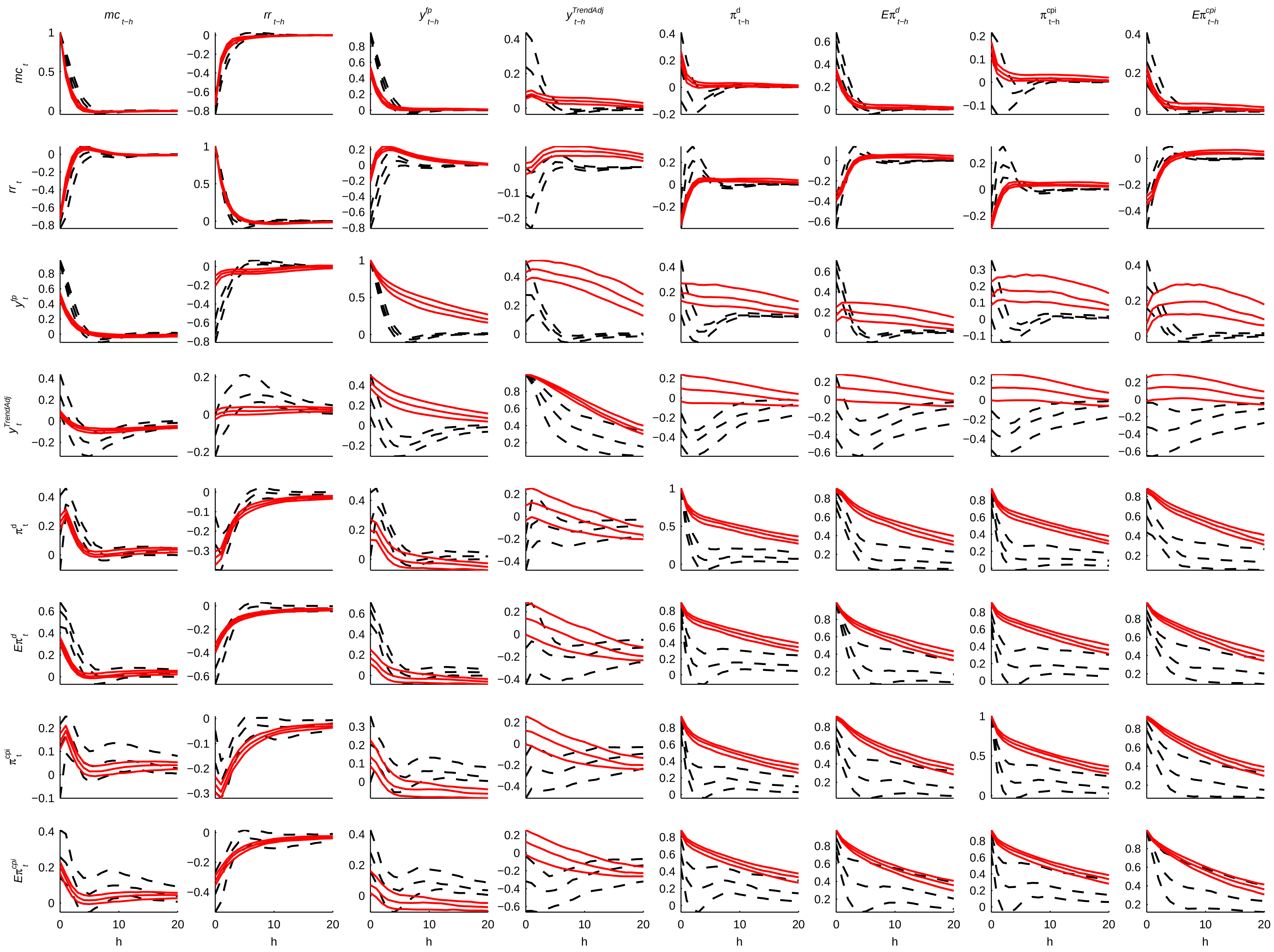


Figure 3. M2 Prior (dashed) vs M2 Posterior (red solid)

