Monetary Policy under Rule-of-Thumb Consumers and External Habits: An International Empirical Comparison

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Abstract. This paper develops and estimates a simple New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model with rule-of-thumb consumers and external habits. Our theoretical model has a closed-form solution which allows the analytical derivation of its dynamical and stability properties. These properties are analyzed and discussed in the light of their implications for the efficacy and the calibration of the conduct of the monetary policy. The model is then evaluated empirically, employing numerical simulations based on Monte Carlo Bayesian estimates of the structural parameters and impulse response analyses based on weakly identified SVECMs. The estimates are repeated for each of the G7 national economies. Providing single country estimates and simulations, we derive some indications on the relative efficacy of monetary policy and of its potential asymmetric effects resulting from the heterogeneity of the estimated models.

Keywords: Rule-of-thumb, habits, monetary policy transmission, price puzzle, DSGE New Keynesian model, monetary policy, SVECM and Monte Carlo Bayesian estimators.

1. Introduction

Nearly fifteen years ago, Campbell and Mankiw (1989, 1990, 1991) provided evidence on the existence of heterogeneous consumers. The relevance of their findings is that they raised the question of a strong violation of the permanent income hypothesis. On the basis of their results, only a fraction of households is able to plan consumption according to the standard Hall’s consumption function, (Savers), while there is a relevant fraction of households that equates current consumption to the current income period by period (Spenders).[1]

The theoretical and policy implications of consumer heterogeneity are rather strong. Considering the fiscal policy theory, an important consequence is that the Barro-Ricardo equivalence theorem does not hold if Spenders are considered. For this reason, savers are often referred to as Ricardian consumers and Spenders as Non-Ricardian consumers (Mankiw, 2005).

The role played by the presence of a fraction of Spenders has been more recently analyzed with respect to its implications for the conduct of monetary policy, in a New Keynesian theoretical framework (Amato and Laubach, 2003; Galì *et al.*, 2003; Bilbiie, 2005).[2] The general finding of this new stream of analyses is that the presence of Spenders’ may alter dramatically the properties of these models and overturn some of the conventional results found in the literature.

Amato and Laubach (2003) explore the optimal monetary rule with rule-of-thumb households and firms. By modeling consumers’ rule-of-thumb behavior as a consumption habit, households’ current decisions mimic past behavior of all agents (including optimizing agents). The authors show that, while the monetary policy implications of rule-of-thumb firms are minimal, the interest rate is sensitive to the presence of rule-of-thumb consumers; in fact, as their fraction increases, higher inertial monetary policy is required.

Galì *et al.* (2003) show how the Taylor principle becomes a too weak criterion for stability when the fraction of rule-of-thumb consumers is large. However, the presence

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[1] Spenders’ behavior can be interpreted in various ways. One can view their behavior as resulting from consumers who face binding borrowing constraints. Alternatively, myopic deviations from the assumption of fully rational expectations should be assumed (rule-of-thumb), i.e. consumers naively extrapolate their current income into the future, or weigh their current income too heavily when looking ahead to their future income because current income is the most salient piece of information available. See Mankiw (2000) and references therein.

[2] Moreover, Christiano *et al.* (2001) investigate the effects of a rule-of-thumb behavior in firms’ decisions. Mankiw (2000) and Muscatelli *et al.* (2003) consider fiscal policy.

of Spenders cannot in itself overturn the conventional result on the sufficiency of the Taylor principle. By contrast, in the case of forward-looking interest rate rules, they show that the conditions for a unique equilibrium are somewhat different from those emerging in a context of contemporaneous rules. In particular, they show that when the share of Spenders is sufficiently large it may not be possible to guarantee a (locally) unique equilibrium or, if it is possible, it may require that interest rates respond less than one-for-one to changes in expected inflation.

Bilbiie (2005) discusses the implications of limited asset market participation for optimal monetary policy, from both a theoretical and empirical point of view. His main point is that when limited asset market participation is considered a passive interest rate rule is consistent with a welfare-maximizing monetary policy.

The aim of this paper is twofold. First of all, we provide the dynamic and stability properties of a model in which both rule-of-thumb consumers and external habits in Savers' consumption are considered. Second, on the basis of country-specific estimates of the structural parameters, we evaluate the empirical relevance of our hypotheses and the potential heterogeneity of the effects of the monetary policy.[3]

By considering a simple setup without capital accumulation, we can give a closed-form solution of the model. This allows us to analytically discriminate, on the basis of the fraction of Spenders, between two different demand regimes (i.e. two IS-curves), characterized by sign inversion of the coefficient capturing the correlation between the real interest rate and expected consumption growth. The possibility of a demand regime shift has a dramatic importance for the analysis of monetary policy efficacy. Moreover, it potentially has serious implications for the analysis of equilibrium determinacy, as discussed in Bilbiie (2004 and 2005) and Di Bartolomeo and Rossi (2005).

With respect to the efficacy of monetary policy, it has been shown that, if the correlation between expected consumption growth and real interest rates is positive, the efficacy of monetary policy increases in the fraction of Spenders (Amato and Laubach, 2003, Di Bartolomeo and Rossi, 2005). A reverse result is instead obtained if the correlation between expected consumption growth and real interest rate is negative (Di Bartolomeo and Rossi, 2005).

Regarding determinacy, we find that, in the case of a positive correlation, standard results hold, i.e. if monetary policy follows a standard Taylor rule determinacy is always associated to the satisfaction of the Taylor principle. By contrast, if the

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[3] For the country-specific empirical analysis we consider the single G7 economies.

correlation is negative, we find different requirements for stability, that are conditional on the magnitude of the effects of interest rates changes on the real output. Hence, the non-conventional results stressed by Galì *et al.* (2003) hold only if the correlation between expected consumption growth and real interest rate is negative.

The joint consideration of habits persistence in consumption and of Non-Ricardian consumers increases the complexity of the model, since the monetary multiplier becomes highly nonlinear. Employing numerical simulations we show that the introduction of habits, by increasing the threshold fraction of Spenders for which a sign inversion of the monetary multiplier can be obtained, reduces the probability of obtaining a regime shift in the demand schedule.

A further motivation for the recent theoretical interest on the introduction of Spenders into the DSGE New Keynesian model is its potential empirical relevance. The presence of Spenders may in fact explain the puzzling result of a negative correlation between expected consumption growth and real interest rate. The correlation between output changes and the real interest rate has been found to be low and sometimes negative across many of the industrialized countries that have been considered in the empirical investigations[4] (see Ahmad, 2004, Canzoneri *et al*., 2002).

The empirical evaluation of the aspects outlined above is particularly important for analyzing the potentially heterogeneous effects of monetary policy shocks among countries. The importance of these potential drawbacks is evident in the fact that the EMU countries face a centralized monetary policy. The empirical relevance of the different theoretical predictions is however still ambiguous. First of all, to the best of our knowledge, there are only few studies that have empirically addressed the effects of deviations from Hall's benchmark consumption for the forward-looking IS relation. Moreover, even when the problem has been explicitly or implicitly considered, the results obtained are weak and substantially inconclusive. In a recent paper, Fuhrer and Olivei (2004) provide empirical evidence for the parameters of a reduced form IS equation, defined in a standard New Keynesian model augmented with habits. The estimated income monetary multiplier resulted weakly negative or not significant in statistical terms. Bilbiie (2005) explicitly deals with the question of the monetary policy

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[4] A direct consideration of these aspects can be found in Bijbiie (2005). In this paper the author shows how the introduction of Spenders into the analysis can justify an alternative explanation of the evolution of the American monetary policy in the pre and post Volker period. He argues that the different reaction function of monetary policy derives from a different development of the financial markets, i.e. from modifications in the fraction of spenders. In this context, monetary policy is optimal in both periods and does not lead to indeterminacy. Bijbiie (2005) also provides some empirical evidence supporting his point of view.

implications of the presence of relevant liquidity constraints in consumption behavior. Even if the paper addresses specific issues regarding the empirical relevance of the liquidity constraints, the evidence cannot be considered conclusive. First, the main purpose of the work is to give an evaluation of the monetary policy conduct, in the pre-Volker and pre-financial liberalization period and not a direct estimate of the fraction of rule-of-thumb households. Second, even if the analysis is based on empirical results, these results cannot be considered particularly informative for our purposes. They are in fact obtained estimating a reduced form IS relation, which coefficients are only a convolution of the (structural) parameters of interest.[5]

In our empirical investigation we are mainly interested to the assessment of the potential heterogeneity of the effects of monetary policy. The efficacy of the monetary policy and its sensitivity to different parameterizations are evaluated simulating DSGE models that are parameterized employing the single countries' estimates of the structural coefficients. These simulations are then confronted with the impulse responses obtained simulating weakly identified monetary SVECMs. The empirical scrutiny is thus implemented in two steps.

In the first step, the analysis is based on the simulation of the structural DSGE model. The values of the deep parameters will not be calibrated or fixed on the basis of previous evidence, as in the standard practice. Our strong empirical stance suggests of estimating the structural coefficients employing quarterly data for the seven most industrialized economies (G7) for the period 1963-2003. Differently from the common practice emerging in recent studies (Smets and Wouters, 2003, Coenen and Straub, 2005), we consider these data separately in order to stress the cross-country heterogeneity. The complexity and nonlinearity of the resulting parameters structure of the model suggests the implementation of a Bayesian Monte-Carlo Markov Chain estimation procedure (MCMC). Once the different sets of structural parameters are obtained on a single country perspective, the resulting structures are simulated, in order to appreciate the different responses to typical shocks, in particular to monetary policy shocks. As it will be stressed with more detail in the following, our analysis is close in spirit to the strategy proposed by Smets and Wouters (2003) for the estimation of their

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[5] Moreover, their empirical relevance is potentially flawed, since they are obtained employing a GMM estimator, which small sample performances have been shown to be dramatically poor. A further problem with GMM estimation is that the chances of finding a theoretically consistent instrumentation for the moment conditions are strongly reduced when the number of modifications to the standard consumption function increases. This problem is of particular relevance if we consider that our theoretical framework includes both habits and rule-of-thumb consumption.

New Keynesian model. The main differences with respect to their analysis are that we do not consider capital accumulation and that we introduce Non-Ricardian consumers. Moreover, we develop a single country analysis for the G7 economies, while their estimates are referred to aggregate data for the Euro area.

In the second step, the empirical performances of the model will be confronted with the results of country-specific VAR-based impulse responses analyses. With respect to the standard practice established by Sims (1992) and Christiano *et al*. (1999), our strategy of analysis is somewhat original. The standard stationary SVAR representation of the monetary system is substituted by a SVECM representation in which the co-integration relation is identified as a Fisher Interest Parity (FIP).

The comparison of the DSGE simulations with the SVECM impulse responses provides a rich set of empirical results that are of particular relevance for discussing some issues that are currently debated in the literature. First, we will address the question of the heterogeneous effects of monetary policies potentially emerging when different consumption equations are assumed. Second, we will address some of the limitations and problems that have emerged in the empirical literature concerning the theoretical predictions of New Keynesian models. Both aspects have received only a minor attention in previous analyses. Employing DSGE simulations and impulse response analyses we show how it is possible to address the problematic result of a positive response of inflation to a policy shock, the so-called "price puzzle" (Eichenbaum, 1992), without questioning the particular conduct of the monetary policy or the specific empirical information employed. The price-puzzle emerged in a number of analyses on the monetary policy transmission channels and has been addressed as being the result of both weak identification of VARs (Sims, 1992, Bernanke, 2004)[6] and of a passive monetary policy conduct characterizing the central bank's pre-inflation targeting regimes (Clarida *et al*., 2000, Cogley and Sargent, 2005, Castelnuovo and Sarico, 2005).[7] On the basis of the simulation of the theoretical model and of the SVECMs, we will show that the "puzzling" VAR-based impulse responses to policy shocks are

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[6] A commodity price index correction of VARs resulted sufficient for resolving the price puzzle (Sims, 1992). This correction has been justified as being a proxy for time-varying inflation expectations.

[7] Castelnuovo and Sarico (2005) have shown that the weak identification and the passive policy explanations are not mutually alternative, as in the presence of a passive policy, indeterminacy is related to the emergence of an *omitted variable bias*, which in turn leads to high persistence in inflation, which is the ultimate responsible of the puzzle. Our SVECM approach addresses this problem as it takes into account the inflation persistence in a model which is specifically designed for I(1) processes. Furthermore, employing long-run restrictions only, we obtain an unrestricted contemporaneous structure which is consistent with the simultaneous structure of the theoretical model.

presumably due to the use of stationary VAR representations for Co-Integrated (CI) non-stationary variables.

The rest of the paper is organized as follows. Section 2 outlines the basic framework and describes the two demand regimes implied by the presence of Spenders and Savers' habits persistence. Section 3 presents an empirical examination of the model employing the relevant data of the seven major economies (G7) and is organized as follows: the first part contains the description of the Bayesian MCMC estimation of the structural parameters of the model and the discussion of the simulation results obtained with the estimated structures; the second part describes and discusses the SVECM analyses, adopting a comparative perspective. Section 4 concludes.

2. The basic theoretical framework

2.1. The model

We consider a simple New Keynesian model augmented with Non-Ricardian consumers and habits formation. In order to simplify the analysis and highlight the demand-side effects of Spenders' behavior we do not consider the capital accumulation process. We assume a continuum of infinitely-lived heterogeneous agents normalized to one. A fraction $1-\lambda$ of them consumes and accumulates wealth as in the standard setup (*Savers*). The remaining fraction λ is composed by agents who do not own any asset, cannot smooth consumption, and therefore, consume all their current disposable income (*Spenders*). We also assume that Savers consumption at time $t+i$ depends on habits inherited from past consumption, i.e. on a fraction γ of lagged aggregate consumption. Representative consumers are indexed by R (*Ricardian or Savers*) and N (*Non-Ricardian or Spenders*). At the date zero, they maximize the following functions:

$$(1) \qquad E_t \sum_{i=0}^{\infty} \beta^i u\left(C_{t+i}^j, M_{t+i}^j P_{t+i}^{-1}, N_{t+i}^j, \phi^j\right) \quad j \in \left\{R, N\right\}$$

where $\beta \in \left(0,1\right)$ is the discount factor, C_t represents household consumption at time t, while $\frac{M_{t+i}}{P_{t+i}}, N_t$ are, respectively, real money balances and labor supply. ϕ^j is a binary variable such that when $j=R$, $\phi^R=1$ and when $j=N$, $\phi^N=0$. For sake of simplicity, we use a logarithmic utility function, which allows us to obtain a closed-form solution of the model. Thus we assume the following instantaneous utility, $u(.) = \ln\left(C^{j}_{t+i} - \gamma\phi^{j} C^{\gamma}_{t+i-1}\right) - \kappa \ln\left(1 - N^{j}_{t}\right) + \phi^{j}\chi \ln\left(M^{j}_{t+i} P^{-1}_{t+i}\right)$ with $\chi > 0$ and $\varepsilon > 0$. In addition, the following budget constraints hold:

$$(2) \qquad C^{j}_{t} = \frac{W_t}{P_t} N^{j}_{t} + \phi^{j}\left[\Pi^{j}_{t} - \frac{M^{j}_{t} - M^{j}_{t-1}}{P_t} - \frac{B^{j}_{t} - (1+i_{t-1})B^{j}_{t-1}}{P_t}\right]$$

where W_t is the nominal wage at time t, Π_t is profit sharing. Real wages are the only source of Spenders' disposable income; therefore, they are subject to a static budget constraint, while Savers face the standard dynamic constraint. In fact, since Spenders do not save, they consume all their current income and the amount of money they hold at the end of period t is zero.

