Sticky contracts or sticky information? Evidence from an estimated Euro area DSGE model*

Matthias Paustian†and Ernest Pytlarczyk‡

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Abstract

This paper empirically evaluates two competing classes of models for introducing nominal rigidities: the Calvo model vs. the sticky information model due to Mankiw and Reis (2002). We estimate variants of the Smets and Wouters (2003) DSGE model for the euro area with Bayesian methods under different assumptions regarding mechanisms of price and wage setting. Our main finding is that the Calvo model overwhelmingly dominates the standard sticky information model in terms of the posterior odds ratio. The origin for the poor fit appears to be the inability of sticky information models to match simultaneously the autocorrelation as well as the volatility of inflation and the real wage.

In a second step, we ask whether heterogeneity in price and wage setting provides a better empirical fit. We develop a model with heterogenous agents in which one fraction follows the Calvo scheme and the other the sticky information scheme. This innovation allows us to validate the empirical relevance of a particular scheme within the same model. For the standard specification we find that the fraction of Calvo price setters is estimated at 99%. For wage setting, the fraction of Calvo wage setters is estimated at 93%. Thus, the data ascribes almost zero mass to sticky information considerations in price setting and only small mass for wage setting. We then allow the distribution of cohorts of information sets to follow two less restrictive patterns than in the baseline sticky information model and find slightly more support for the sticky information idea. This leads to an estimated population share of sticky information agents of roughly 15% for price setting and 30%-35% for wage setting. However, the marginal density of the nested model is lower than for the pure sticky price model a la Calvo. Summing up, our analysis turns around the view of Mankiw and Reis (2002) that the Calvo model is *hard to square with the facts* and concludes that the data strongly favors the Calvo model over the sticky information model.

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†Bowling Green State University, Economics Department, 302 Business Administration Building, Bowling Green, OH 43403. E-Mail: paustim@cba.bgsu.edu

‡Universität Hamburg, Institut für Wachstum und Konjunktur, Von-Melle-Park 5, 20146 Hamburg, Germany. E-Mail: pytlarczyk@econ.uni-hamburg.de

1 Introduction

The New Keynesian Phillips Curve - according to McCallum (1997) the closest thing there is to a standard specification for nominal rigidities - has recently been challenged by the proposal of Mankiw and Reis (2002) to replace it with a sticky information framework. While some prices are exogenously fixed for certain periods in sticky price models such as Calvo (1983), sticky information models assume that information sets are only updated sporadically. This allows agents to change their prices in any period, but typically at a different level than in a full information environment.

The contribution of this paper is to perform an extensive empirical comparison of these two competing frameworks for introducing nominal rigidities in wage and price setting. Our study is motivated by a discrepancy in the literature; the shortcomings of the extensively studied Calvo model are very well known, while relatively little research exists that aims at empirically evaluating sticky information models.[1] The models we estimate are identical in the specification of the real side of the economy to Smets and Wouters (2003). The main features of this closed economy model are external habit formation in consumption, capital adjustment costs specified in terms of the rate of change of investment, variable capacity utilization as well as a large number of shocks.

We empirically evaluate sticky information models and the Calvo model in a Bayesian framework by comparing posterior odds ratios using Euro area aggregate data. This comparison has two parts. In the first part, we compare the Calvo model with indexation to a baseline specification of a truncated Mankiw and Reis (2002) model. Agents base their prices and wages on information that is outdated by at most 12 quarters. Furthermore, the shares of agents working with information sets outdated by j periods is geometrically declining in j as in Mankiw and Reis (2002). Our striking result is that the posterior odds ratio shows overwhelming support for the Calvo model. The difference in log marginal density between the two competing models is so large that one would require a prior probability for the sticky information model that is 10^{48} times larger than the one for the Calvo model. According to Jeffreys' rule of thumb this is very strong evidence against the sticky information model. Extending the maximum age of outdated information sets from 12 to 24 quarters and allowing for different parameterizations of the size of cohorts operating with the various information sets improves the performance of the sticky information model only slightly. These results are striking since Mankiw and Reis (2002, p. 1295) criticize the Calvo model as *hard to square with the facts*. Our Bayesian model comparison indicates the opposite: It appears difficult to defend the sticky information model against the Calvo model.