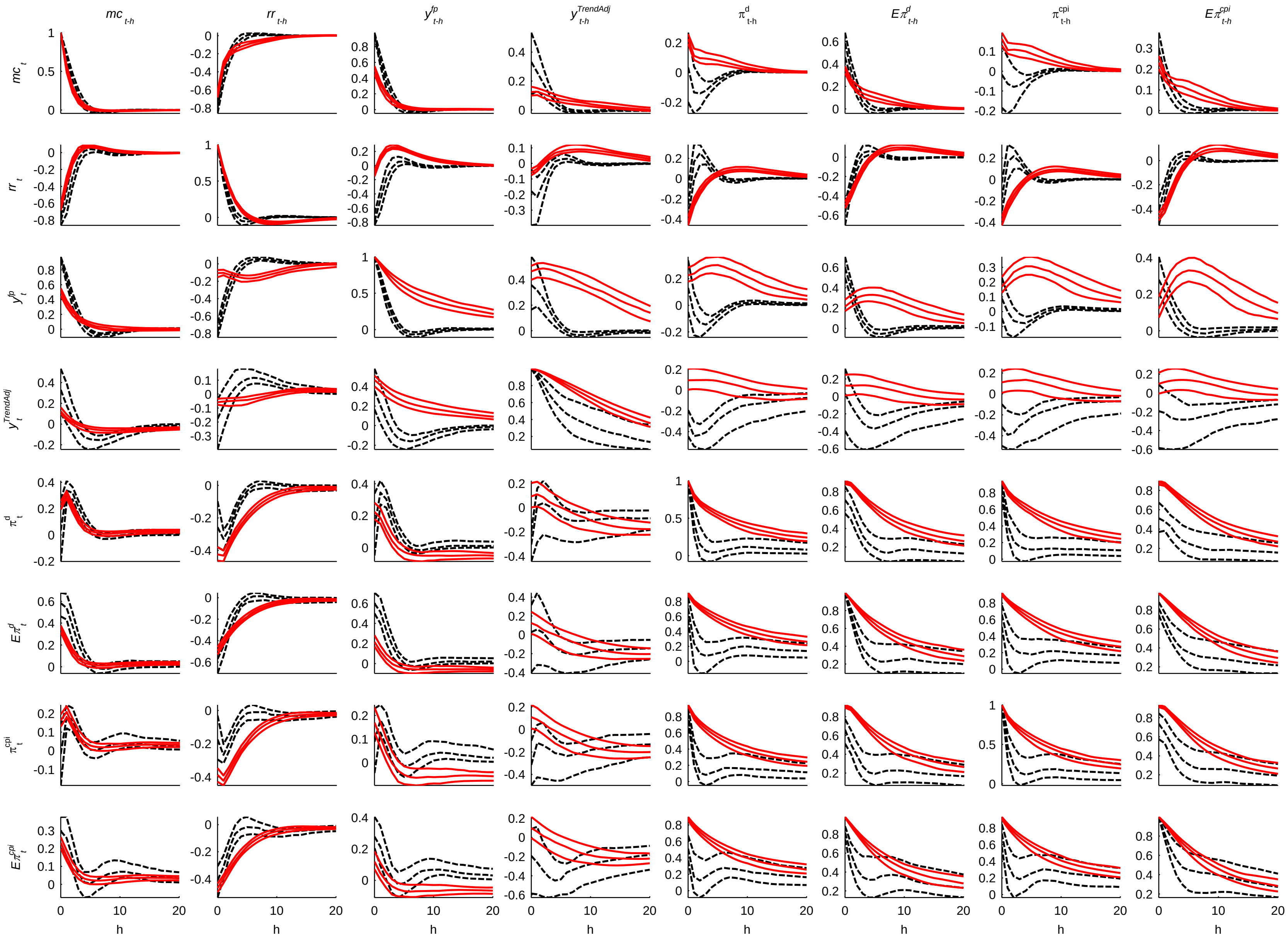


Figure 4. M3 Prior (dashed) vs M3 Posterior (red solid)