By solving the inter-temporal optimization problems of Savers and Spenders, aggregating and then log-linearizing, we obtain the following description of the demand side of the economy:

$$(3) \qquad c_t = -\frac{1-\varpi-\lambda\zeta^{N}}{1+\varpi}\left(i_t - E_t\pi_{t+1}\right) + \frac{\varpi}{1+\varpi}c_{t-1} + \frac{1}{1+\varpi}c_{t+1} - \frac{\lambda\zeta^{N}}{1+\varpi}\Delta\left(w_{t+1} - p_{t+1}\right)$$

$$(4) \qquad w_t - p_t = \upsilon n_t + \left(1-\varpi\right)c_t - \varpi\left(1-\varpi\right)c_{t-1}$$

where c_t is consumption, i_t is the nominal interest rate, π_t is the inflation rate and $w_t - p_t$ is the real wage. Concerning parameters, $\varpi = \gamma\left(1-\lambda\right)$ is the habit coefficient in aggregate term (given that only Ricardian consumers have consumption habits); $\upsilon = N\left(1-N\right)^{-1} = \theta\kappa^{-1}\left(1-\varpi\right)^{-1}$ is the inverse Frish elasticity, where $\theta = \left(\eta-1\right)\eta^{-1} \in \left(0,1\right)$ depends on the elasticity of substitution of intermediate goods η, thus on firms mark-up, and κ is labor disutility. The parameter $\zeta^{N} = \kappa\left(1+\kappa\right)^{-1}\left(1+\upsilon\right)\left(1-\varpi\right)$ is the steady state share of Spenders' consumption, which is a function of labor supply elasticity κ, of the habits parameter γ and of the proportion of Ricardian consumers $1-\lambda$. Equation (3) represents a modified version of the standard consumption Euler equation, Equation (4) is the consumers' aggregate labor supply.

Our Euler equation differs from the standard equation with habits formation, in which the last term of the right hand side of equation (3) is absent. This is due to the presence of Savers, which establish a link between the demand for goods and the real wage (see equation (4)).

Considering the economy production function, $y_t = a_t + n_t$, the resource constraint, $y_t = c_t$ and equation (4), equation (3) can be expressed as a modified IS-curve:

$$(5) \qquad y_t = \frac{1-\lambda\zeta^N\left[\left(1+\upsilon\right)+\varpi\right]}{1+\varpi-\lambda\zeta^N\left(1+\upsilon-\varpi^2\right)} E_t y_{t+1} + \frac{\varpi\left[1-\left(1+\varpi\right)\lambda\zeta^N\right]}{1+\varpi-\lambda\zeta^N\left(1+\upsilon-\varpi^2\right)} y_{t-1} +$$

$$-\frac{1-\varpi-\lambda\zeta^N}{1+\varpi-\lambda\zeta^N\left(1+\upsilon-\varpi^2\right)}\left(i_t - E_t\pi_{t+1}\right) + \frac{\lambda\zeta^N\upsilon}{1+\varpi-\lambda\zeta^N\left(1+\upsilon-\varpi^2\right)} \Delta E_t a_{t+1}$$

As in the standard New-Keynesian framework, the supply side of the economy can be represented by a continuum of firms producing differentiated intermediate goods for a perfectly competitive final goods market.

The forward-looking Phillips curve is the following:

$$(6) \qquad \pi_t = \beta E_t \pi_{t+1} + \tau mc_t ,$$

in which $\tau = \left(1-\varphi\right)\left(1-\beta\varphi\right)\varphi^{-1}$. The parameter φ defines price staggering, i.e. the fraction of firms maintaining their price fixed each period. Equation (6) is a forward looking equation for inflation, which links movements of current inflation to contemporaneous movements in real marginal cost and expected inflation. Given the model assumptions, sticky-price equilibrium real marginal costs are given by:

$$(7) \qquad mc_t = \frac{1+\upsilon\left(1-\varpi\right)}{1-\varpi} y_t - \frac{\varpi}{1-\varpi} y_{t-1} - \left(1+\upsilon\right) a_t .$$

Since markup is constant at the steady-state, under flexible price equilibrium real marginal costs are equal to zero. Substituting this relation in (5) and solving for y_t we can give an expression for the natural rate of output, which is the output under flexible price equilibrium y_t^f,

$$(8) \qquad y_t^f = \frac{(1+\upsilon)(1-\varpi)}{1+\upsilon(1-\varpi)} a_t + \frac{\varpi}{1+\upsilon(1-\varpi)} y_{t-1}^f .$$

The flexible price equilibrium output is a weighted average of technology and of its past value. Equation (8) shows that the inertial component is increasing in ϖ, hence in the aggregate habits stock and decreasing in the inverse Frisch elasticity. Given the definition of ϖ, the introduction of rule-of-thumb consumers reduces the role played by the inertial component in the natural rate of output adjustment process. If habits persistence is not present, equation (8) collapses to the standard natural output equation, in which the technological component alone drives the evolution of the natural output process. Considering the equations above, we finally find that (6) can be rewritten as:

$$(9) \qquad \pi_t = \beta E_t \pi_{t+1} + \frac{\tau(\kappa+\theta)}{\kappa(1-\varpi)}\left(y_t - y_t^f\right).$$

Notice that if we assume nonzero habits persistence in consumption, the fraction of Non-Ricardian consumers affects the coefficient for the inflation response to the output gap, otherwise it has no role.

An interesting result is that neither γ nor λ can change the sign of the correlation between inflation and output gap. In the next section we will show that the qualitative irrelevance result of the two modifications for consumption does not hold when considering the monetary multiplier in the equation defining the demand side of the economy.

2.2. Demand regimes and monetary policy

The dynamics of our model is summarized by equations, (8) and (9), which respectively describe the IS curve, the flexible-price real output adjustment and the Phillips curve.

The model is close in spirit to that proposed by the New-Keynesian literature. However, the existence of Spenders has serious implications for the impact of the interest rate – thus of monetary policy – on aggregate demand, from both a quantitative and a qualitative point of view. Other things equal, by increasing the fraction of rule-of-thumb consumers we can in fact generate an inversion in the sign of the monetary income multiplier. According to the sign of the income multiplier, equation (5) can in fact individuate two different demand regimes:

1. A standard demand regime – i.e. a negatively sloped IS curve – holds if the income monetary multiplier is positive. Such a regime is dominated by the hypothesis of life-cycle permanent income and thus by the consumption smoothing theory;
2. An inverse demand regime – i.e. a positively sloped IS curve – holds if the income monetary multiplier is negative. In other terms, the demand regime is dominated by the liquidity-constraint effect, for which an increase in real interest rates is expansionary and interest rate cuts imply demand contractions since many consumers cannot access to financial markets and saving.

The income elasticity of consumption is increasing in the share of Spenders - who are insensitive to interest rate movements – and in the extent to which labor supply is inelastic, because small variations in hours (and output) are associated to large variations in the real wage and hence in Spenders' consumption. Hence, if Spenders are many and/or the inverse of the Frisch elasticity is high, the income elasticity can become greater than one and the income monetary multiplier becomes negative, so that an increase in the interest rates can lead to an increase in output and aggregate consumption

We first discuss the case without habits, i.e. $\gamma = 0$ or $\varpi = 0$. The model in this case is described by the following equations:

(10) $$y_t = E_t y_{t+1} - \frac{1-\lambda\zeta^N}{1-\lambda\zeta^N\left(1+\upsilon\right)}\left(i_t - E_t\pi_{t+1}\right)$$

(11) $$\pi_t = \beta E_t\pi_{t+1} + \tau\left(1+\upsilon\right)\left(y_t - a_t\right).$$

Notice that ζ^N and υ are in this case independent of the Non-Ricardian consumer' fraction and that $y_t^f = a_t$.

Formally, the two regimes depend on a threshold value of λ. The traditional regime holds for:

(12) $$\lambda < \lambda^* = \frac{1}{\zeta_N\left(1+\upsilon\right)} = \frac{\kappa\left(1+\kappa\right)}{\left(\kappa+\theta\right)^2}.$$

If the inequality (12) is not satisfied, we fall in the liquidity-constraint regime. For relatively low values of θ and high values of κ, the threshold value is greater than one ($\lambda^* > 1$). In such a case, only the standard regime occurs since $\lambda \in [0,1]$. In other terms, the inverse Frish elasticity is smaller than one. For relatively high values of θ and low values of κ, the liquidity-constrained regime can emerge. In addition, if θ is greater than 0.5, λ^* is always smaller than one. Thus, in such a case, the liquidity-constraint regime can emerge for sufficiently high values of λ.

The simplified framework briefly analyzed above is still incomplete for deriving tight predictions on the model outcomes. First of all, we have to consider that the threshold value of λ^* only shows the critical fraction of rule-of-thumb in consumption above which an inversion in the sign of the income monetary multiplier emerges, and not for getting clear indications on the effects of, say, a monetary policy shock. These effects can be obtained only after considering the full set of equations and parameters of the monetary DSGE model. In particular, we have to consider the expectation-consistent Phillips relation and the monetary policy rule. If we substitute into (5) equation (11) and consider a Taylor-like reaction function for monetary authorities, we can see that the contemporaneous response of y_t to a positive policy shock is still deflationary for given values of the monetary policy coefficients, irrespective of λ being above the threshold. This result is particularly interesting for the conduct of monetary policy, as outcomes depend strongly on policy parameters.[8]

Moreover, when considering habits formation, the monetary multiplier becomes highly non linear in λ since ζ^N and υ depend on it. Thus, the analytical derivation of the conditions for regime shifts becomes problematic. Anyway, an implicit condition can be easily derived:

$$(13) \qquad \lambda < \frac{\left(1-\varpi^2\right)\kappa\left(1+\kappa\right)}{\left[\kappa\left(1-\varpi\right)\left(1-\varpi^2\right)+\theta\right]\left[\kappa\left(1-\varpi\right)+\theta\right]}$$

From the expression above it is clear that as θ increases the inverse regime is more likely to be observed. The effects of κ are more ambiguous; numerical simulations show that for high values of κ the inverse regime is never observed. The joint effect of λ and γ

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[8] This point is discussed in a later section, dedicated to the numerical simulation of the model.

on the regime is also ambiguous. Figure A1 shows the results from sensitivity analysis simulations, obtained employing a reasonable set of parameters values.[9] Dark areas represent the combination of γ and λ where the standard regime holds.

Numerical simulations show also that, other things equal, by augmenting the parameter defining habits persistence the threshold value of λ needed to obtain the monetary multiplier sign inversion tends to increase, hence the probability of observing a demand regime shift decreases.

The following two subsections briefly stress the relevance of the demand regimes in determining the quantitative and qualitative model predictions on the model properties and outcomes. In other words, as we are going to show, the demand regime affects not only quantitatively but even qualitatively the model predictions and results. Thus empirical evaluation of the different regimes acting in different economies becomes crucial to understand the monetary policy behavior.

2.3. Demand regimes and equilibrium determinacy

The recent literature on central banking has shown that one the fundamental tasks of the monetary authority is to support rational expectation equilibrium determinacy. In order to study determinacy in our mode, we consider two simple widespread-used Taylor rules:[10]

$$(14) \qquad i_t = \alpha_1 \pi_t + \alpha_2 y_t + k_1 ,$$

$$(15) \qquad i_t = \alpha_3 E_t \pi_{t+1} + k_2 .$$

where α_1, α_2 and α_3 are positive parameters and k_1 and k_2 constants, which do not affect the conditions for determinacy.[11] Note that, by using the Phillips curve (9), the

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[9] Without loss of generality, we plot the case of k between 0.1 and 1.5 and q between 0.3 and 0.6 (corresponding to an elasticity of substation between 1.4 and 2.5). Further plots, available upon request, do not show different qualitative paths.

[10] John Taylor has proposed that U.S. monetary policy in recent years can be described by an interest-rate feedback rule as that considered here (see, among others, Taylor (1993 and 1999) or Woodford (2004)).

[11] It is worth noticing that coefficient α_3 can be also determined in an endogenous manner by solving a central bank optimization problem. More in detail, equation (11) is derived from the so-called *flexible inflation targeting approach* (Svensson, 1999, 2003; Honkapohja, 2005). It can be also seen as the results of the utility-based welfare maximization (Woodford, 2003: Ch. 6). However, to generalize our results to such a case one should show that the central bank's loss parameters (and thus α_3) are independent of the Spenders fraction. An analysis of the utility based welfare criterion is beyond the scope of the present paper.

equation (15) can be re-written in the form of equation (14) by considering $\alpha_1 = \frac{1}{\beta}\alpha_3$, $\alpha_2 = -\frac{\tau(\kappa+\theta)}{\kappa\beta(1-\varpi)}\alpha_3$ and $k_2 = k_1 + \frac{\tau(\kappa+\theta)y_t^f}{\kappa\beta(1-\varpi)}\alpha_3$.. Thus, determinacy can be easily studied from equation (14) in both the above cases. Henceforth, we refer to equation (14) as a feedback Taylor rule and to equation (15) as a forward-looking Taylor rule.

Determinacy crucially depends on two factors: the demand regime and monetary policy efficacy, which will be also discussed in the next subsection in details. These factors can identified by the sign and size of $\Omega \equiv \frac{\partial y_t}{\partial i_t} = -\frac{1-\varpi-\lambda\zeta^N}{1+\varpi-\lambda\zeta^N\left(1+\upsilon-\varpi^2\right)}$ (from equation (5)). A negative (positive) sign occurs in the standard (inverse) regime. Efficacy increases in $|\Omega|$ thus to simply the exposition, we define $\bar{\Omega} = -\Omega$ as a positive measure of the monetary policy efficacy in the standard regime.

In the standard regime determinacy under a feedback Taylor rule requires an *active* policy rule satisfying:

$$(16) \qquad a_1 > 1 - \frac{1-\beta}{k} a_2,$$

where $k = \frac{\tau(\kappa+\theta)}{\kappa\beta(1-\varpi)}$ is the semi-elasticity of the price adjustment with respect to the real output (see equation (9)).

The above determinacy condition has a simple usual interpretation. A feedback rule satisfies the Taylor principle if in the event of a sustained increase in the inflation rate by one percentage point, the nominal interest rate will eventually be raised by more than one percentage point. Each percentage point of permanent increase in the inflation rate implies an increase in the long-run average output gap of $\left(1-\beta\right)k^{-1}$ percent. An exogenous Taylor rule thus conforms to the Taylor principle if and only if its coefficients satisfy $a_1 + \left(1-\beta\right)k^{-1}a_2 > 1$ (see, among others, Woodford, 2004).

In the liquidity-constrained regime, Ω is negative. To simply the exposition, we redefine it as $\bar{\Omega} = -\Omega$, which is a positive measure of monetary policy efficacy. Determinacy thus requires

$$(17) \qquad a_1 > \max\left\{1 - \frac{1-\beta}{k}a_2, \left(\frac{2}{\Omega} - a_2\right)\frac{1+\beta}{k} - 1\right\} \text{ or}$$

(18) $$a_1 < \min\left\{\frac{1+\beta}{k}-\frac{a_2}{k}, 1-\frac{1-\beta}{k}a_2, \left(\frac{2}{\Omega}-a_2\right)\frac{1+\beta}{k}-1\right\}$$

If $\Omega > \frac{1+\beta}{k}$, the Taylor principle (9) holds, but the equilibrium is stable also if $a_1 < \min\left\{\frac{1+\beta}{k}-\frac{a_2}{k}, \left(\frac{2}{\Omega}-a_2\right)\frac{1+\beta}{k}-1\right\}$. By contrast, if $\Omega < \frac{1+\beta}{k}$, $a_1 > \left(\frac{2}{\Omega}-a_2\right)\frac{1+\beta}{k}-1$ or $a_1 < \min\left\{\frac{1+\beta}{k}-\frac{a_2}{k}, 1-\frac{1-\beta}{k}a_2\right\}$ is requested.

Summarizing, in the standard regime, the Taylor principle is the necessary and sufficient condition for determinacy. In the liquidity-constrained regime, we have to consider two cases. i) If monetary policy has a relative high efficacy ($\Omega > (1+\beta)k^{-1}$), the Taylor principle is only a sufficient condition for determinacy since also a (relatively) loose policy leads to the same result. ii) By contrast, if monetary policy has a relatively low efficacy ($\Omega < (1+\beta)k^{-1}$), the Taylor principle does not leads to determinacy, a sufficient condition for determinacy requires a stronger reaction to inflation or, also in this case, a (relatively) loose policy.