In a second part of the paper we ask whether we can find partial support for the sticky information idea once we allow for heterogeneity in price and wage setting.[2] To this end, a model of heterogeneous price and wage setters is built. In this model, a fraction of agents is assumed to set Calvo contracts whereas the remaining fraction of agents operates according to the sticky information framework. Such a setup allows us to assess the importance of sticky information vs. Calvo contracts in a nested model that reduces to either specification

[1] Mankiw and Reis (2002) point out that the New Keynesian Phillips cannot explain the gradual and delayed effects of monetary shocks on inflation. They further criticize that it cannot reproduce the conventional view that announced and credible disinflations should be contractionary and fails to account for a positive correlation of the change in inflation with output.

[2] Heterogeneity in price setting has been emphasized by Carvalho (2005)

in the extreme cases. We can thus estimate the share of sticky information agents in a nested Calvo-Mankiw population of wage and price setters. This estimated share serves as another measure for how relevant the sticky information framework is in Euro Area aggregate data. Again there is overwhelming evidence against the standard sticky information model. For the baseline specification the mode of the posterior distribution of the fraction of agents operating according to the Calvo framework is 0.99 for price setters and 0.93 for wage setters despite the fact that our priors assume shares of 50 percent each. In other words, the data ascribes almost zero mass to sticky information agents in price setting and only little more in wage setting. Consequently, there is very little support for sticky information in wage and price setting.

Next, we allow the distribution of the shares of agents working with different outdated information sets to follow two less restrictive patterns than in the baseline model. This leads to an estimated population share of sticky information agents of roughly 15% for price setting and 30-35% for wage setting. It should be noted however that these nested sticky price - sticky information models have smaller marginal density than the standard Calvo model which is a special case of this nested model. The fact that the rich model ranks worse than the nested simple model is due to the Bayesian model comparison criteria we employ. These criteria often favor parsimonious models. Finally, the distribution of the population shares of agents working with different outdated information sets is highly irregular. In particular, the idea that the shares of agents working with older information sets should decline as in the standard model of Mankiw and Reis (2002) is not supported by the data.

What explains the overwhelmingly poor performance of sticky information models? Inspecting impulse responses and the match of models moments with the data suggests the following. First, the estimated sticky information models deliver the delayed and hump-shaped response of output and inflation to monetary shocks that were pointed out by Mankiw and Reis (2002) for their highly stylized model. Hence, the poor performance cannot be explained by a lack of robustness of the Mankiw-Reiss framework to deliver inflation inertia as is found in Coiboin (2006) or Keen (2005). These papers argue that large real rigidities are necessary to generate inflation inertia in sticky information models and that interest rate rules rather than money growth rules make inflation inertia less likely. These issues are not problematic in our model. However, it appears that the estimated sticky information model has difficulties at matching the volatility of inflation as well as the persistence of inflation and real wages. In the Smets and Wouters (2003) sticky price model, so-called markup shocks to the Phillips curve allow the model to match both the persistence and the volatility of inflation. Without such markup shocks, inflation would be too smooth as the underlying marginal cost series is smooth. In sticky information models, markup shocks induce quite different impulse responses. Here, markup shocks increase inflation volatility at the cost of reducing the autocorrelation of inflation. Hence, this trade off is one possible explanation for the poor fit of the sticky information models. It should be noted that price markup shocks are not only important in helping the Calvo model match the volatility of inflation, they are also a big factor for overall model fit. Estimated versions of the Calvo model with price markup shocks strongly dominate the restricted versions without the markup shock as indicated by a Bayes factor of roughly 50.

We now turn to how our findings compare with the literature. Much of the related literature has compared sticky information models to the data along a few selected dimensions. For instance, Collard and Dellas (2004) and Trabandt (2005) compare sticky price and sticky information models based on their ability to match stylized facts. Khan and Zhu (2002) estimate sticky information Phillips curves in a partial equilibrium framework without testing the model against a specific alternative. Carroll (2003) estimates an inflation formation process using U.S. micro-data in which households only sporadically update their inflation expectations based on professional forecasts. A similar study by Döpke, Dovern, Fritsche, and Slacalek (2005) is conducted for the Euro area.