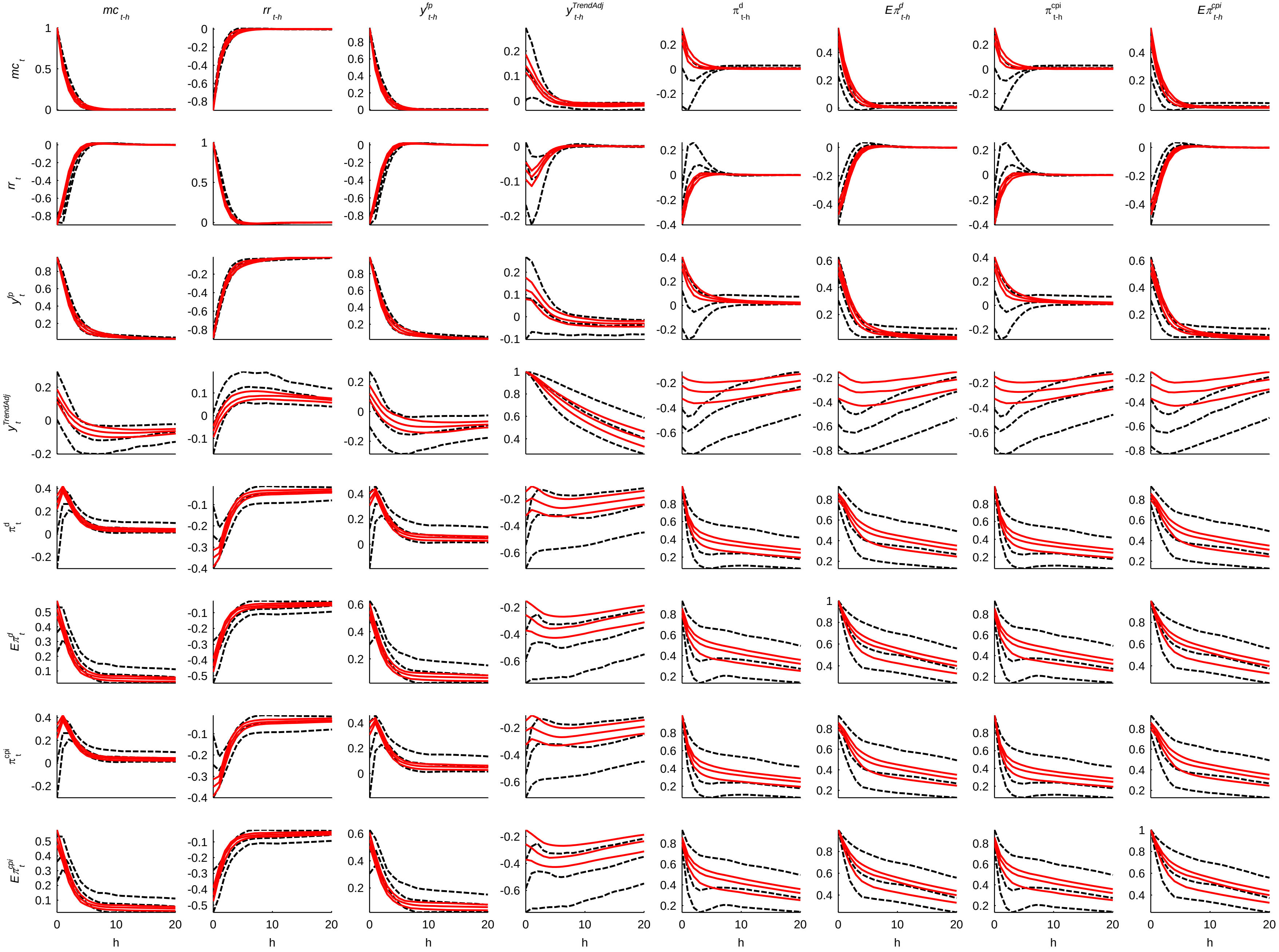
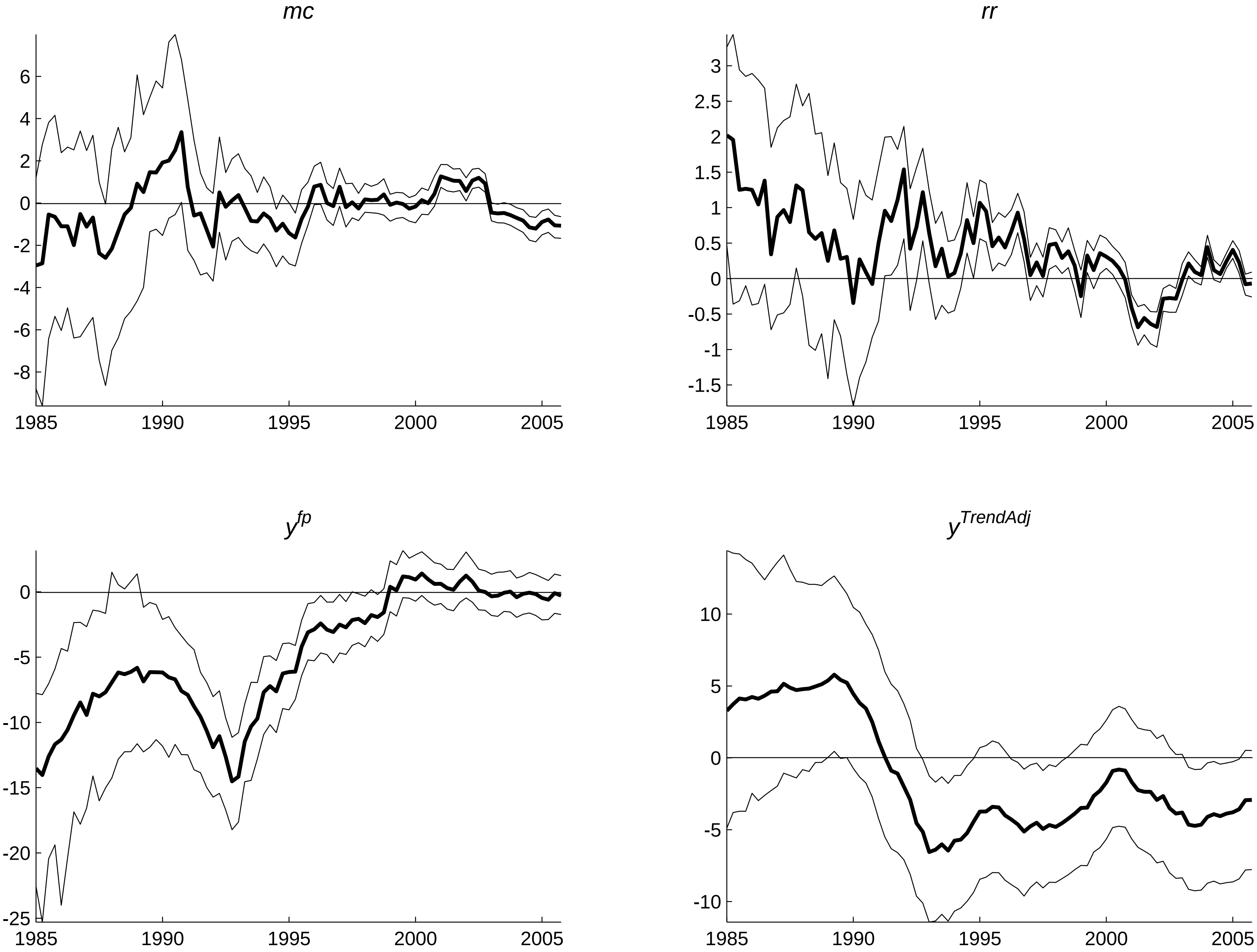