By considering a forward-looking specification for the monetary policy, determinacy requires in the standard regime, determinacy:

(19) $$a_3 \in \left(1, 1+2\frac{(1-\beta)}{k\bar{\Omega}}\right).$$

Equation (19) is standard and nests the Taylor principle: monetary policy should respond more than one-to-one to increases in inflation, and should also not be too aggressive as noticed by Bernanke and Woodford (1997).

In the inverse regime, stability requires:

(20) $$a_3 \in \left(1-\frac{2(\beta+1)}{\Omega k}, 1\right).$$

In this regime monetary policy has to be conducted by a sort of inverted Taylor Principle. The central bank should respond less than one-to-one to increases in inflation. However, too loose monetary policies may also lead to indeterminacy. In particular, if monetary policy has relatively high effectiveness, $\Omega > 2\frac{\beta+1}{k}$, indeterminacy may also derives from a loose positive reaction to expected inflation, i.e. $a_3 < 1 - \frac{2(\beta+1)}{\Omega k}$.

The rationale of the inverse Taylor principle is as follows. In the standard regime, if the policy rule is not active, a non-fundamental increase in expected inflation generates an increase in the current output gap and, by the current Phillips curve, inflation increases, validating the initial non-fundamental expectation. The Taylor principle is needed to guarantee determinacy since an active rule generates a fall in output gap and thus in actual inflation, contradicting initial expectations. By contrast, in a liquidity-constrained regime, if the policy rule is active, a non-fundamental increase in expected inflation generates an increase in the current output gap and an increase in inflation (by the Phillips curve), validating the initial non-fundamental expectation. Thus, in such a regime, the Taylor principle leads to indeterminacy, instead a passive policy rule is requested. In fact, if the central bank follows a passive policy rule, a non-fundamental increase in expected inflation is associated with a fall in the real interest rate, a fall in the output gap, and deflation, contradicting the initial expectation that are hence not self-fulfilling.

2.4. Monetary policy efficacy and policy regimes

Different demand regimes, defined as above, imply different policy regimes, i.e. effects of monetary policy on the economic outcomes. The emersion of different policy regimes is related to both the sign of the semi elasticity of the demand with respect to the real interest rate (demand regime) and its side (monetary policy efficacy). Consider that monetary policy is set according to a Taylor rule of the kind (14) augmented by a white noise shock (i.e. a monetary policy disturbance), in such a case, thee different policy regime can be individuated.

1. In the standard demand regime ($\Omega < 0$), as usual, a negative interest rate disturbance i.e. a reduction in the nominal interest rate, always implies a increase in the output gap and inflation.
2. In the inverse regime ($\Omega > 0$) two different situations can occur:
   (a) If $\Omega > (a_1 + a_2)^{-1}$, a positive monetary disturbance will affect the economic outcomes as in the standard regime even if the semi elasticity of the aggregate demand with respect to the real interest rate is positive.
   (b) By contrast, if $\Omega < (a_1 + a_2)^{-1}$ a positive monetary shock has a deflationary

effect by decreasing inflation and real activity.

The rationale of the two different policy regimes in the case of a positive semi-elasticity of the demand with respect to the real interest rate can be explained as follows. In the inverse regime a negative monetary shock initially shifts the aggregate demand backwards and, thus, it reduces real output and inflation. The reaction of the central bank to this change (equation (14)) can imply either an increase or a reduction of the real interest rate The policy regime that will emerge depends on the monetary policy efficacy.

Neglecting the importance of habits formation, the efficacy of monetary policy is increasing in the fraction of Spenders in the standard demand regime. By contrast, in the liquidity-constrained regime, its efficacy is decreasing in the fraction of Spenders. By introducing habits, the effects becomes more difficult to investigate and numerical and calibration exercises are needed, we will discuss it again after our empirical investigation as well as the policy regimes.

3. Empirical evaluation of the model

3.1 Bayesian MCMC estimation of the structural parameters

On the basis of the derivations made in section 2, for the purpose of estimation and simulation we consider the log-linear system defined by equations 5 to 8 augmented with a Taylor-like monetary policy reaction function, an output gap definition and five structural shocks.

For the monetary policy reaction function we assume autoregressive interest rate smoothing, which intensity is defined by the parameter ρ_i, and that the monetary authorities react to deviations from targeted inflation π_t^* (assumed to be zero at the beginning of the simulation) and to the output gap x_t.

The structural shocks hitting the economy are: *i)* a preference shock ε_t^{IS}, *ii)* a technology shock ε_t^a, *iii)* a cost-push shock ε_t^{cp}, *iv)* a monetary policy shock ε_t^i and *v)* a shock on the monetary policy target, i.e. on targeted inflation, $\varepsilon_t^{\pi^*}$.

We also assume that the preference, the technology and the monetary policy target shocks are somewhat persistent, giving rise to autoregressive stationary processes governing preferences, technology and targeted inflation. The other shocks are represented by serially uncorrelated *i.i.d.* innovations. This characterization of the shocks is needed in order to reproduce the persistence and hump-shaped responses found in the data. It represents a quite weak assumption from a theoretical point of view, in fact it is commonly accepted that technology shocks, as well as preference shocks, have generally long-lasting effects, while the permanence of the monetary policy target can be justified on the grounds that, once convinced and committed on a given target, authorities change their mind slowly.

The operational structure is thus the following:

$$\begin{cases} y_t = \Omega_1 E_t y_{t+1} + \Omega_2 y_{t-1} - \Omega_3 \left(i_t - E_t \pi_{t+1} - \mu_t^{IS} + E_t \mu_{t+1}^{IS} \right) + \Omega_4 E_t \Delta a_{t+1} \\ \pi_t = \beta E_t \pi_{t+1} + \tau mc_t \\ i_t = \rho_i i_{t-1} + (1 - \rho_i) \left[\pi_t^* + \psi_\pi \left(\pi_t - \pi_t^* \right) + \psi_x x_t \right] + \varepsilon_t^i \\ mc_t = \dfrac{1 + \upsilon (1 - \varpi)}{1 - \varpi} y_t + \dfrac{\varpi}{1 - \varpi} y_{t-1} - (1 + \upsilon) a_t + \varepsilon_t^{cp} \\ x_t = y_t - y_t^f \\ y_t^f = \dfrac{(1 + \upsilon)(1 - \varpi)}{1 + \upsilon (1 - \varpi)} a_t + \dfrac{\varpi}{1 + \upsilon (1 - \varpi)} y_{t-1}^f \\ \pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_t^{\pi^*} \\ a_t = \rho_a a_{t-1} + \varepsilon_t^a \\ \mu_t^{IS} = \rho_{IS} \mu_{t-1}^{IS} + \varepsilon_t^{IS} \end{cases} , \tag{14}$$

where the first equation is the IS relation, in which the four reduced form coefficients Ω_i, i = 1,…,4, represent the corresponding structural parameters in equation (5), the second equation is the expectation-augmented Phillips curve and the third equation is a Taylor-like rule in the spirit of that employed by Smets and Wouters (2003). The fourth equation is the marginal costs definition under rule-of-thumb and habits persistence, the fifth the output gap definition and the sixth defines the process for natural output. The last three equations define the autoregressive processes for the three permanent components of our model.

3.1.1 A brief description of the estimation approach

Since we are interested to the estimation of the structural parameters of the model described above, the resulting computational task is somewhat complicated, as the strong nonlinearities in model parameters may significantly affect the performances of the numerical methods for Full Information Maximum Likelihood (FIML) estimation.[12] Even if a viable solution would be to restrict the parameters to assume values within a defined range that we deem as "reasonable", we adopt a Bayesian Monte Carlo approach.

The Bayesian approach that we adopt here[13] is close in spirit to restricted FIML estimation. Instead of employing interval restrictions on FIML estimated parameters, we use a procedure which nests a formalized *a priori* on parameters means and dispersions with the conditional distributions - i.e. with the likelihood function - in order to obtain a posterior density that we will consider as the benchmark distribution for our Monte Carlo parameter estimates. The final estimates will be obtained employing the Metropolis-Hastings (M-H) Monte Carlo Markov Chain (MCMC) procedure implemented in Dynare for Matlab (Juillard, 2004).

The posterior density is a result of a weighted average of the prior distributions and of the likelihood function (i.e. the empirical information), with weights inversely related to, respectively, the variance of the prior distributions and the variance of the sample information ("precisions.") The bigger the informative power of the likelihood (i.e. the lesser the variances of the likelihood-based parameters), the closer the posterior will be to the conditional distribution. In the limiting case in which the data allow a perfect knowledge of the parameter values, the posterior density collapses to the conditional distribution. Contrary, if the empirical information is weakly informative, the priors will correspondingly have more weight in the estimation. Formalizing a tight prior will result in highly constrained estimation, while assuming a diffuse prior will result in weakly constrained estimation.

Formally, our procedure requires of nesting the prior distribution $P(\boldsymbol{\theta})$ for the parameter vector $\boldsymbol{\theta} \in \boldsymbol{\Theta}$ and the conditional distribution (or likelihood)[14] $P(Y_T \mid \boldsymbol{\theta})$, $Y_T = \{y_t\}_{t=1}^{T}$ to get the posterior distribution $P(\boldsymbol{\theta} \mid Y_T)$. Basically, this is obtained employing the Bayes theorem, i.e.

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[12] For some reference applications of the methodology, cf. Ireland (1999).

[13] In our applications we follow the Bayesian strategy adopted in Smets and Wouters (2003), which in turn draws on Geweke (1998), Landon-Lane (2000), Otrok (2001), Fernandez-Villaverde and Rubio-Ramirez (2001) and Schorfheide (2002).

[14] The conditional distribution is obtained employing the Kalman filter (Sargent, 1989).

$$(15) \qquad P(\boldsymbol{\theta} \mid Y_T) = \frac{L(Y_T \mid \boldsymbol{\theta}) P(\boldsymbol{\theta})}{P(Y_T)},$$

where $P(Y_T)$ is the marginal distribution. Once the posterior distribution is obtained, it will be employed as the "proposal density" to initialize the M-H MCMC sampling method,[15] which substantially generates a large number of random draws from the posterior density in order to obtain a Monte-Carlo estimate of the parameters' means and distributions.

Operationally, the proposed model (14) is estimated employing four observable variables, log real private output, first differences of the log GDP deflator, the quarterly nominal interest rate and a measure of the log real output gap, obtained as explained in the section dedicated to the description of the data.

3.1.2 The subjective component: prior distributions

The shape of the prior distributions is chosen according to the following assumptions: we assume, as in Smets and Wouters (2003), that the reference distribution for the structural shocks is the inverted gamma distribution with two degrees of freedom, which is consistent with a diffuse prior on perturbations and positive variances; for parameters theoretically defined in a 0-1 range, we assume a beta distribution, while for the other parameters we assume a normal distribution. The means and standard deviations are defined on the basis of the empirical reliability of the information obtainable from other studies or from the results of preliminary GMM and ML estimates conducted on reduced-form equations for the seven countries.

Differently from Smets and Wouters (2003), since in our log-linear formulation of utility the dimensionality of the parameterization is reduced, with the exception of the discount factor β which is fixed at 0.995 (this is consistent with a steady state real rate of 2%), we do not employ fixed parameters values. Anyway, we adopt relatively tight priors for the elasticity of substitution across intermediate goods η and for labor disutility κ.

As a result of the model assumptions described above, we have to estimate 16 parameters, of which 5 define the distribution of the structural shocks and 3 their

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[15] More precisely, the algorithm employs the mode and the Hessian evaluated at the mode for the initialization of the M-H procedure.

persistence.

Concerning prior mean values, in line with Galì *et al.* (2003), the expected elasticity of substitution across intermediate goods η is set to 6, which is consistent with a steady-state mark-up of 20%. The mean of the labor disutility parameter κ, set to 3, is chosen on the basis of the ratio between hours spent at work and total available time. For both parameters, we assume a relatively small prior variability of, respectively, 0.3 and 0.15, consistent with a 5% coefficient of variation, and a normal prior shape. Concerning the Taylor rule parameters, we assume that the mean values for the parameter on expected inflation and for the parameter on output gap are, respectively, 1.5 and 0.125. Prior standard deviations are, respectively 0.15 and 0.05 and the prior shape of the distribution is again the normal. The chosen variability implies a moderately diffuse prior for the first parameter and a very diffuse prior for the second parameter. These values are also consistent with the average ML estimates of the Taylor rule parameters conducted for the seven countries included in the analysis. The prior mean of the interest rate smoothness parameter, consistently with the average ML estimates, is 0.8, while for its variability we assume a prior of 0.10, which can be considered relatively large with respect to the empirical standard deviations found with the ML estimates. The chosen prior shape for the distribution of the interest rate smoothness parameter is the beta distribution.

For the fraction of firms maintaining the price fixed φ we assume a prior mean of 0.75, which is consistent with the results of Galì *at al*. (2001). These authors obtained an average duration of the price contracts of approximately one year and a rather small prior variability, consistent with a range between 3 and 6 quarters.

For the parameters defining the persistence of shocks, following Smets and Wouters (2003), we adopt a common mean value of 0.85 and a prior variability of 0.10. The choice of a relatively concentrated prior for the persistence parameters is justified by the need of having a tight separation between persistent and transitory shocks, which enhances the identification of the two shocks entering the interest rate equation. The prior shape is the beta distribution.

For the habits persistence parameter we assume a prior mean value of 0.7 associated with a moderately diffuse prior variability of 0.1. The shape of the prior distribution is again the beta distribution. Prior mean and variability are chosen on the basis of the evidence emerged in a number of previous studies and on the basis of the results of our GMM estimates of the parameters of an Euler equation for consumption, modified in order to account for habits persistence.

For the rule-of-thumb parameter we set a prior mean of 0.5 and a prior S.D. of 0.10, while the reference distributional shape is again the beta. These prior values are consistent with the findings of Campbell and Mankiw (1989) and with the average result from our GMM estimates for the seven major economies.[16]

For the structural shocks we basically adopt a parameterization which is similar to that employed by Smets and Wouters (2003). Apart from the large interval implied by the assumption of 2 degrees of freedom for the inverted gamma distribution, the prior mean values are obtained from previous estimations conducted with very diffuse priors.

The table below reassumes the prior distributions for the structural parameters considered in the analysis.

Table 1. Prior distributions for the structural parameters

Parameter	Definition	Prior shape	Prior mean	Prior S.D.
sigma_*e* _*a*	Structural technology shock	inv_gamma	0.090	2
sigma_*e* _*IS*	Structural technology shock	inv_gamma	0.220	2
sigma_*e* _*pi*	Structural technology shock	inv_gamma	0.010	2
sigma_*e* _*i*	Structural technology shock	inv_gamma	0.012	2
sigma_*e* _*dP*	Structural technology shock	inv_gamma	0.050	2
rho_*a*	Persistence parameter for tech. shock	beta	0.850	0.10
rho_*IS*	Persistence parameter for tech. shock	beta	0.850	0.10
rho_*pi*	Persistence parameter for tech. shock	beta	0.850	0.10
rho_*i*	Smoothness parameter for nominal interest	beta	0.800	0.10
beta	Discount factor	-	0.995	0
eta	Elasticity of substitution among intermediate goods	normal	6.000	0.30
k	Labor disutility	normal	3.000	0.15
psi_*pi*	Taylor rule parameter on inflation	normal	1.500	0.15
psi_*x*	Taylor rule parameter on output gap	normal	0.125	0.05
phi	Calvo parameter	beta	0.750	0.10
gamma	Habits persistence parameter	beta	0.700	0.10
lambda	Fraction of rule of thumb consumers	beta	0.500	0.10

Note: for the inverted gamma distribution the degrees of freedom are indicated

3.1.3 Numerical simulation under prior means parameterization

For a better understanding of the dynamical properties of the model, the model is solved numerically and simulated adopting, for the parameterization, the mean values of the

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[16] E.g. Fuhrer (2000) finds that about one-fourth of income accrues to rule-of-thumb consumers in the United States. Muscatelli *et al*. (2003) find an even larger proportion. They suggest that about 37% of consumers are rule-of-thumb consumers, whilst 84% of total consumption in steady state is given by optimizing consumers. Rule-of-thumb consumers account for about 59% of total employment. Additional evidence is provided by Jappelli (1990), Shea (1995), Parker (1999), Souleles (1999), Fuhrer and Rudebusch (2003), and Ahmad (2004).

prior distributions. Impulse responses are reported in figures A2-A6 in the Appendix.