A related paper is Korenok (2005) who compares sticky information and sticky price models based on the theoretical relations these models imply between prices and unit labor costs. The work by Korenok (2005) for the U.S. also favors the sticky price model over the Mankiw-Reis model. Andres, Lopez-Salido, and Nelson (2005) compare the Calvo model with a sticky information model by maximum likelihood estimation and find that the sticky information model attains a higher value of the likelihood function than the Calvo model. However, they consider a very stylized model without capital accumulation and wage rigidities which is driven by only three shocks. Most closely related to our approach is the recent paper by Laforte (2005) who also compares different price setting models based on Bayesian estimation using U.S. data. Our paper differs from Laforte (2005) in the following aspects. We consider both wage and price setting with sticky information vs. Calvo contracts whereas Laforte (2005) considers only sticky prices. Furthermore, the structure of the economy assumed in this paper incorporates a larger number of frictions and shocks that are often claimed to be necessary for achieving a good fit with data. Finally, our model is estimated on a total of 7 observable time series whereas Laforte (2005) estimates the model on 4 observable variables. As Canova and Sala (2005) point out problems of parameter identification are less likely to occur when the model is estimated using a large number of observed variables. These differences notwithstanding, Laforte (2005) finds that sticky price models dominate the sticky information model for USA data as we do for Euro area data. We finally note that none of the studies mentioned above include price and wage markup shocks into the model. These studies also do not consider sticky information in both wage and price setting. These differences may explain why this paper finds stronger evidence against the sticky information model than the previous studies.

This paper proceeds as follows. Section 2 outlines the core of the model that is independent across contracting schemes in wage and price setting. Section 3 describes Calvo wage and price setting as well as the sticky information schemes that we use for the estimation of the models. Section 4 presents the empirical results for the baseline model and two extension. Section 5 presents the results for the nested model. Finally, section 6 concludes. An appendix contains tables with variance decompositions and figures displaying impulse responses.

2 Outline of the model

We keep the exposition of real side of the model short, since it has been described more extensively in Smets and Wouters (2003). To facilitate comparison we use the same notation as in the aforementioned paper.

2.1 Households

There is a continuum of households indexed by i supplying differentiated labor l_{it}, consuming C_{it} of the final output good and accumulating capital K_{it}. Households' objective is to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left[\frac{(C_{it} - hC_{t-1})^{1-\sigma_c}}{1-\sigma_c} - \frac{\varepsilon_t^L}{1+\sigma_l} l_{it}^{1+\sigma_l} \right]. \tag{1}$$

Here, C_t is aggregate consumption reflecting external habit formation.[3] ε_t^b denotes a preference shock affecting the intertemporal elasticity of substitution, ε_t^l is a labor supply shock and β, h, σ_l and σ_c are parameters. The budget constraint of household i is

$$b_t \frac{B_{it}}{P_t} + C_{it} + I_{it} = \frac{B_{it-1}}{P_t} + w_{it} l_{it} + A_{it} + \left(r_t^k z_{it} - \Psi(z_{it}) \right) K_{it-1} + D_{it}. \tag{2}$$

Households buy one period bonds B_t at price b_t. P_t is the aggregate price index, w_{it} the real wage for household i, A_{it} is the real net cash inflow from participating in the market for state-contingent securities. r_t^k is the real rental rate households obtain from renting out capital to firms. $\Psi(z_{it})$ is a function capturing the resource cost of capital utilization when the utilization rate is z_{it}. D_{it} are dividends to household i from the intermediate good firms.

Households choose the capital stock, the utilization rate and investment subject to the following capital accumulation equation

$$K_{it} = (1-\tau) K_{it-1} + \left[1 - S\left(\varepsilon_t^I \frac{I_{it}}{I_{it-1}} \right) \right] I_{it}. \tag{3}$$

τ is the depreciation rate and $S(\cdot)$ is a function capturing costs of altering the rate of change of investment. In the steady state $S(\cdot)$ equals zero. Furthermore, the first derivative evaluated at the steady state is also assumed to equal zero such that the linearized dynamics only depend on the second derivative. ε_t^I is a shock to the investment adjustment cost function.

The assumption of state contingent securities implies that households can fully insure against variations in their labor income arising from nominal rigidities in wage setting, allowing us to drop the subscript i. Maximizing the objective with respect to bonds and consumption subject to the budget constraints yields the familiar consumption Euler equation

$$\lambda_t = \beta E_t \frac{R_t}{\pi_{t+1}} \lambda_{t+1}. \tag{4}$$

Here, $R_t \equiv \frac{1}{b_t}$ is the gross nominal interest rate on the non-contingent bond, $\pi_{t+1} \equiv \frac{P_{t+1}}{P_t}$ is the aggregate CPI inflation rate and $\lambda_t \equiv \varepsilon_t^b (C_t - hC_{t-1})^{-\sigma_c}$ is the marginal utility of consumption.