Figure 5a. Smoothed estimates.



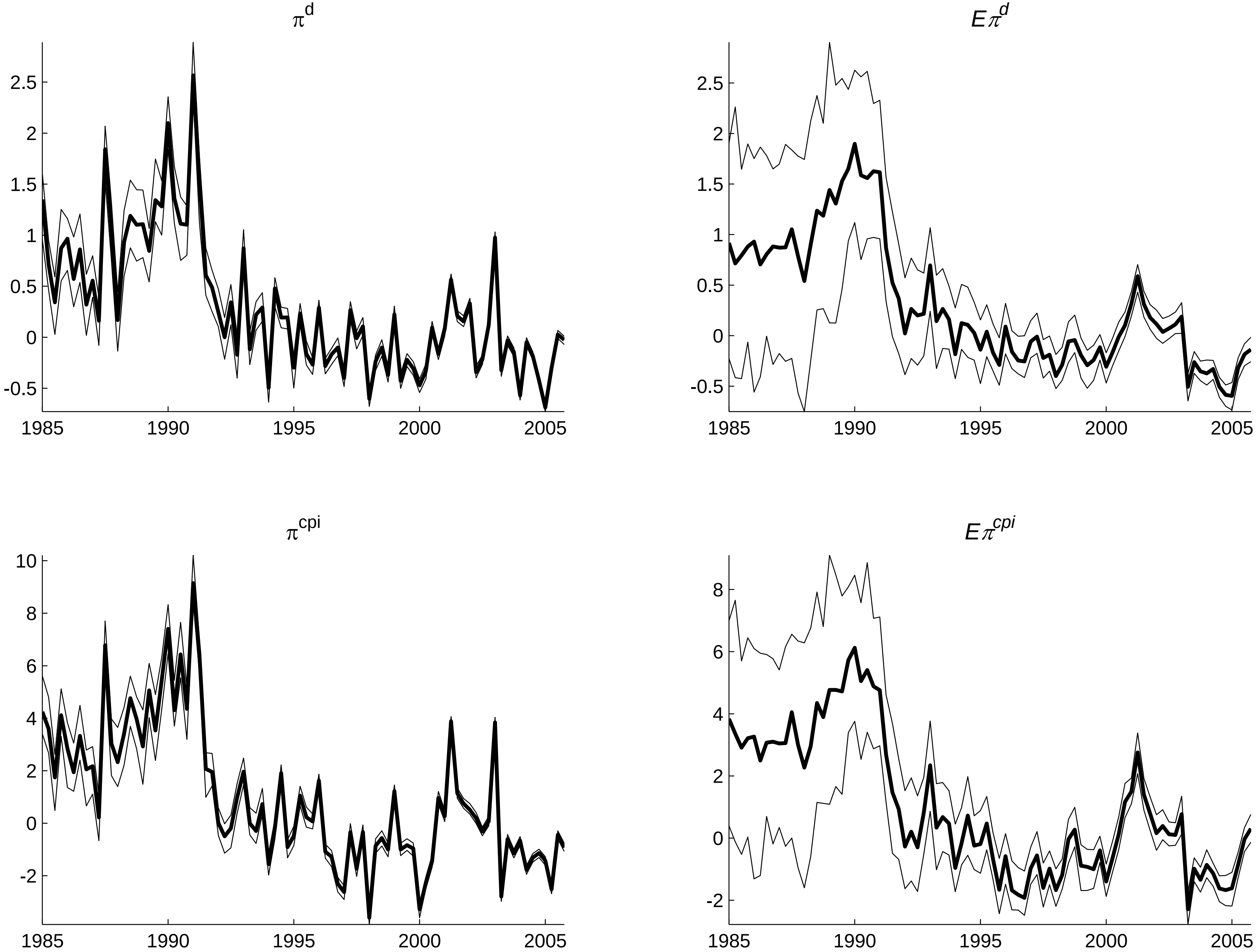
mc

rr

y^{fp}

$y^{TrendAdj}$

Figure 5b. Smoothed estimates.