The prior calibration and simulation of the model gives encouraging results. The simulated moments of the artificial series are close to the empirical moments of the U.S., and the impulse responses are qualitatively consistent with the theoretical expectations. The typical hump-shaped behavior of the empirical impulse responses is well reproduced both in the extent and in the duration of the deviations from steady-state equilibrium.

It is interesting to highlight that, other things equal, when the habits parameter is increased above 0.8, the price puzzle emerges even assuming values of the inflation parameter in the Taylor rule that are well above the standard prescription for determinacy.[17] If we set the Taylor rule inflation parameter at 1.2, the price puzzle can be obtained by augmenting the fraction of rule-of-thumb consumers above 0.58. The price puzzle also emerges increasing the fraction of rule-of-thumb consumers above 0.7, irrespective of the values adopted for the habits and the Taylor rule inflation parameters. Indeterminacy emerges for rule-of-thumb parameter values that are above 0.85, while a regime inversion can be obtained, under this parameterization, solely by increasing the rule-of-thumb parameter at values that are well above the indeterminacy threshold.

This means that, as long as the parameterization employed is credible, the probability of a demand regime shift is very low, since it requires a very high percentage of Non-Ricardian consumers. Such percentage is realistically improbable, both in the light of the theoretical results and of the empirical evidence provided by the literature. Conversely, the price puzzle is an empirical result that can be considered being consistent with the model properties, especially when there are substantial but dimensionally “reasonable” deviations from Hall’s consumption behavior, and/or a not particularly tight conduct of the monetary policy.

3.1.4 Parameter estimates and country-specific simulations

Table 2 summarizes the MCMC estimates of the structural parameters and their posterior distributions, obtained with the Metropolis-Hastings sampling algorithm.

We find relevant heterogeneity across countries, in particular for the parameters indicating the fraction of rule-of-thumb households and habit persistence. Since the other parameters show a lower cross-country variability, the heterogeneity found with respect to the rule-of-thumb and the habits parameters emerges as the main cause of the

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[17] The price puzzle is in this case observed for a Taylor rule inflation parameter equal to 1.2.

differences that we get when the model is simulated employing the country-specific parameterization.

Italy shows the highest rate of habits (0.8), while Germany the lowest (0.6). The average habits persistence parameter is 0.7, a value that is strictly in line with the results obtained in previous empirical investigations.

The average fraction of Spenders for the G7 economies is 26%, a value that is well below the prior mean employed in the estimations, which has been chosen on the basis of the results of preliminary GMM estimates of reduced-form consumption functions and of other studies. Anyway, this value is broadly consistent with the outcomes of the analysis of Campbell and Mankiw (1991), who obtained a fraction of Spenders of approximately 35% for the U.S. and 20% for the U.K.. It is also marginally consistent with the results obtained by Banerjee and Batini (2003) who, employing the solution procedure of Anderson and Moore (AIM, 1985), obtained a fraction of Spenders of nearly 26% for the US and of nearly 15% for the UK.

Interestingly, the fraction of rule-of-thumb households in Italy, Germany and Japan is relatively low (nearly 7% on average), while it is high in France (0.44), in the U.K. (0.42), in the U.S. (0.37) and in Canada (0.30). This result is surprising, since it requires explanations that are not in line with the standard view on the meaning of rule-of-thumb consumption.

In many studies the existence of Spenders is considered a proxy of the development and efficiency of the financial sector. As long as our estimates are reliable, since the higher fraction of Spenders is found for countries in which the financial markets are considered developed and efficient, the standard interpretation of rule-of-thumb consumption appears misleading. Under this perspective, differences are more likely to be related to psychological and cultural factors rather than to financial factors.[18]

The estimates also show a considerable degree of Calvo price stickiness, which average estimate is 0.84, consistent with an average duration of the price contracts of approximately 6 quarters.

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[18] Japan, Germany and Italy, though different in many respects, have some relevant similarities. In particular, they are relatively similar with respect to the importance of the generational and family transfers, to the role of the Banking sector, and show the highest saving rates among industrialized countries.

Table 2. MCMC estimates of the structural parameters. G7 countries

	USA			JAP			GER			FRA		
Parameter	Mean	inf	sup	Mean	inf	sup	Mean	inf	sup	Mean	inf	sup
sigma_e_a	0.048	0.048	0.048	0.048	0.048	0.048	0.346	0.294	0.358	0.048	0.048	0.048
sigma_e_IS	0.125	0.113	0.123	0.086	0.090	0.097	0.041	0.043	0.045	0.128	0.122	0.135
sigma_e_pi	0.008	0.005	0.012	0.006	0.004	0.008	0.017	0.015	0.018	0.020	0.016	0.024
sigma_e_i	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
sigma_e_dP	0.162	0.159	0.175	0.241	0.227	0.251	0.238	0.229	0.247	0.156	0.133	0.163
rho_a	0.767	0.735	0.767	0.780	0.737	0.757	0.828	0.815	0.839	0.709	0.695	0.718
rho_IS	0.948	0.946	0.949	0.935	0.934	0.938	0.826	0.827	0.830	0.881	0.866	0.882
rho_pi	0.746	0.744	0.763	0.970	0.967	0.976	0.840	0.841	0.844	0.933	0.932	0.933
rho_i	0.801	0.801	0.803	0.861	0.858	0.863	0.821	0.821	0.822	0.876	0.876	0.878
beta	0.995	-	0.995	-	0.995	-	0.995	-	0.995	-	0.995	-
eta	5.895	5.810	5.917	6.055	6.096	6.186	5.977	6.001	6.059	5.958	5.865	6.008
k	3.128	3.143	3.250	3.032	2.977	3.018	3.075	3.036	3.116	3.009	3.009	3.055
psi_pi	1.491	1.493	1.502	1.498	1.518	1.587	1.507	1.474	1.496	1.494	1.494	1.495
psi_x	0.204	0.195	0.263	0.131	0.117	0.144	0.114	0.126	0.130	0.133	0.133	0.134
phi	0.837	0.833	0.846	0.823	0.817	0.825	0.865	0.864	0.865	0.854	0.854	0.854
gamma	0.710	0.687	0.714	0.729	0.729	0.756	0.610	0.610	0.612	0.685	0.684	0.685
lambda	0.372	0.298	0.409	0.087	0.065	0.126	0.077	0.049	0.102	0.442	0.441	0.443

	UK			ITA			CAN			G7		
	Mean	inf	sup	Mean	inf	sup	Mean	inf	sup	Mean	inf	sup
sigma_e_a	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.090	0.083	0.092
sigma_e_IS	0.056	0.060	0.066	0.105	0.109	0.143	0.111	0.079	0.099	0.093	0.088	0.101
sigma_e_pi	0.009	0.005	0.008	0.006	0.005	0.006	0.006	0.005	0.006	0.010	0.008	0.012
sigma_e_i	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
sigma_e_dP	0.200	0.182	0.214	0.300	0.287	0.364	0.288	0.204	0.281	0.226	0.203	0.242
rho_a	0.779	0.674	0.802	0.853	0.825	0.881	0.829	0.778	0.846	0.792	0.751	0.801
rho_IS	0.856	0.876	0.896	0.928	0.909	0.943	0.909	0.899	0.908	0.897	0.894	0.906
rho_pi	0.969	0.966	0.990	0.979	0.970	0.992	0.990	0.978	0.998	0.918	0.914	0.928
rho_i	0.879	0.876	0.883	0.864	0.846	0.879	0.849	0.827	0.847	0.850	0.843	0.853
beta	0.995	-	0.995	-	0.995	-	0.995	-	0.995	-	0.995	-
eta	6.070	5.930	5.999	5.971	5.861	6.029	5.971	5.896	6.022	5.985	5.923	6.031
k	3.095	2.995	3.136	3.168	3.060	3.173	3.049	3.039	3.139	3.079	3.037	3.126
psi_pi	1.507	1.504	1.514	1.496	1.429	1.614	1.454	1.399	1.452	1.492	1.473	1.523
psi_x	0.136	0.140	0.145	0.192	0.199	0.285	0.166	0.129	0.156	0.154	0.148	0.180
phi	0.806	0.804	0.805	0.846	0.837	0.869	0.877	0.852	0.884	0.844	0.837	0.850
gamma	0.646	0.641	0.644	0.818	0.804	0.859	0.753	0.723	0.735	0.707	0.697	0.715
lambda	0.422	0.427	0.439	0.090	0.062	0.119	0.314	0.301	0.377	0.258	0.235	0.288

Computations obtained with Dynare for Matlab

We find a significant positive central bank's short-term reaction to the current change in inflation and the output gap. Our estimation delivers plausible parameters for the long and short-run reaction function of the monetary authorities, and results are broadly in line with those discussed in Taylor (1993). The parameter for the policy reaction to inflation is rather stable across countries and in line with the prior assumptions. Some heterogeneity is found with respect to the policy elasticity to the output gap. The highest values are obtained for the U.S. and for Italy (nearly 0.2), while the lowest for Germany (0.11), Japan, France and the U.K..

In agreement with the large literature on estimated interest rate rules, we also find evidence of a substantial degree of interest rate smoothing, which in addition is also rather stable across countries.

The simulation of the DSGE model conducted employing the estimated structural parameters provides an appreciation of the degree of heterogeneity of the dynamic properties of the stylized economies. In particular, the simulations allow a recognition of the country specific efficacy of monetary policy and of the degree of asymmetry of its effects. Figure A7 contains the impulse responses to a technology shock, while Figure A8 the impulse responses to a monetary policy shock.

Concerning the reaction to monetary policy, the biggest impulse response of inflation to a positive interest rate shock is found for Japan, for which the half-life deviation from price stability is approximately 4 quarters, while the smaller if found to the U.S. which half life is nearly 2 quarters. The responses of output are even more differentiated among countries. A common feature is that the maximum effect on output of the monetary policy shock is reached after 2 quarters. The maximum responsiveness and duration of effects is found for the U.K., the minimum for the U.S.. The half life of the response is approximately 4 quarters for the U.S., 6 quarters for Italy, Germany and Japan, 7 for Canada and 8 quarters for U.K. and France. In line with the theoretical predictions, with the exception of the U.S., the output sensitivity to monetary policy is thus stronger in those countries that show the highest fraction of rule-of-thumb consumers.

3.2 VAR analysis

In this section the results obtained from the Bayesian MCMC estimation of the model are confronted with the outcomes obtainable with the simulation of a weakly-identified VAR structure. The common practice with monetary VARs has been to estimate and simulate stationary structural representations.[19] The choice for a stationary representation is made possible by the use of pre-filtered or de-trended variables, while the structural representation is generally obtained with the orthonormalization of the variance-covariance matrix of errors and the imposition of exclusion restrictions on the contemporaneous impact matrix of the VMA representation. In a three-variable stationary VAR representation with output, inflation and nominal interest rates

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[19] Sims (1992) and Christiano *et al*. (1999) can be considered the benchmark for the standard practice.

$\mathbf{x}_t' = [y_t, \pi_t, i_t]$, the structural identification is thus generally obtained, given the particular ordering of variables defined above, by imposing a triangular structure to the impact multipliers, i.e. by operating a Cholesky decomposition.

We criticize this approach from two points of view. First, we argue that, as long as we deal with non-stationary variables, the stationary VAR representation is potentially badly specified, as Co-integration (CI) may emerge between the levels of the variables in the VAR. In such a case, the VECM is the appropriate structure. Second, even if the triangular structure defined by the Cholesky decomposition allows the identification of shocks as "original," the resulting contemporaneous structure is not model-consistent.

In other terms, the stationary triangular SVAR representation is unsatisfactory for being unable to render, on the one hand, a statistically appropriate representation of the data, as it omits the potential error-correction dynamics implied by CI and, on the other hand, a model consistent contemporaneous structure.[20]

3.2.1 The structural identification of the VECM

The SVECM approach that we employ in this analysis is convenient in both respects. In particular, the presence of CI entails a reduction of the number of contemporaneous restrictions needed for the exact identification of the system. We will show that, with a three variables system and in the case of the presence of only one co-integrating vector (CV),[21] we can just-identify the VECM by imposing the ortho-normalization of errors and only one restriction on the long-run response matrix; in this case no restrictions have to be imposed to the contemporaneous effects matrix.

Operationally, an important intermediate step for the use of the VECM representation is thus the assessment of the order of integration of the series and of the presence of CI. On the basis of the indications from the ACFs and from standard DF-ADF tests we can assume that all the series employed in the analysis are I(1),[22] hence the VECM is a viable representation. From the Johansen LR tests we also obtain that a CI relation is present for all the specifications when a 90% statistical criterion is adopted. Results do not change significantly when employing bootstrapped distributions for the CI test.

Coherently with the theoretical indication of a long-run relationship between the

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[20] We have shown that the model outcomes depend on the whole contemporaneous structure of the model, hence the recursive specification implied by the Cholesky decomposition is not model consistent, irrespective of the ordering of the variables.

[21] The number of CVs is established via the Johansen test.

[22] This implies that the price level is I(2).

nominal interest rate and the price dynamics, we assume that the CV is the Fisher Interest Parity (FIP).[23]

Formally, given the VECM in structural form $\mathbf{A}_0\Delta\mathbf{y}_t = \mathbf{H}\mathbf{y}_{t-l} + \sum_{l=1}^{p-1}\mathbf{A}_l\Delta\mathbf{y}_{t-l} + \boldsymbol{\varepsilon}_t$ and its reduced form $\Delta\mathbf{y}_t = \boldsymbol{\Pi}\mathbf{y}_{t-l} + \sum_{l=1}^{p-1}\boldsymbol{\Gamma}_l\Delta\mathbf{y}_{t-l} + \mathbf{v}_t$, where $\boldsymbol{\Pi} = \mathbf{A}_0^{-1}\mathbf{H}$, $\boldsymbol{\Gamma}_l = \mathbf{A}_0^{-1}\mathbf{A}_l$, $\mathbf{v}_t = \mathbf{A}_0^{-1}\boldsymbol{\varepsilon}_t$, $\mathbf{v}_t \sim (\mathbf{0},\boldsymbol{\Omega})$, $\boldsymbol{\Omega} = \mathbf{A}_0^{-1}\boldsymbol{\Sigma}\mathbf{A}_0^{-1}{}'$, $\mathbf{H} = \boldsymbol{\eta}\boldsymbol{\beta}'$ and $\boldsymbol{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$, the identification of the long-run relation with the FIP implies that $\boldsymbol{\beta} = [0,-b,1]$. The VMA representation of the reduced-form VECM is the following (Johansen, 1995):

$$(16) \qquad \mathbf{y}_t = \mathbf{C}(1)\sum_{i=1}^{t}\mathbf{v}_{t-l} + \mathbf{C}^*(L)\mathbf{v}_t + \mathbf{y}_0,$$

where $\mathbf{y}_0$ depends on initial conditions and $\mathbf{C}^*(L) = \sum_{j=0}^{\infty}\mathbf{C}_j^* L^j$ is a polynomial with elements converging to zero as j goes to infinity. In other terms, $\mathbf{C}^*(L)$ is the transitory effects matrix and $\mathbf{C}_j^*$ contains the contemporaneous impact effects. The long-run effects matrix $\mathbf{C}(1)$ contains the unit roots of the model and, because of co-integration, it has a reduced rank $k = m - r$, where r is the number of long-run relations.

Since the relationship between the reduced form and the structural errors of the VECM is $\mathbf{v}_t = \mathbf{A}_0^{-1}\boldsymbol{\varepsilon}_t$, the structural VMA representation can be written as:

$$(17) \qquad \mathbf{y}_t = \mathbf{C}(1)\mathbf{A}_0^{-1}\sum_{i=1}^{t}\boldsymbol{\varepsilon}_{t-l} + \mathbf{C}^*(L)\mathbf{A}_0^{-1}\boldsymbol{\varepsilon}_t + \mathbf{y}_0.$$

The exact identification of the system requires m^2 restrictions, of which $m(m+1)/2$ are given by the usual hypothesis of ortho-normality[24] of the structural errors, i.e. by the assumption that $E(\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t') = \mathbf{A}_0\boldsymbol{\Omega}\mathbf{A}_0{}' = \mathbf{I}_m$, thus leaving $m(m-1)/2$ restrictions for the identification of the model.