Optimizing the objective function with respect to capital, investment and the capital utilization rate subject to the budget constraint and the capital accumulation equation yields the following first-order conditions:

$$r_t^k = \Psi'(z_t), \tag{5}$$

$$\lambda_t Q_t = \beta E_t \lambda_{t+1} \left[(1-\tau) Q_{t+1} + z_{t+1} r_{t+1}^k - \Psi(z_t) \right], \tag{6}$$

$$1 = -Q_t \left[1 - S(\cdot)_t - S'(\cdot)_t \frac{\varepsilon_t^I I_t}{I_{t-1}} \right] + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} Q_{t+1} S'(\cdot)_{t+1} \varepsilon_{t+1}^I \left(\frac{I_{t+1}}{I_t} \right)^2. \tag{7}$$

[3] Throughout this paper, for a generic variable X_{it}, its aggregate counterpart is defined as $X_t \equiv \int_0^1 X_{it} di$

Here $S^{'}(\cdot)_t$ is shorthand for $S^{'}\left(\varepsilon_t^I \frac{I_{it}}{I_{it-1}}\right)$. (5) equates the marginal gains from higher capacity utilization to the marginal cost. (6) states that the household installs capital until the cost today equals the discounted gains tomorrow.

2.2 Firms

There is a continuum of monopolistically competitive firms indexed by j of unit mass that produce differentiated intermediate goods Y_{jt}. Intermediate output is aggregated to final output Y_t according to the technology $Y_t^{1+\lambda_{pt}} = \int_0^1 Y_{jt}^{1/(1+\lambda_{pt})} dj$. λ_{pt} is a time varying markup parameter capturing fluctuations in the degree of market power. The aggregate consumption based price index P_t that corresponds to this aggregator is defined by the well-known relation $P_t^{-\lambda_{pt}} = \int_0^1 P_{jt}^{-1/\lambda_{pt}} dj$. Differentiated labor l_{it} is aggregated to composite labor L_t that enters as input into production via the relation $L_t^{1+\lambda_{wt}} = \int_0^1 l_{it}^{1/(1+\lambda_{wt})} di$. λ_{wt} is a time varying wage markup. The aggregate wage index is defined by $W_t^{-\lambda_{wt}} = \int_0^1 W_{it}^{-1/\lambda_{wt}} di$. The production function for intermediate output is given by

$$Y_{jt} = \varepsilon_t^a \tilde{K}_{jt}^{\alpha} L_{jt}^{1-\alpha} - \Phi.$$

Here, ε_t^a denotes the exogenous total factor productivity shock, K_{jt} is effective capital services defined as $\tilde{K}_{jt} \equiv z_t K_{jt}$, L_{jt} denotes the aggregate labor index and Φ is a fixed cost parameter. We assume that capital is freely mobile across firms. Therefore, an economy wide rental market for capital induces all firms to operate with the same capital-labor ratio. Cost minimization implies

$$\alpha w_t L_{jt} = (1-\alpha) r_t^k \tilde{K}_{jt}, \tag{8}$$

where $w_t = W_t/P_t$ is the aggregate real wage.

2.3 Market clearing, monetary policy and exogenous processes

Clearing of the final goods market requires

$$\frac{\varepsilon_t^a}{\tilde{P}_t} K_t^{\alpha} L_t^{1-\alpha} = C_t + I_t + G_t + \Psi(z_t) K_{t-1} + \Phi \tag{9}$$

Here, $\tilde{P}_t \equiv \left(\frac{P_{jt}}{P_t}\right)^{-(1+\lambda_{pt})/\lambda_{pt}} dj$ is an index of price dispersion that captures the output loss due to asynchronized price setting. Since we analyze small fluctuations around a steady state of zero price dispersion this term can be ignored for a log-linear analysis. Monetary policy is assumed to follow an interest rate rule of the following form:

$$\begin{aligned} \log\left(\frac{R_t}{\overline{R}}\right) = & \rho \log\left(\frac{R_{t-1}}{\overline{R}}\right) + r_{d\pi} \Delta \log\left(\frac{\pi_t}{\overline{\pi}}\right) + r_{dy} \Delta \log\left(\frac{Y_t}{Y_t^*}\right) \\ & + (1-\rho)\left\{ r_\pi \log\left(\frac{\pi_{t-1}}{\overline{\pi}}\right) + r_y \log\left(\frac{Y_t}{Y_t^P}\right)\right\} + \eta_t^R. \end{aligned} \tag{10}$$