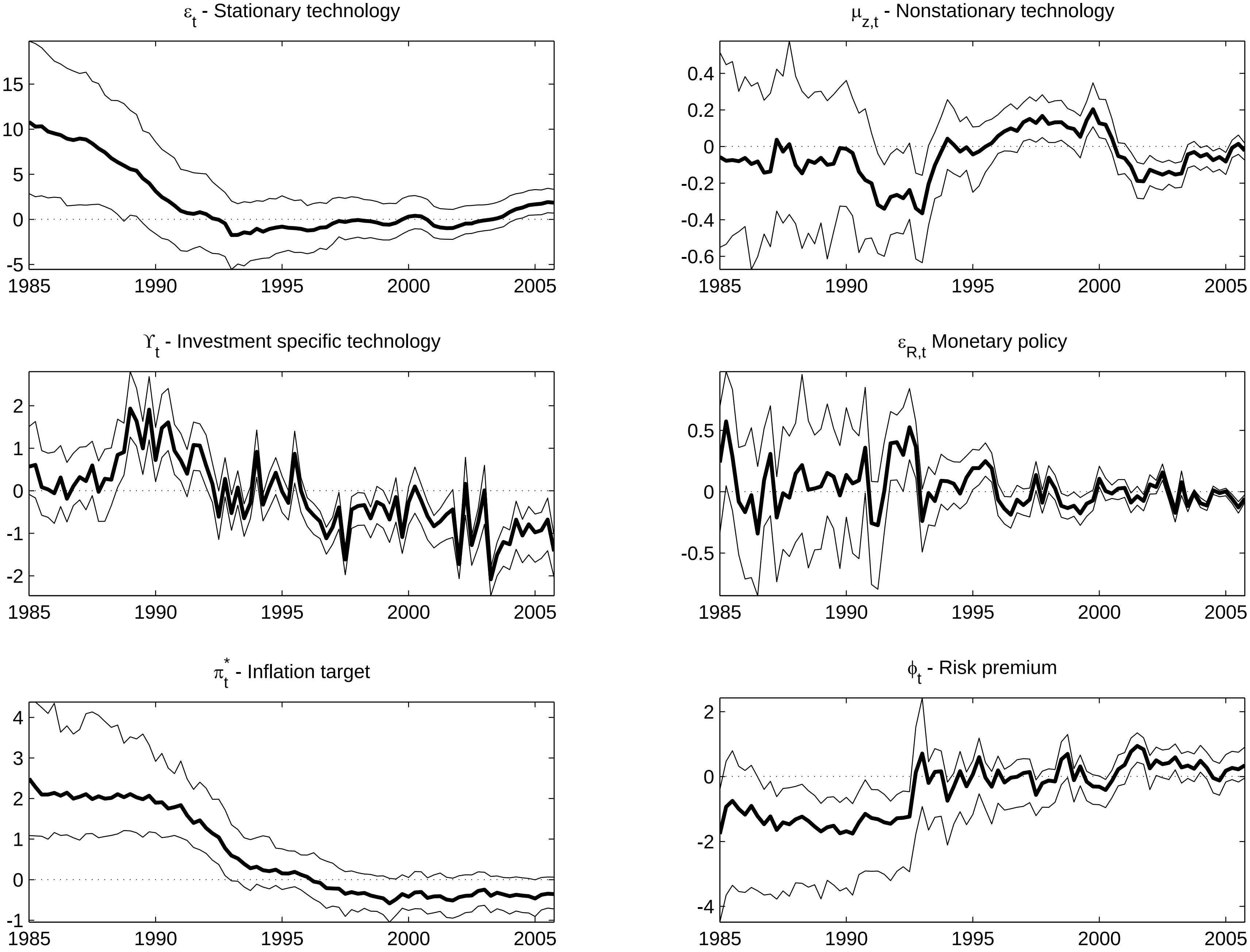


Figure 6. Smoothed estimates.

ε_t - Stationary technology

$\mu_{z,t}$ - Nonstationary technology

Υ_t - Investment specific technology

$\varepsilon_{R,t}$ Monetary policy

π_t^* - Inflation target

ϕ_t - Risk premium

Figure 7a. Historical Decomposition, Technology Shocks.