Since the system is co-integrated, the number of contemporaneous restrictions needed for exact identification is reduced. $(m-r)(m-r-1)/2$[25] restrictions must be imposed

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[23] The idea of employing the FIP as a theory-based identifying long-run relation is quite common in the empirical literature for monetary models. See, for an application, Garratt *et al.*, 2003.

[24] The structural shocks are assumed to be mutually independent and of unit variance.

[25] The co-integration relations are identifying in that they impose the shocks to have no long-run effects on CVs.

on the long-run effects matrix and $r(r-1)/2$ restrictions on the contemporaneous effects matrix. In our specific case with m = 3 and r = 1, the model is thus identifiable with only one restriction on the permanent effect matrix $\mathbf{C}(1)$.

For the identification of the long-run response matrix we adopt the hypothesis that only technology shocks can have permanent effects on output, i.e.:

$$(18) \qquad \mathbf{C}(1)=\begin{bmatrix} C_{1,1} & C_{1,2} & 0 \\ C_{2,1} & C_{2,2} & 0 \\ C_{3,1} & C_{3,2} & 0 \end{bmatrix},\ C_{1,2}=0\,.$$

Our identifying restriction is equivalent to that employed by Blanchard and Quah (1989) in their influential paper on the assessment of the respective roles of “demand” and “supply” shocks over the business cycle. The unique difference is that we are employing it in a non-stationary VAR framework.

Once the system is identified, the SVMA given in (17) can be estimated and simulated, thus the results can be confronted with those obtained from the simulation of the estimated DSGE structure.

3.2.2 Impulse response analysis based on SVECMs

The results obtained with the impulse response analysis, reported in figures A9-A15, are basically in line with those obtained with the simulation of the structural DSGE model. Concerning the impulse responses to a monetary policy shock, we can observe that the response of inflation is negative at the impact and that its half-life duration is between 4 and 10 quarters, depending on the specific economy considered. The lowest half-life duration is registered for the U.S. and Japan, while the lowest is found for Canada.

The important result, beyond considerations of quantitative consistency among DSGE simulations and VAR-based impulse responses, is that the price puzzle does not emerge in any of the country considered in the analysis. This result is obtained without having to impose particular restrictions on the contemporaneous structure of the VAR (which is actually left unrestricted) or particular modifications of the data set employed. Given the structural parameter estimates obtained with the Bayesian Monte Carlo method, the fact that the price puzzle does not emerge in the VAR analysis can be considered a confirmation of the reliability of the M-H MCMC estimates, since they suggest a parameterization of the New Keynesian DSGE model for which the price puzzle cannot come out.

Concerning the impulse responses of output to a monetary policy shock, we observe that they are on average qualitatively consistent with the predictions of the standard model, i.e. there are no signs inversions and a certain degree of slackness of responses is observed. In line with the results obtained with the DSGE model simulations, the average half-life of the responses is about 6-8 quarters, even if they are quantitatively heterogeneous across countries.

The results obtained with the impulse response analyses based on weakly identified SVECMs thus confirm the outcomes obtained with the estimation and simulation of our New Keynesian DSGE model. Beyond the implications of the specific results, the consistency between estimates signals that our theoretical hypotheses are empirically relevant. This consideration is reinforced by the fact that the identifying restrictions imposed to structuralize the VECM are rather weak and, most importantly, not model specific. The FIP is a well documented phenomenon and its existence is justified by commonly accepted arbitrage conditions. Analogously, the hypothesis that technology shocks are the unique source of permanent growth is consistent with many theoretical approaches and cannot be considered a too restrictive hypothesis.

3.3 The data

The sample employed for our estimates is composed of quarterly time series for GDP, GDP deflator, labor compensation, employment, and short-term and long-term nominal interest rates. The time period covered by the sample information is 1963:1 to 2003:2 and the countries considered are the seven most industrialized economies. In the benchmark formulations, we employ short term nominal interest rate definitions such as the Federal Funds Rate for the United States, the Overnight Rate (OR) for Canada and the United Kingdom and the Money Call Rate (MCR) for the remaining countries. In order to check for robustness, we also re-run the estimations by substituting the reference short-term rates with the three months Treasury Bill Rate (TBR) and the 10-years Government Bonds Rate (10yGBR). Data are all drawn from the IMF International Financial Statistics (IFS) data base. The log real output gap is obtained as the difference between log real output and its trend, the latter estimated employing the Hodrick-Prescott filter. Following Smets and Wouters (2003), real output is de-trended assuming a linear trend while, on the basis of their co-trending behavior, both inflation and the nominal interest rate are de-trended on the basis of the estimated linear component in inflation.

4. Conclusions

In this paper we have developed a simple DSGE New Keynesian model augmented with rule-of-thumb consumers and habits persistence in consumption. On the basis of these strong violations of the Hall's benchmark consumption function, we have analyzed their implications for the stability properties of the model and, in particular, for the efficacy of the conduct of monetary policy. We have shown that the presence of rule-of-thumb consumers can significantly alter the conventional policy prescriptions.

We have shown the relevance of the demand regimes in determining the properties of monetary policy and how demand regimes are affected by our assumptions on the consumers' behavior. In particular, we have shown the importance of the sign and the size of the semi elasticity of the aggregate demand with respect tot the real interest rate, which respectively determines the demand regime and the monetary policy efficacy.

Both demand regime and the monetary policy efficacy individuates three possible policy regimes, i.e. behavior of the economic variables to a monetary policy shock. More specifically, if monetary policy is set according to a Taylor rule augmented by a monetary policy disturbance, in the standard demand regime, a negative interest rate disturbance always implies a increase in the output gap and inflation as usual. By contrast, in the inverse regime two different situations can occur. For relative high values of monetary policy efficacy, a positive monetary disturbance will affect the economic outcomes as in the standard regime even if the semi elasticity of the aggregate demand with respect to the real interest rate is positive, but for a relatively low monetary policy efficacy, the monetary shock has a deflationary effect as it will decreases inflation and real output.

The rationale of the two different policy regimes in the case of a positive semi elasticity of the demand with respect to the real interest rate can be explained as follows. In the inverse regime a negative monetary shock initially shifts the aggregate demand backwards and, thus, it reduces real output and inflation. The reaction of the central bank to this change can imply either an increase or a reduction of the real interest rate.

In order to obverse an inverse behavior of the economic variables with respect to a money disturbance, the inverse demand regime is thus a necessary but not sufficient condition because the activity of the central bank. The reverse behavior of economic variables is only observed for relative low value of the monetary policy efficacy, which makes the central bank reaction insufficient to reverse the disturbance effect.

The policy regime that will emerge depends on the monetary policy efficacy and the demand regime observed. Both of them depend on the semi elasticity of the aggregate demand, which depends non-linearly on a large set of parameters. In the simplest case of no habits formation, the demand regimes are determined buy a threshold value of the share of Spenders and the monetary policy efficacy is increasing in the share of spenders in the standard regime whereas it is decreasing in it in the inverse regime. Thus an inverse behavior of the economic variables to a monetary shock can be observed only for a very high share of Spenders, larger than the values that supports the inverse demand regime. The strong non-linearity of the relations between the semi-elasticity of the demand with respect to the real interest rate and the deep parameters makes difficult to provided general results if habits are introduced. Numerical simulations show that *ceteris paribus* the threshold value of the Spenders share needed to obtain the monetary multiplier sign inversion tends to increase in the parameter defining habits persistence, hence, by introducing habits, the probability of observing a demand regime shift decreases.

The non-linearity makes necessary a correct calibration of the model for policy experiments and to understand the policy dynamics. The empirical relevance of our hypotheses has thus been evaluated estimating the structural parameters of the DSGE model for the seven most industrialized economies, and then employing these structural estimates for obtaining country-specific simulations of the dynamics of the stylized economies.

The simulations have evidenced the general efficacy of the monetary policy even if they have also highlighted the presence of relevant asymmetries in the monetary transmission mechanisms. The presence of asymmetries in the monetary transmission channels stimulates a serious reconsideration of the policy prescriptions, in particular of those that have been obtained without taking into account that the differences among economies may result decisive in the determination of the effects of the policy. Despite the heterogeneous sensitivity to shocks, the dynamical properties of the models resulted qualitatively in line with those predicted by the conventional New Keynesian DSGE model. In particular, the estimated structural parameters rule out the possibility of demand regime inversions due to the presence of rule-of-thumb consumers. Even if the fraction of Spenders is relevant in many countries (0.26 on average), in none of them this fraction is high enough to generate the regime inversion. A further interesting result is that, despite the model is able to generate the so-called “price puzzle” for habits and rule-of-thumb parameters values that are not prohibitively high, the estimation has generated a parameterization that is not consistent with this result.

The simulations obtained with the country-specific parameterizations of our DSGE model have been confronted with the outcomes of the impulse response analyses obtained with the simulation of seven country-specific SVECM monetary models. Even if the SVECM is a weakly identified structure, the impulse responses resulted qualitatively broadly consistent with the predictions of the New Keynesian conventional model and also with the simulations obtained with our structural DSGE models. Even in this case, there are no signals of demand regime inversion, i.e. of a positive conditional correlation between the interest rate and output. More surprisingly, none of the SVECM impulse responses has evidenced the presence of the price puzzle, i.e. of the positive conditional correlation between the interest rate response to monetary policy shocks and the response of inflation.

The main result of this analysis is thus that, even if the theoretical implications of the presence of rule-of-thumb consumers and of persistence in consumption habits are potentially strong, their empirical evaluation suggests that the model properties remain qualitatively unchanged. The estimated degree of habits persistence and fraction of Non Ricardian consumers, even if dimensionally relevant on average, are not able to overturn the qualitative properties of the standard New Keynesian sticky price model. However, the analysis has also shown that these modifications should be taken in serious consideration, since their presence affects the relative efficacy of the monetary policy and can influence the symmetry of its effects.

It is finally worth noticing that this work has been prepared as working paper. We plan to further develop and separate many of the results as independent works. In particular, we will focus on equilibrium determinacy issues and on the price puzzle separately. In our view, these two issues, as well as their empirical evaluation, are the most relevant findings of our work.

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Appendix of results

Determinacy is studied by augmenting the log-linearized dynamic system with a simple Taylor feedback rule, which also nests the simple case of the forward-looking Taylor rule:[26]

$$\text{(A.1)} \qquad \begin{bmatrix} 1 & \Omega \\ 0 & \beta \end{bmatrix} E_t \begin{bmatrix} y_{t+1} \\ \pi_{t+1} \end{bmatrix} = \begin{bmatrix} 1+\Omega a_2 & \Omega a_1 \\ -k & 1 \end{bmatrix} \begin{bmatrix} y_t \\ \pi_t \end{bmatrix}$$

Stability depends on the eigen-structure of the following matrix:

$$\text{(A.2)} \qquad M = \begin{bmatrix} 1 & \Omega \\ 0 & \beta \end{bmatrix}^{-1} \begin{bmatrix} 1+\Omega a_2 & \Omega a_1 \\ -k & 1 \end{bmatrix} = \begin{bmatrix} 1+\Omega\left(a_2+\dfrac{k}{\beta}\right) & \Omega\left(a_1-\dfrac{1}{\beta}\right) \\ -\dfrac{k}{\beta} & \dfrac{1}{\beta} \end{bmatrix}$$

By indicating with $D(.)$ and $T(.)$ the determinant and trace operators, we have:

$$\text{(A.3)} \qquad \begin{cases} D(M) = \beta^{-1} + \Omega\left(a_2 + k a_1\right)\beta^{-1} \\ T(M) = 1 + a_2\Omega + \left(1 + k\Omega\right)\beta^{-1} \end{cases}$$

The eigen-structure of matrix M is studied by following Woodford (2003: Appendices to Chapter 4). Since the analysis of the standard one does not differs from Woodford (2003), we only consider the liquidity-constrained regime. In this regime, determinacy requires either: *i)* $D(M) > 1$, i.e. $a_1 < \left[\left(1-\beta\right)\bar{\Omega}^{-1} - a_2\right]k^{-1}$, $D(M) \pm T(M) + 1 > 0$ or *ii)* $D(M_1) \pm T(M_1) + 1 < 0$.
Being:

$$\text{(A.4)} \qquad D(M) + T(M) + 1 = \left\{2\left(1+\beta\right) - \bar{\Omega}\left[\left(1+\beta\right)a_2 + \left(1+a_1\right)k\right]\right\}\beta^{-1}$$

$$\text{(A.5)} \qquad D(M) - T(M) + 1 = -\bar{\Omega}\left[\left(1-\beta\right)a_2 + k\left(a_1 - 1\right)\right]\beta^{-1}$$

from equations (A.4) and (A.5) we derive the reported in the main text conditions (10) and (11), respectively. Moreover, by considering a rule (12), it is easy to verify that $D(M) = \beta^{-1} > 1$, thus stability requires $D(M_1) \pm T(M_1) > -1$ and $D(M_1) \pm T(M_1) < -1$. By considering $\alpha_1 = \beta^{-1}\alpha_3$ and $\alpha_2 = -\beta^{-1}k\alpha_3$, it is easy to verify that $D(M_1) \pm T(M_1) < -1$ is never satisfied. By contrast, $D(M_1) \pm T(M_1) > -1$ requires condition (14).

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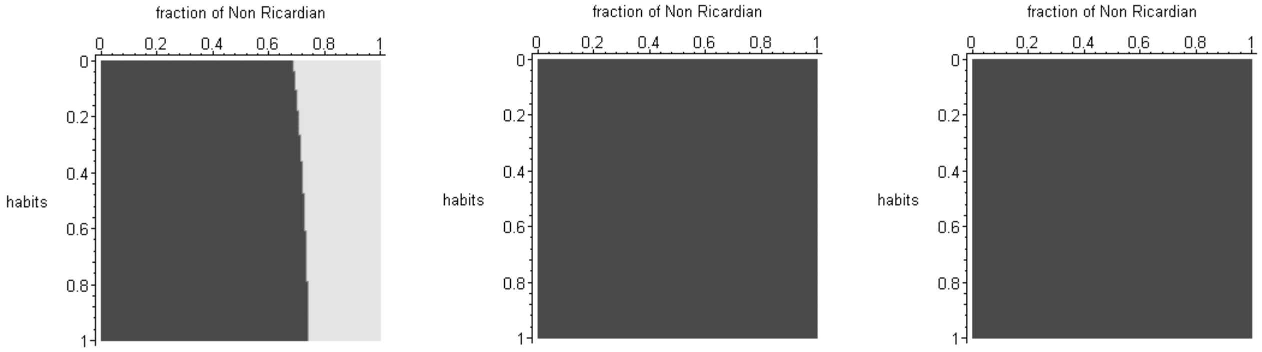
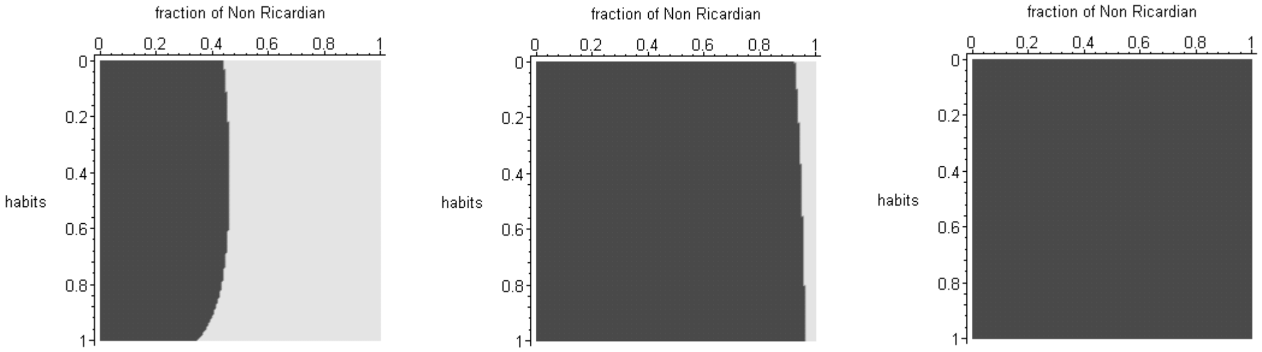
[26] In order to investigate the stability properties we do not need to look at the stochastic part and constants that thus are omitted for the sake of brevity. We assume stationary disturbance processes.