Here, Δ is the first difference operator, $\bar{\pi}$ the steady state gross inflation rate (assumed to be unity) and $\bar{R}$ denotes the steady state nominal interest rate. According to this interest rate rule, the nominal rate reacts to its own lag, to the first difference of inflation and of the output gap Y_t/Y_t^P as well as to inflation and output gap with coefficients $\rho, r_{d\pi}, r_{dy}, r_\pi$ and r_y, respectively. The natural rate of output Y_t^P is defined as output with perfectly flexible wages and prices in the absence of the cost-push shocks $\{\eta_t^w, \eta_t^p, \eta_t^q\}$.

The model is driven by 9 exogenous stochastic processes: The five shocks $\{\varepsilon_t^b, \varepsilon_t^l, \varepsilon_t^I, \varepsilon_t^a, G_t\}$ are modeled as following mutually uncorrelated AR(1) processes in logs with AR coefficients $\rho_b, \rho_l, \rho_I, \rho_a, \rho_g$. The stochastic wage and price markup parameters obey the equations $\lambda_{pt} = \lambda_p \eta_t^p$ and $\lambda_{wt} = \lambda_w \eta_t^w$, where λ_p, λ_w are the steady state values and η_t^p, η_t^w are stochastic i.i.d. innovations.[4] As in Smets and Wouters (2003) we include an innovation η_t^q into the log-linearized equation for the price of capital that is not derived from first principles. This 'external finance premium' shock drives a wedge between the risk free real rate and the expected return on physical capital. The innovations $\{\eta_t^R, \eta_t^p, \eta_t^w, \eta_t^q\}$ are assumed to have an i.i.d. log-normal distribution. We do not include an inflation objective shock as in Smets and Wouters (2003). These authors only linearly detrend the observed nominal interest rate and inflation data, such that the detrended data exhibits a downward trend for which the time varying inflation objective may account. In this paper, these time series are HP filtered as in Juillard, Karam, Laxtan, and Pesenti (2004) eliminating the need for the inflation objective shock.

3 Staggered Wage and price setting

The monopoly power of firms and households implies that they are price and wage setters in their respective markets. In this section we describe the baseline version of the Calvo and the sticky information model of staggered wage and price setting.

3.1 Calvo set up

In each period firms receive a random signal with constant probability $1-\xi_p$ that allows them to change the price. Is the signal not received, they update the posted price by indexing it to the last period inflation rate: $P_{it} = \pi_{t-1}^{\gamma_p} P_{it-1}$. Here, $\gamma_p \in [0,1]$ is a parameter allowing for partial indexation. Firms that are allowed to change their price maximize expected profits as valued by the households' marginal utility in those states of the world where the price remains fixed. The first-order condition for the optimal nominal reset price P_t^* is

$$E_t \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{t+i} Y_{jt+i} \left[\frac{P_t^*}{P_t} \frac{(P_{t-1+i}/P_{t-1})^{\gamma_p}}{P_{t+i}/P_t} - (1+\lambda_{pt+i}) MC_{t+i} \right] = 0. \tag{11}$$

Here, $MC_t = W_t^{1-\alpha} \left(r_t^k\right)^\alpha / \varepsilon_t^a \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)}$ is real marginal cost. The aggregate price index evolves according to

$$P_t^{-1/\lambda_{pt}} = (1-\xi_p) \left(P_t^*\right)^{-1/\lambda_{pt}} + \xi_p \left(P_{t-1} \pi_{t-1}^{\gamma_p}\right)^{-1/\lambda_{pt}}. \tag{12}$$

Similarly for wage setting, we assume that households face a constant probability $1 - \xi_w$ of receiving a signal that allows them to change their wage. Households that do not receive the signal to update their nominal wage index it to last period's price inflation rate:

[4] The interpretation of these 'structural' shocks is somewhat ambiguous. They enter the log-linear Phillips curve as disturbances and are isomorphic to time variation in distortionary taxation of the firms revenue.