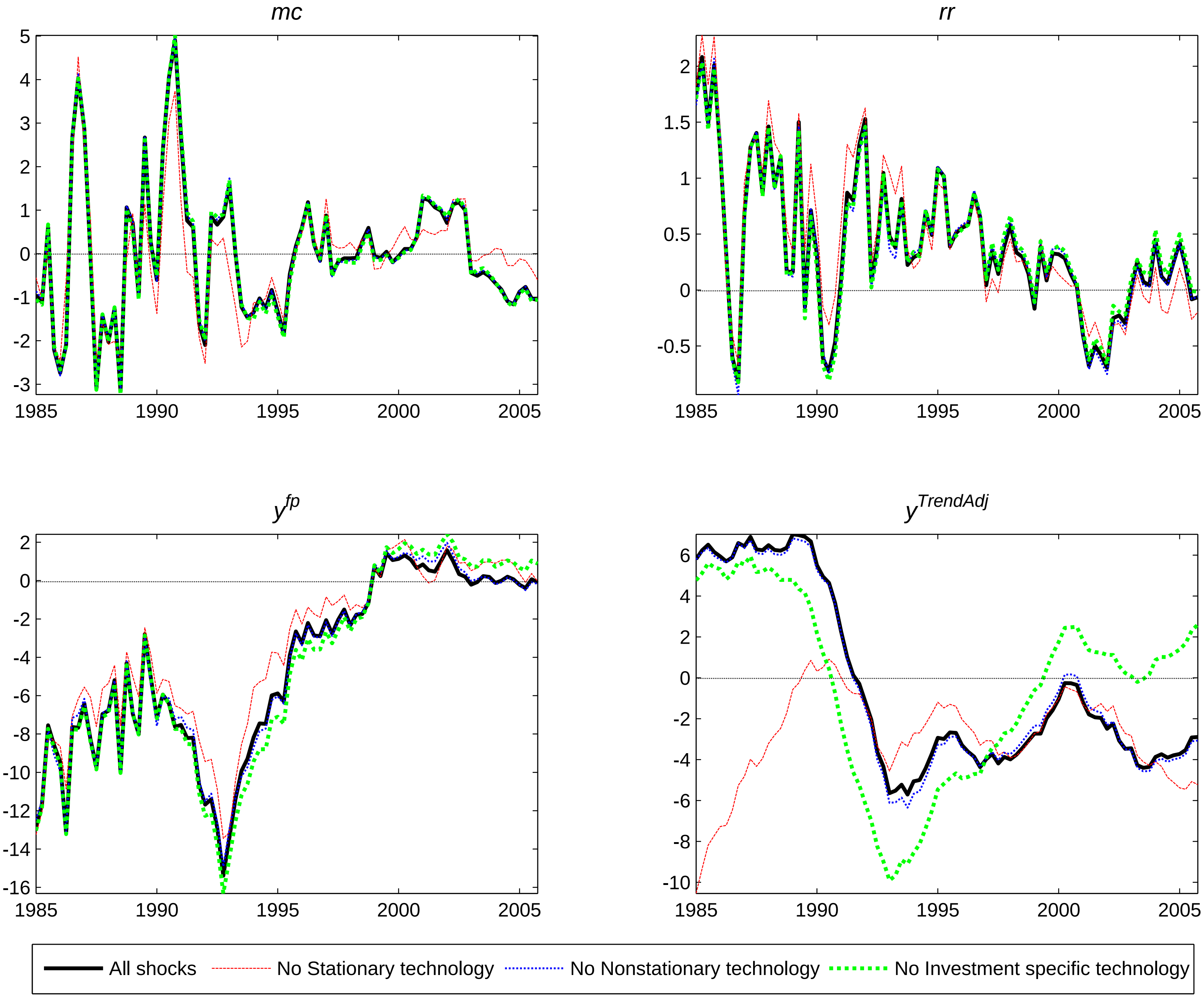


Figure 7b. Historical Decomposition, Technology Shocks.