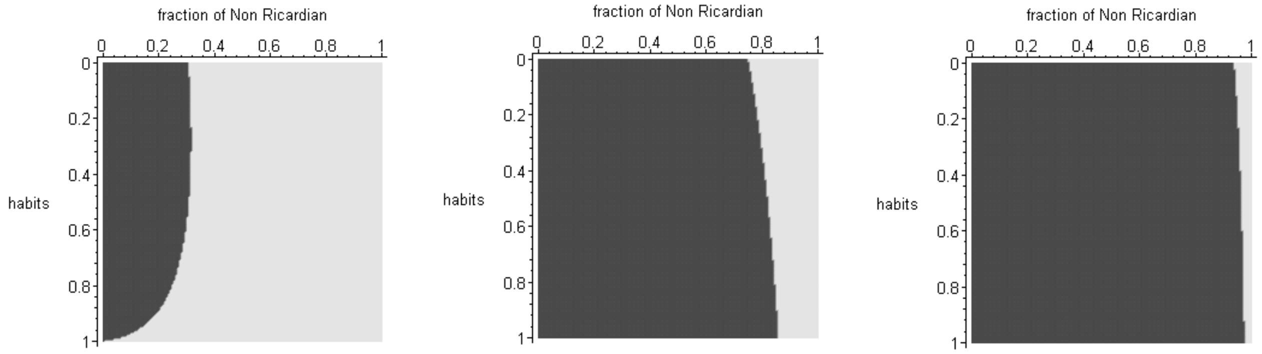
Figure A1 – Demand regimes, habits and Non Ricardian consumers



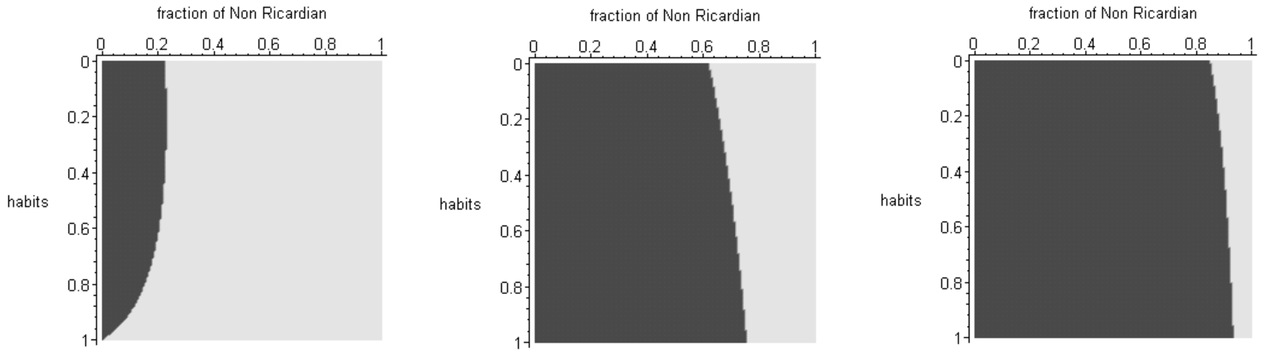
(a1) $\kappa = 0.1$ and $\theta = 0.3$ (a2) $\kappa = 0.5$ and $\theta = 0.3$ (a3) $\kappa = 1.5$ and $\theta = 0.3$



(b1) $\kappa = 0.1$ and $\theta = 0.4$ (b2) $\kappa = 0.5$ and $\theta = 0.4$ (b3) $\kappa = 1.5$ and $\theta = 0.4$

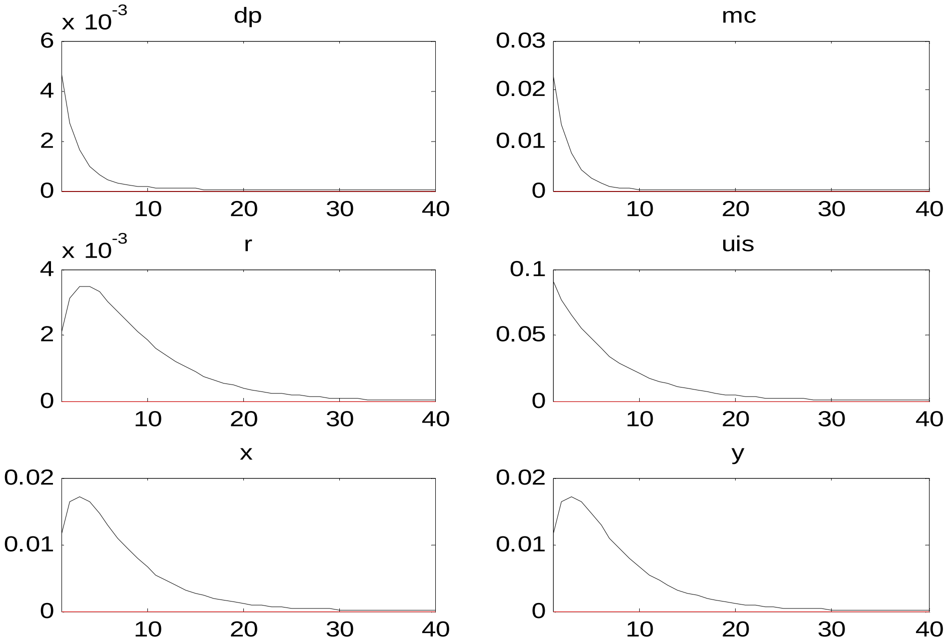


(c1) $\kappa = 0.1$ and $\theta = 0.5$ (c2) $\kappa = 0.5$ and $\theta = 0.5$ (c3) $\kappa = 1.5$ and $\theta = 0.5$



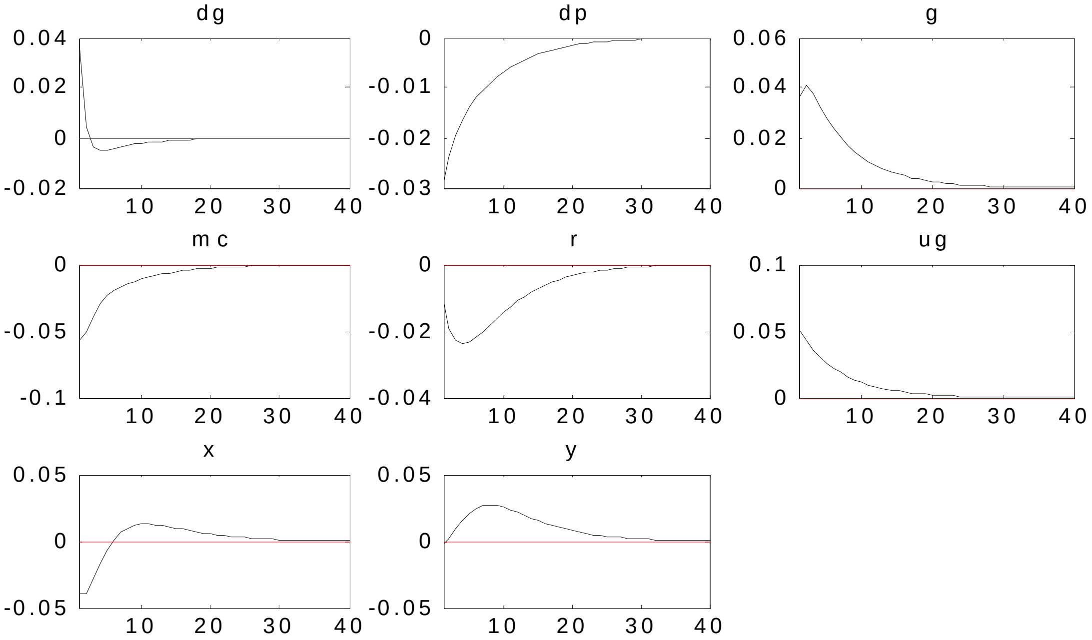
(d1) $\kappa = 0.1$ and $\theta = 0.6$ (d2) $\kappa = 0.5$ and $\theta = 0.6$ (d3) $\kappa = 1.5$ and $\theta = 0.6$

Figure A2. Impulse responses to a preference shock, parameterization based on priors



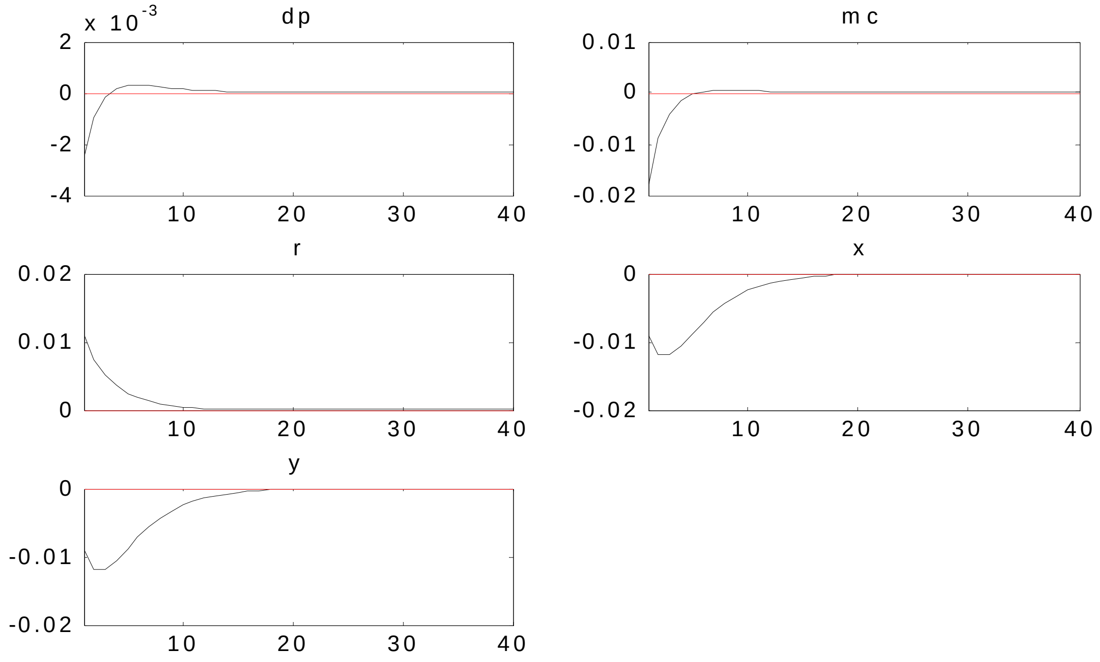
Computations obtained with Dynare for Matlab.

Figure A3. Impulse responses to a technology shock, parameterization based on priors



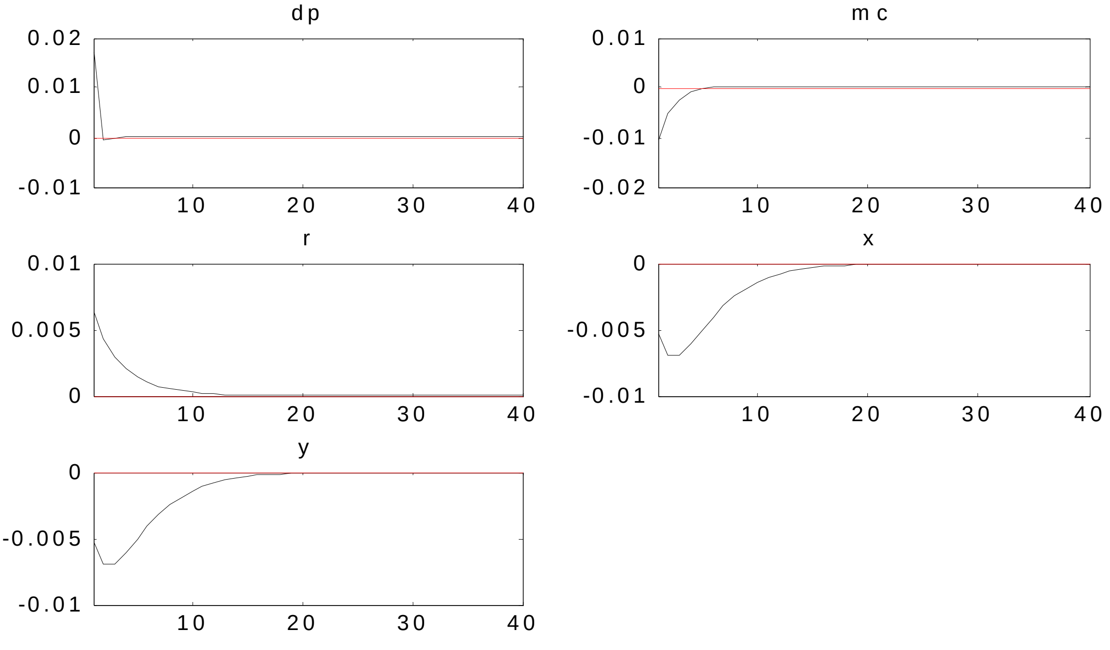
Computations obtained with Dynare for Matlab.

Figure A4. Impulse responses to a policy shock, parameterization based on priors



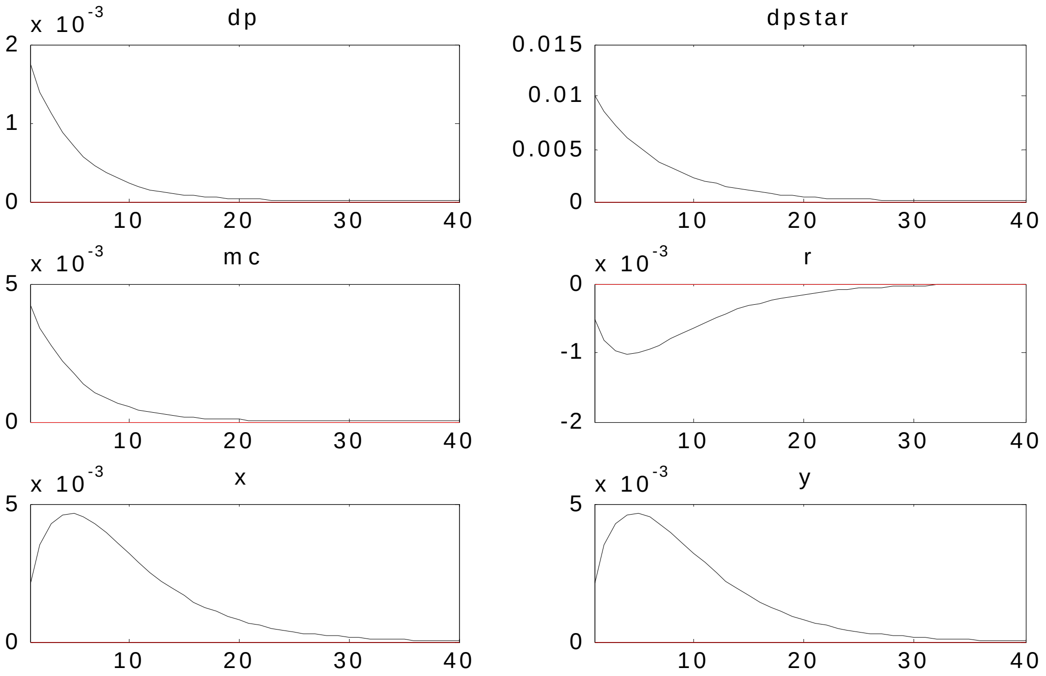
Computations obtained with Dynare for Matlab.

Figure A5. Impulse responses to a cost push shock, parameterization based on priors



Computations obtained with Dynare for Matlab.