$W_{it} = \pi_{t-1}^{\gamma_w} W_{it-1}$. The wage setting optimization problem results in the following first-order condition:

$$E_t \sum_{j=0}^{\infty} \beta^j \xi_w^j \left[\frac{W_t^*}{P_t} \left(\frac{(P_t/P_{t-1})^{\gamma_w}}{P_{t+j}/P_{t+j-1}} \right) \frac{l_{it+j} U_{t+j}^c}{1+\lambda_{w,t+i}} - l_{it+j} U_{t+j}^l \right] = 0. \tag{13}$$

Here, U_{t+i}^c is the marginal utility of consumption and U_{t+i}^l is the marginal utility of labor in those states of the world where the price remains fixed. The aggregate wage index evolves according to

$$W_t^{-1/\lambda_{wt}} = (1-\xi_w) (W_t^*)^{-1/\lambda_{wt}} + \xi_p \left(W_{t-1} \pi_{t-1}^{\gamma_w} \right)^{-1/\lambda_{wt}}. \tag{14}$$

For γ_p, γ_w equal to zero the specification of Calvo price and wage setting collapses to the form originally proposed by Calvo (1983). We will refer to this specification as to a standard Calvo.

3.2 Sticky information

For computational reasons, the sticky information scheme adopted in this paper truncates the infinite tail in the age distribution of information sets that is present in the sticky information model of Mankiw and Reis (2002). Agents set their prices and wages based on information outdated by no more than $J = 12$ periods, i.e. 3 years. This allows to compute the model solution fast enough to estimate the parameters while still incorporating quite outdated information. In a robustness check later on, the model is also estimated with $J = 24$ to identify how the choice of the truncation point affects the fit of sticky information models.[5]

We begin by outlining the basic sticky information price setting problem. Each period a randomly chosen fraction of agents updates their information set about the state of the world. One can think of the firms‘ problem at the time of receiving the most recent information as choosing a whole sequence of prices. It chooses $J+1$ different prices all based on current information: one for the current period and one for each of the following J periods. These prices are applicable only if the firm will not receive more recent information in the meantime.

In the aggregate this will imply that at time t a fixed proportion ω_j^p of firms set their price $P_{t,t-j}^*$ based on the state vector j periods ago. The first-order condition for the price setting problem of the generic cohort j is

$$0 = E_{t-j} \left\{ \lambda_t Y_t \lambda_{pt}^{-1} \left(P_{t,t-j}^* \right)^{-1/\lambda_{pt}-2} P_t^{1/\lambda_{pt}} \left[P_{t,t-j}^* - (1+\lambda_{pt}) MC_t P_t \right] \right\}. \tag{15}$$

Once log-linearized, this yields the condition that prices are a markup over the conditional expectation of current period nominal marginal cost.

In the standard version of the sticky information scheme, price setting is completely described by $J+1$ such conditions, the definition of aggregate price index and the parameters $\omega_j^p,\ j = 0, 1, ..., J$ denoting the shares of agents working with information sets outdated by j periods. The aggregate price index is given by:

$$P_t^{-1/\lambda_{pt}} = \sum_{j=0}^{J} \omega_j^p \left(P_{t,t-j}^* \right)^{-1/\lambda_{pt}}. \tag{16}$$

[5] In a simpler model Trabandt (2005) has shown that $J = 20$ is a good approximation in the sense that the recursive equilibrium law of motion changes by less than a very small tolerance criterion if further cohorts are added.

Wage setting under the sticky information scheme is analogous to price setting. The first-order condition for the generic cohort j is

$$0 = E_{t-j}\left\{\lambda_{wt}^{-1}\left(W_{t,t-j}^{*}\right)^{-1/\lambda_{wt}-2} W_t^{1/\lambda_{wt}+1} L_t \left[\lambda_t \frac{W_{t,t-j}^{*}}{P_t} - (1+\lambda_{wt})\varepsilon_t^L l_{t,t-j}^{\sigma_l}\right]\right\} \tag{17}$$

Here, $l_{t,t-j}$ is labor supply by the j-th cohort. Once log-linearized, this condition states that households set the real wage $W_{t,t-j}^{*}/P_t$ as a markup over the marginal rate of substitution between consumption and leisure based on time $t-j$ conditional expectation. There are $J+1$ such conditions characterizing wage setting together with the following definition for the wage index:

$$W_t^{-1/\lambda_{wt}} = \sum_{j=0}^{J}\omega_j^w \left(W_{t,t-j}^{*}\right)^{-1/\lambda_{wt}} \tag{18}$$