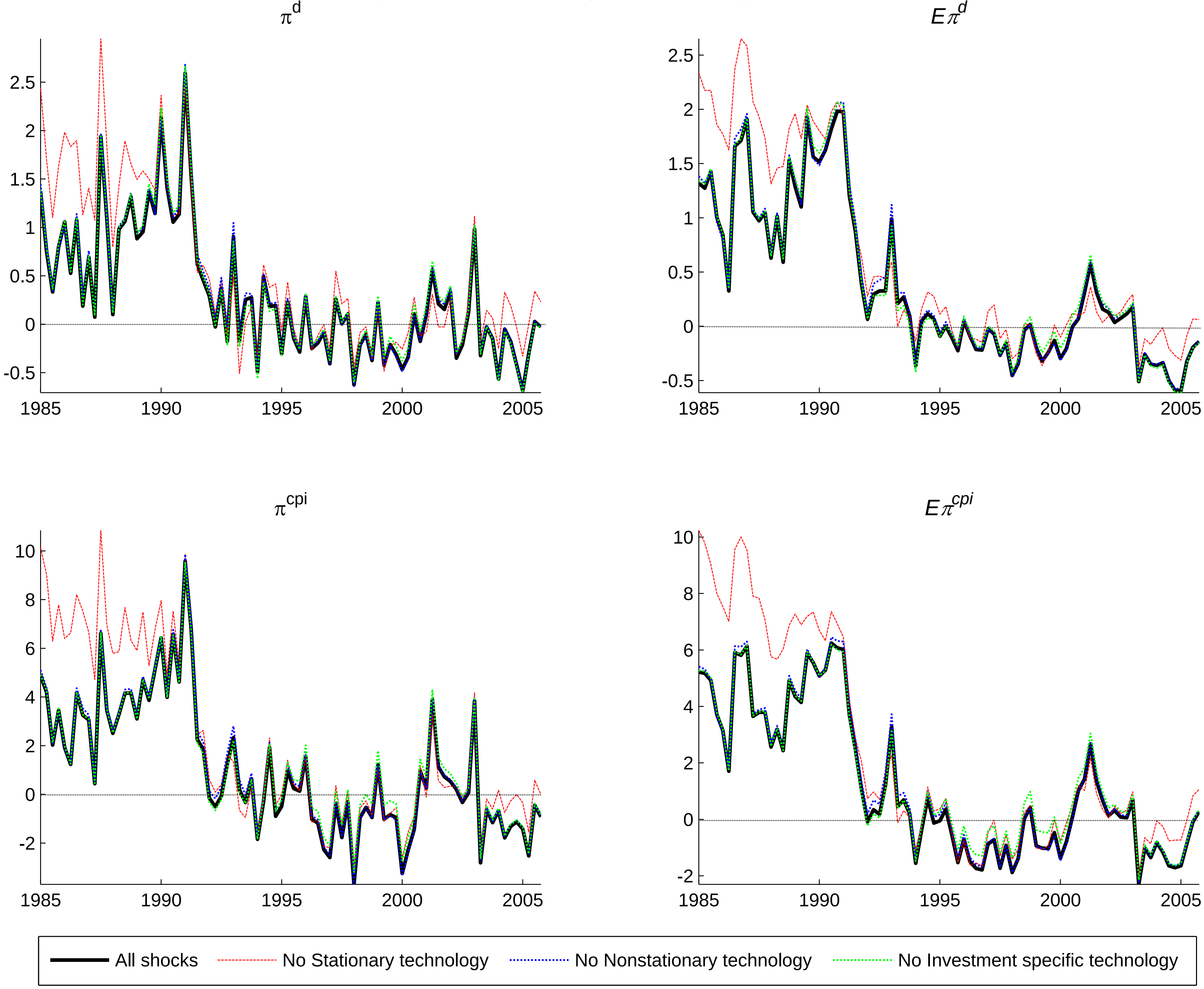


Figure 8a. Historical Decomposition, Interest Rate Shocks.