Figure A6. Impulse responses to a policy-target shock, parameterization based on priors



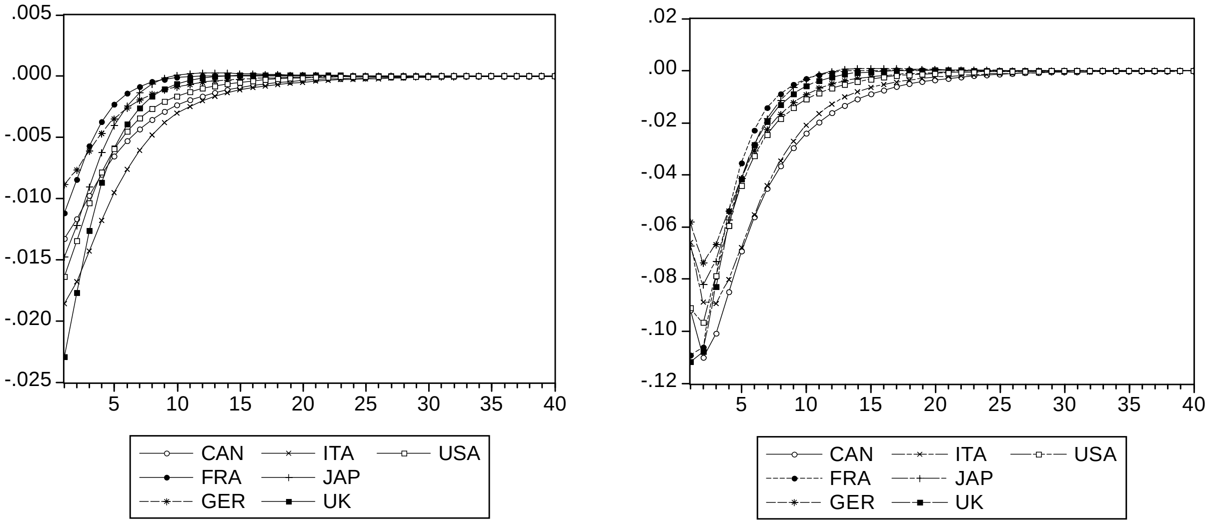
Computations obtained with Dynare for Matlab.

Table A1. Estimated posterior mode and S.D. (Hessian). Direct method

	USA		JAP		GER		FRA		UK		ITA		CAN	
Parameter	Mode	S.D.	Mode	S.D.	Mode	S.D.	Mode	S.D.	Mode	S.D.	Mode	S.D.	Mode	S.D.
sigma_*e* _*a*	0.048	0.000	0.048	0.000	0.411	0.033	0.048	0.000	0.048	0.000	0.048	0.000	0.048	0.000
sigma_*e* _*IS*	0.102	0.186	0.085	0.057	0.051	0.031	0.156	0.481	0.054	0.060	0.108	0.072	0.119	0.031
sigma_*e* _*pi*	0.019	0.269	0.011	0.056	0.021	0.141	0.062	0.972	0.013	0.039	0.004	0.001	0.007	0.004
sigma_*e* _*i*	0.012	0.000	0.012	0.000	0.012	0.079	0.012	0.000	0.012	0.000	0.015	0.005	0.012	0.000
sigma_*e* _*dP*	0.126	0.025	0.202	0.117	0.256	0.401	0.110	0.681	0.274	1.529	0.181	0.069	0.165	0.140
rho_*a*	0.773	0.230	0.712	0.034	0.762	0.467	0.745	0.041	0.783	1.235	0.758	0.277	0.701	0.440
rho_*IS*	0.954	0.021	0.943	0.071	0.825	0.017	0.883	0.082	0.881	0.055	0.949	0.079	0.914	0.031
rho_*pi*	0.754	0.144	0.969	0.082	0.839	0.033	0.933	0.019	0.911	1.390	0.981	0.124	0.951	0.187
rho_*i*	0.799	0.002	0.864	0.007	0.821	0.002	0.876	0.002	0.877	0.010	0.851	0.027	0.870	0.023
beta	0.995	-	0.995	-	0.995	-	0.995	-	0.995	-	0.995	-	0.995	-
eta	6.000	0.105	6.001	0.119	6.000	0.109	6.000	0.128	6.001	0.117	6.001	0.101	6.001	0.108
k	2.999	0.169	2.998	0.184	3.001	0.153	3.001	0.511	2.997	0.596	2.996	0.107	2.997	0.395
psi_*pi*	1.501	0.017	1.489	0.743	1.499	0.120	1.495	0.001	1.508	0.019	1.493	0.127	1.488	0.086
psi_*x*	0.126	0.191	0.143	0.143	0.095	0.029	0.133	0.002	0.138	0.011	0.128	0.179	0.131	0.063
phi	0.813	0.028	0.815	0.024	0.865	0.006	0.854	0.001	0.806	0.007	0.798	0.028	0.815	0.071
gamma	0.671	0.098	0.664	0.625	0.600	0.015	0.685	0.003	0.638	0.021	0.702	0.064	0.731	0.043
lambda	0.506	0.175	0.380	1.899	0.491	0.673	0.442	0.011	0.431	0.077	0.441	0.611	0.397	0.128

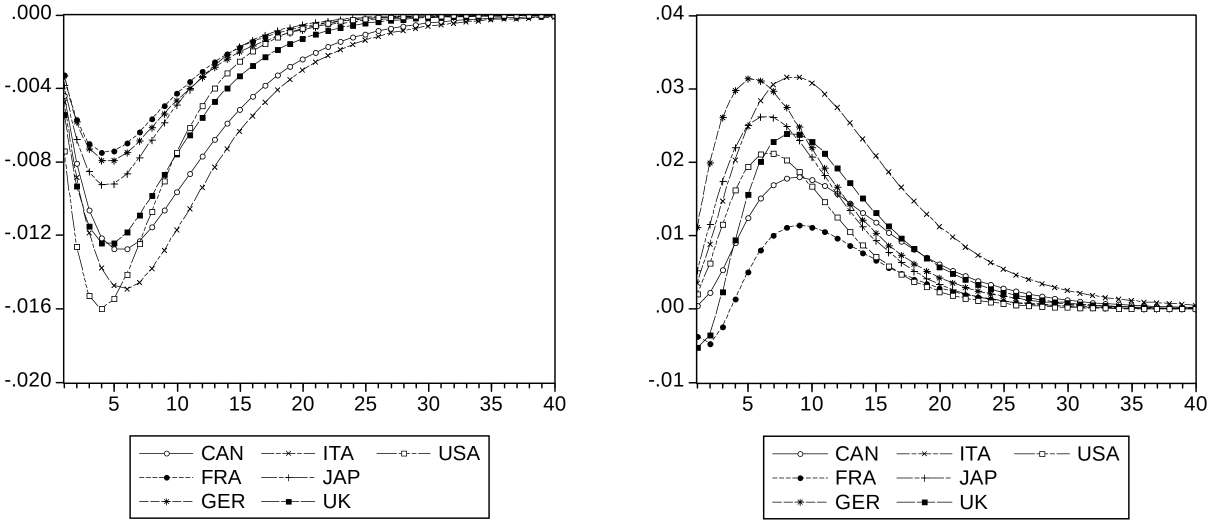
Computations obtained with Dynare for Matlab.

Figure A7. Impulse responses to a technology shock, G7 economies, M-H MCMC estimates



a) inflation

b) marginal costs



c) nominal interest rate

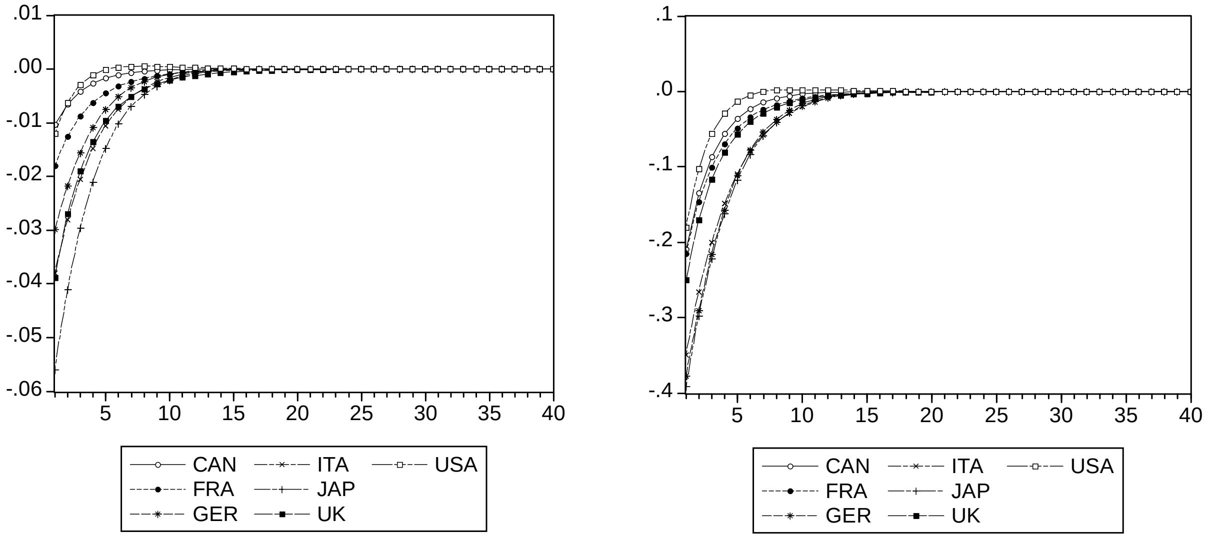
d) output

Computations obtained with Dynare for Matlab.

Figure A8. Impulse responses to a monetary policy shock, G7 economies, M-H MCMC estimates

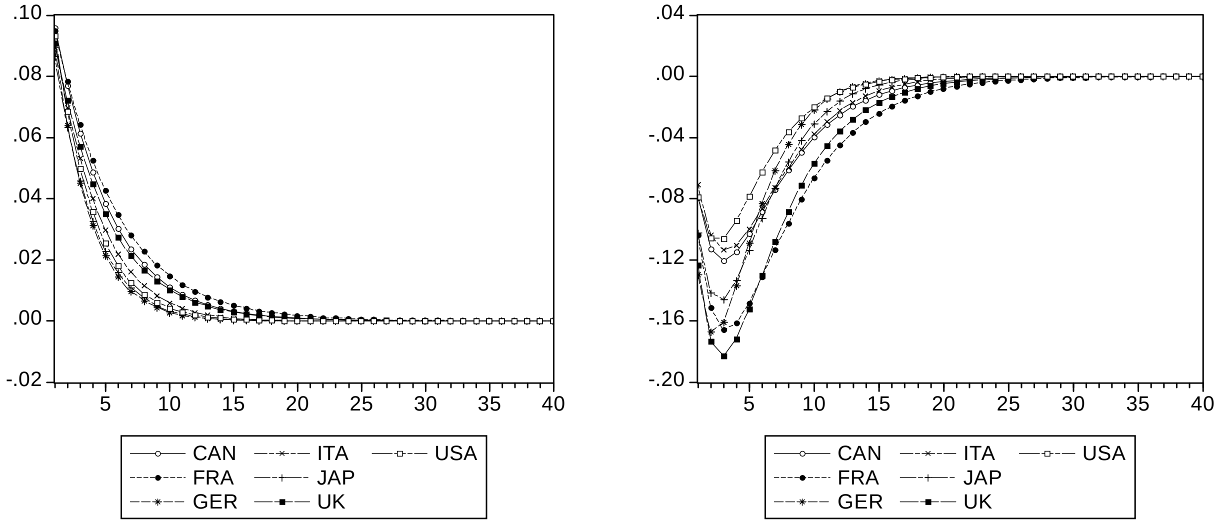
a) inflation

b) marginal costs



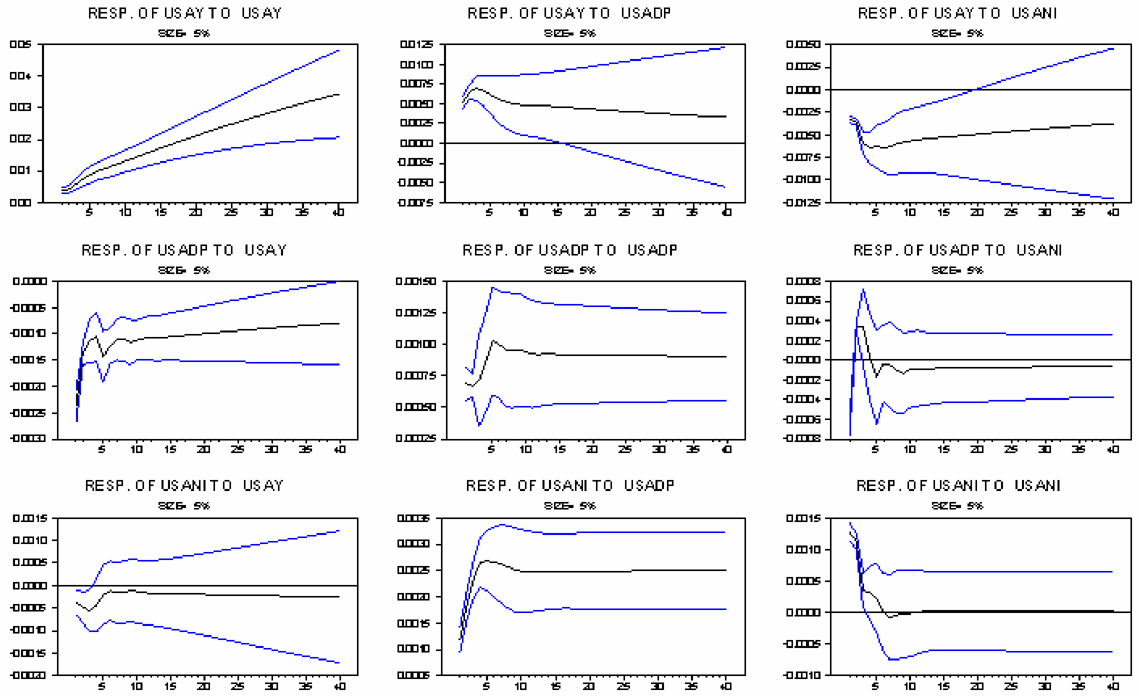
c) nominal interest rate

d) output



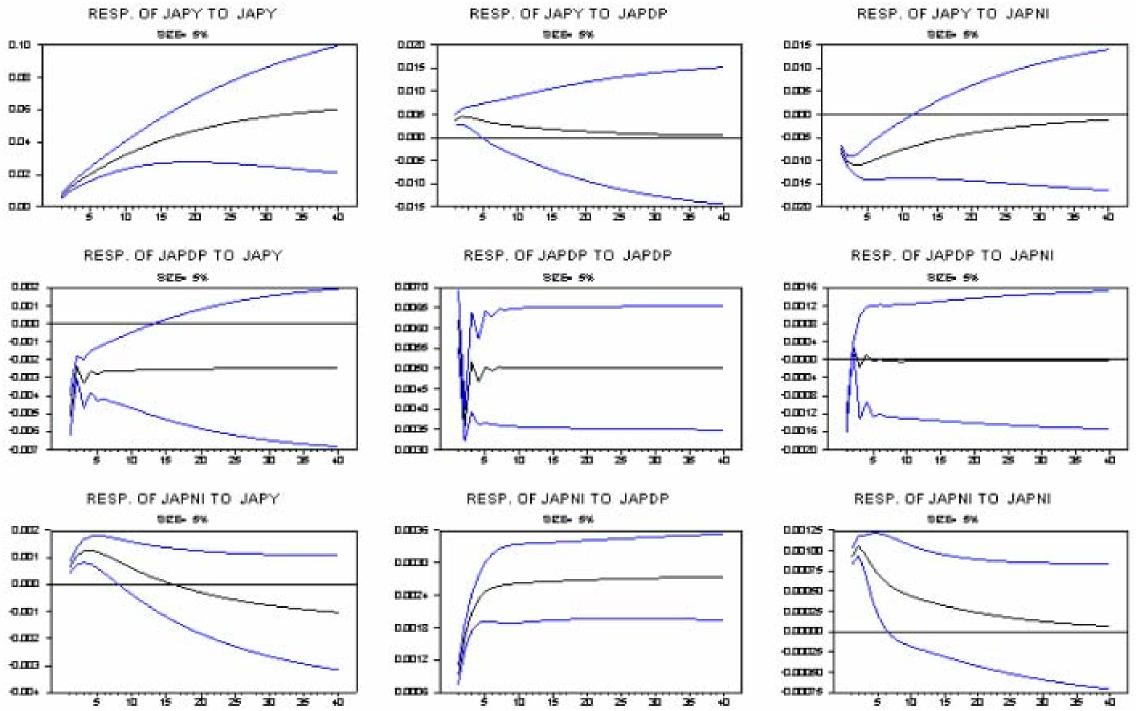
Computations obtained with Dynare for Matlab.