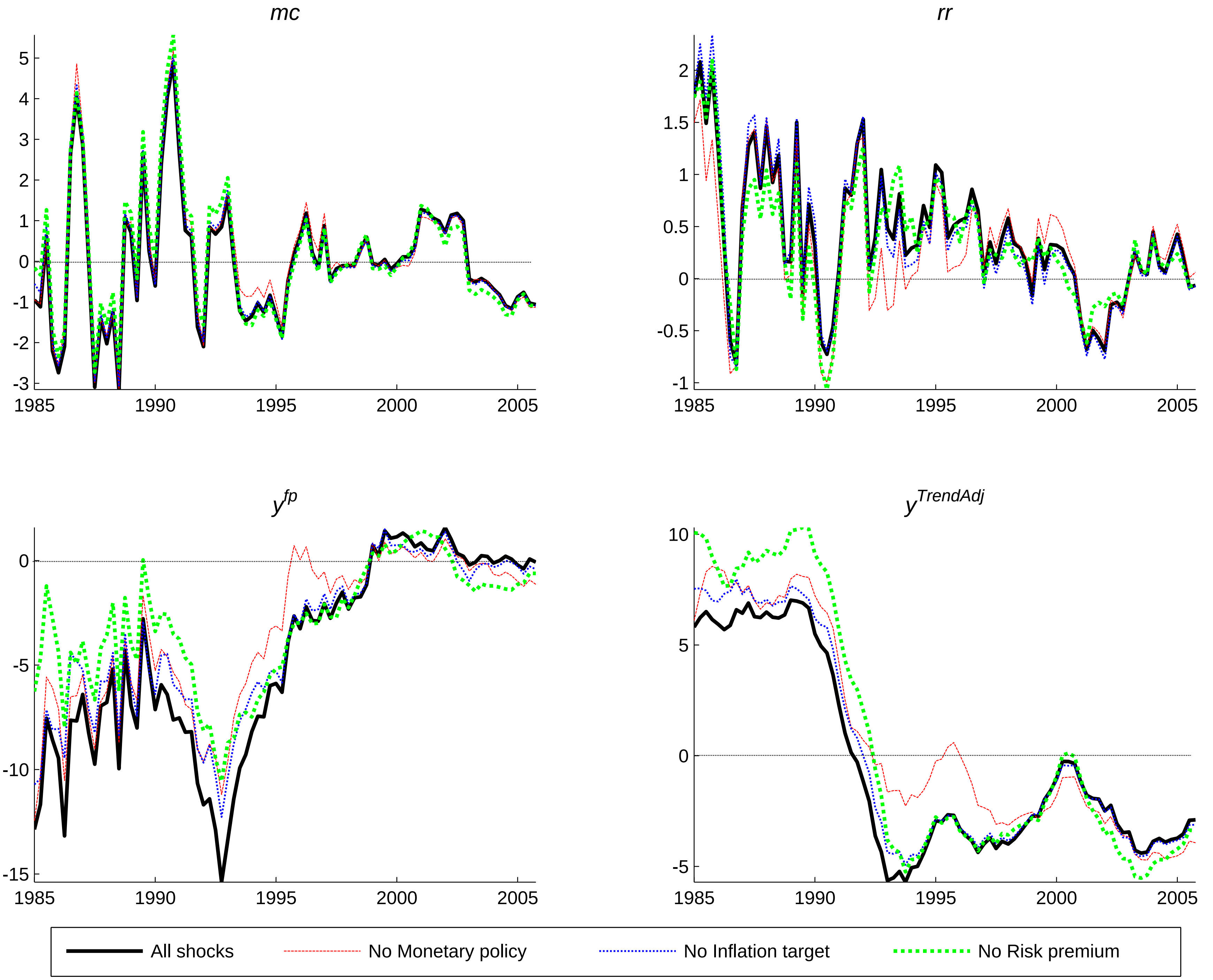


Figure 8b. Historical Decomposition, Interest Rate Shocks.