Figure A9. SVECM-based Impulse responses to structural shocks. USA



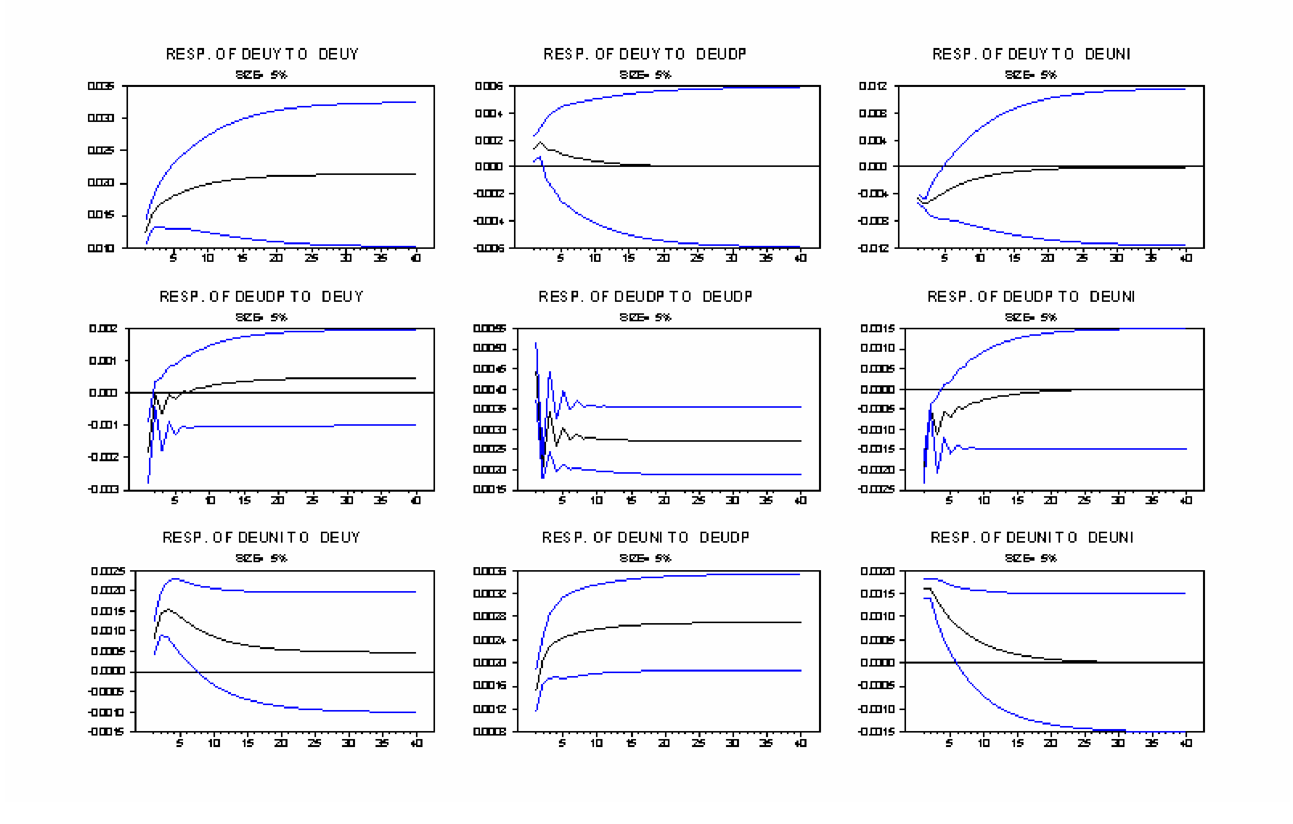
Computations executed with Malcolm 2.9 for Rats.

Figure A10. SVECM-based Impulse responses to structural shocks. Japan



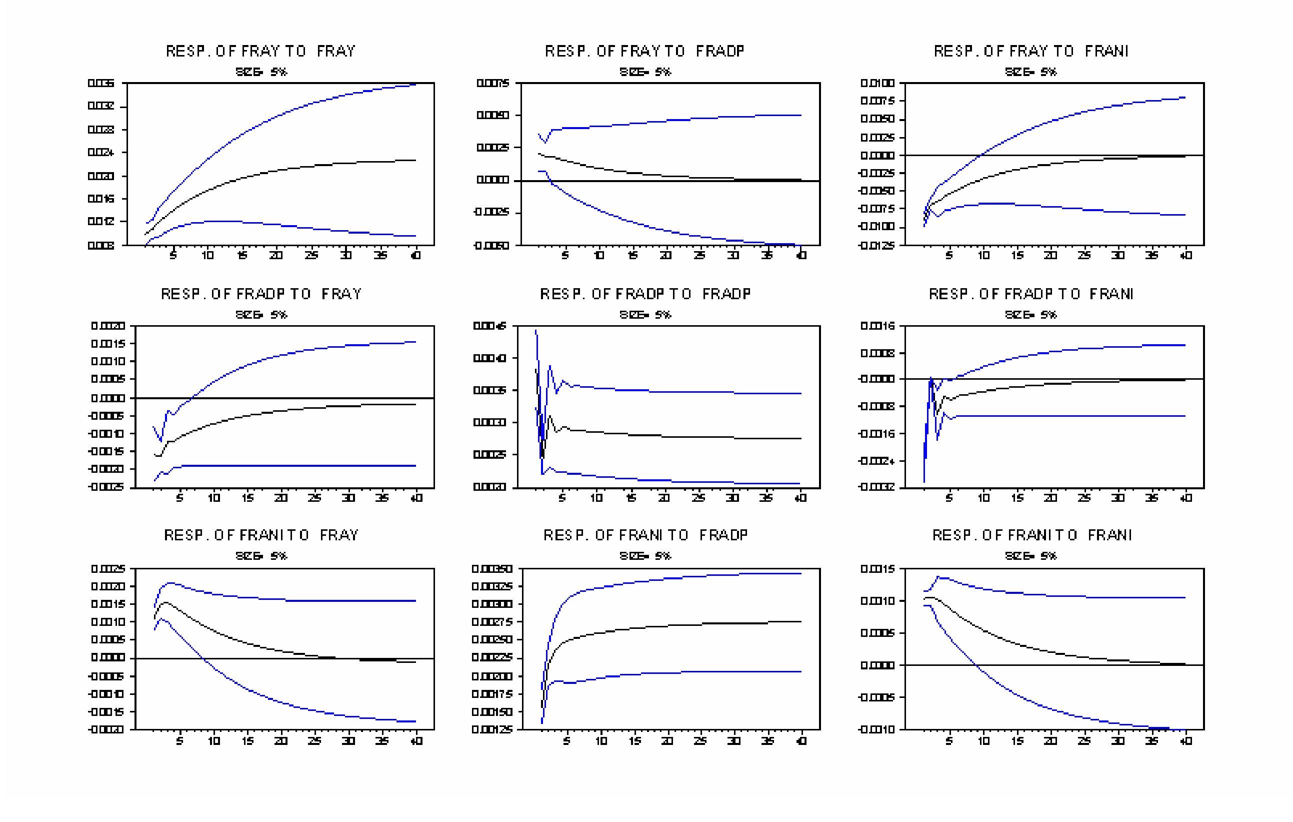
Computations executed with Malcolm 2.9 for Rats.

Figure A11. SVECM-based Impulse responses to structural shocks. Germany



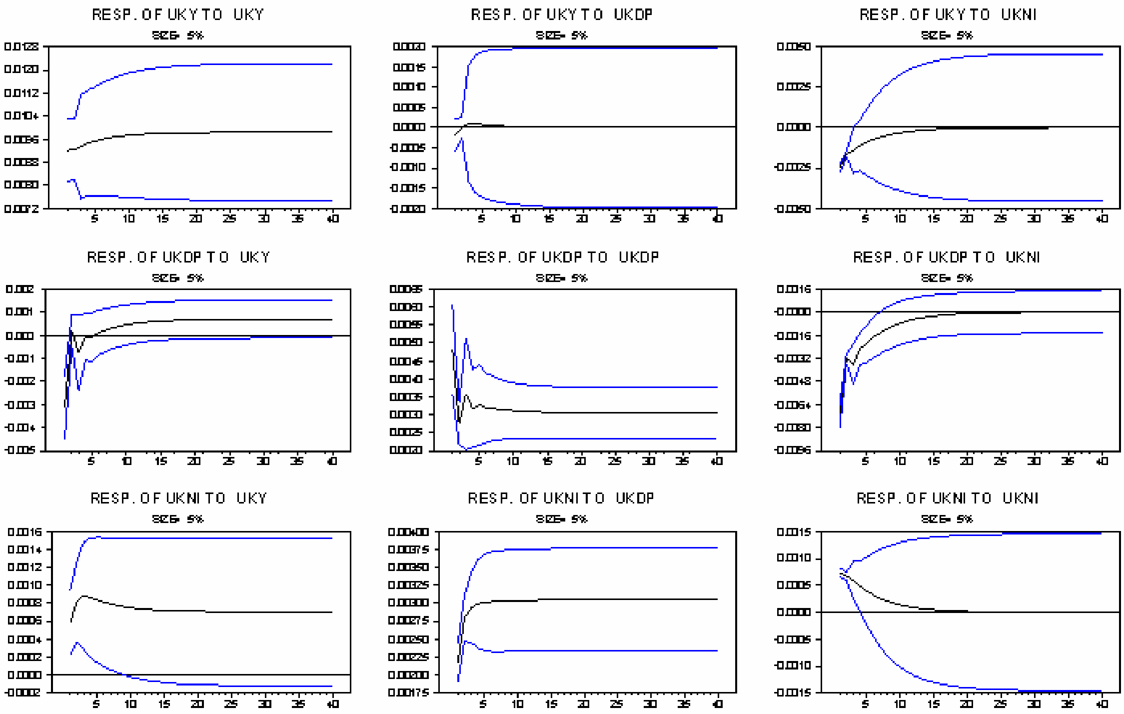
Computations executed with Malcolm 2.9 for Rats.

Figure A12. SVECM-based Impulse responses to structural shocks. France



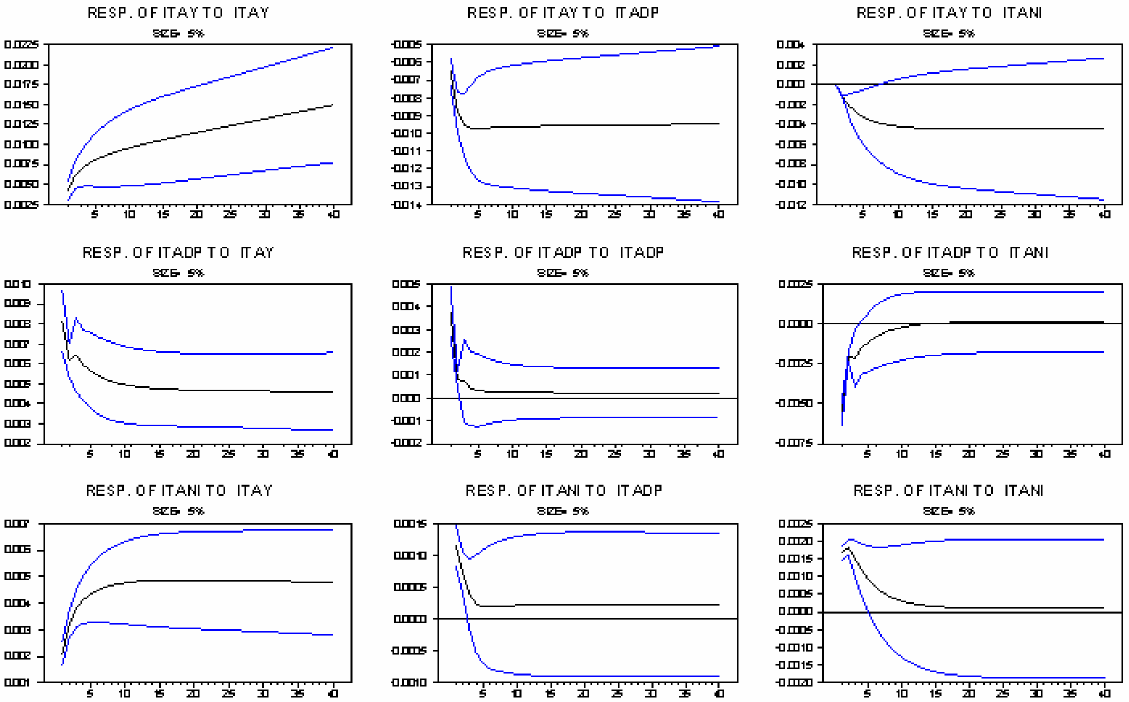
Computations executed with Malcolm 2.9 for Rats.

Figure A13. SVECM-based Impulse responses to structural shocks. United Kingdom



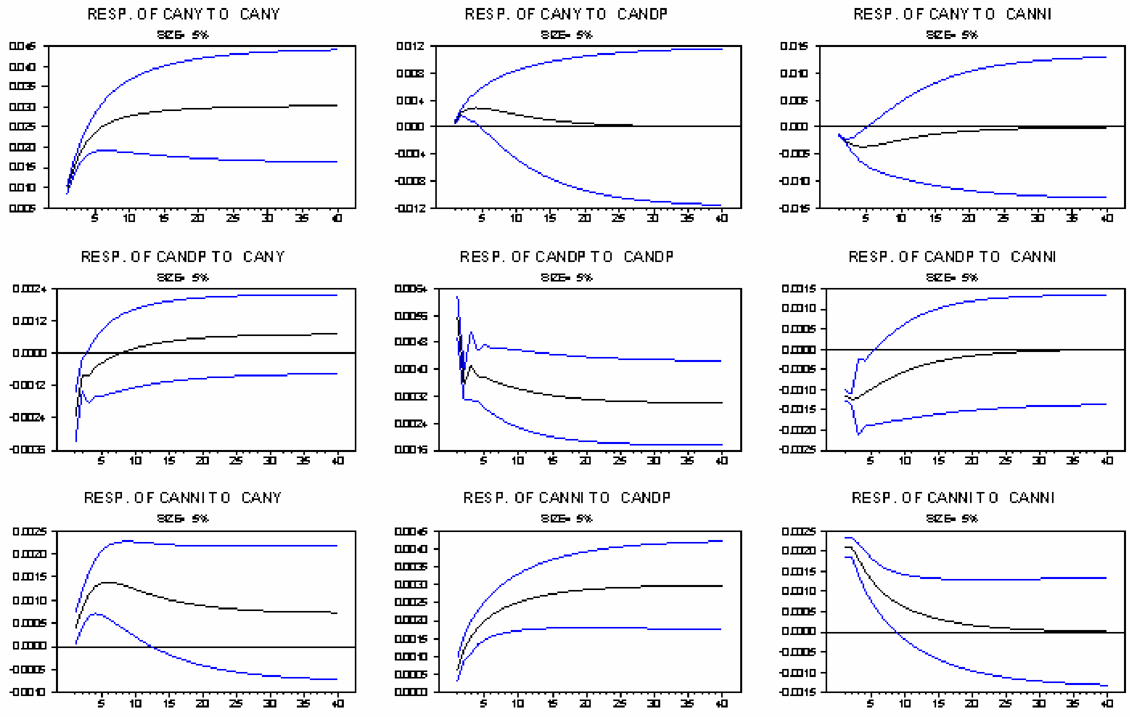
Computations executed with Malcolm 2.9 for Rats.

Figure A14. SVECM-based Impulse responses to structural shocks. Italy



Computations executed with Malcolm 2.9 for Rats.

Figure A15. SVECM-based Impulse responses to structural shocks. Canada



Computations executed with Malcolm 2.9 for Rats.