To evaluate the empirical fit of sticky information models two important choices must be made. First which truncation point J to choose. Second whether to estimate all ω_j^p and ω_j^w in an unrestricted fashion or to impose some restrictions in order to reduce the number of parameters. Rabanal and Rubio-Ramirez (2005) note that the Bayesian model selection criterium that we employ in later sections has a built-in *Occam's razor* that punishes models with a large number of parameters. Therefore, we estimate three versions the model, labeled parsimonious parameterization, intermediate parameterization I, intermediate parameterization II. For some selected models we also estimate a rich specification that imposes no restrictions on the shares. These specifications are described in detail in section 4.3

3.3 Equilibrium and linearized equations

A rational expectations equilibrium in the Calvo model is a sequence of allocations $\{K_t, L_t, C_t, I_t, Z_t, Q_t\}_{t=0}^{\infty}$ as well prices $\left\{r_t^k, R_t, P_t, P_t^{*}, W_t^{*}, W_t\right\}_{t=0}^{\infty}$ that satisfy equations (3)-(14) as well as transversality conditions for capital holdings given initial values for $\{K_{-1}, P_{-1}\}$ and the exogenous sequences
$\left\{\varepsilon_t^b, \varepsilon_t^l, \varepsilon_t^I, \varepsilon_t^a, G_t, \eta_t^R, \eta_t^p, \eta_t^w, \eta_t^q\right\}_{t=0}^{\infty}$.

In the model with sticky information the rational expectations equilibrium is given by sequences of allocations $\{K_t, L_t, C_t, I_t, Z_t, Q_t\}_{t=0}^{\infty}$ as well prices $\left\{r_t^k, R_t, P_t, W_t, \left\{P_{t,t-j}^{*}\right\}_{j=0}^{J}, \left\{W_{t,t-j}^{*}\right\}_{j=0}^{J}\right\}_{t=0}^{\infty}$ that satisfy equations (3)-(10) $J+1$ conditions of the type (15) and $J+1$ conditions of the type (17), the wage and price indices (16) and (18) for given initial values of $\{K_{-1}, W_{0,-j}^{*}, P_{0,-j}^{*},$ for $j = 1, ...J\}$.

We analyze the empirical properties of this model log-linearized around the steady state using the software package DYNARE.[6] Below we collect the core equations that remain unchanged when we vary our assumptions about wage and price setting. These equations are

[6] Thanks to Michel Juillard and team members for developing this software.

log-linearized around a zero inflation deterministic steady state.

$$\hat{C}_t = \frac{h}{1+h}\hat{C}_{t-1} + \frac{1}{1+h}E_t\hat{C}_{t+1} - \frac{1-h}{(1+h)\sigma_c}\left(\hat{R}_t - E_t\hat{\pi}_{t+1}\right) \tag{19}$$

$$+ \frac{1-h}{(1+h)\sigma_c}\left(\hat{\varepsilon}_t^b - E_t\hat{\varepsilon}_{t+1}^b\right) \tag{20}$$

$$\hat{I}_t = \frac{1}{1+\beta}\hat{I}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{I}_{t+1} + \frac{\varphi}{1+\beta}\hat{Q}_t - \frac{\beta}{1+\beta}\left(E_t\hat{\varepsilon}_{t+1}^I - \hat{\varepsilon}_t^I\right) \tag{21}$$

$$\hat{Q}_t = \left(\hat{R}_t - \hat{\pi}_t\right) + \frac{1-\tau}{1-\tau+\bar{r}^k}E_t\hat{Q}_{t+1} + \frac{\bar{r}^k}{1-\tau+\bar{r}^k}E_t\hat{r}_{t+1}^k + \eta_t^Q \tag{22}$$

$$\hat{K}_t = (1-\tau)\hat{K}_{t-1} + \tau\hat{I}_{t-1} \tag{23}$$

$$\hat{L}_t = -\hat{w}_t + (1+\psi)\hat{r}_t^k + \hat{K}_{t-1} \tag{24}$$

$$\hat{Y}_t = c_y\hat{C}_t + \tau k_y\hat{I}_t + g_y\hat{\varepsilon}_t^G + \bar{r}^k k_y\hat{z}_t \tag{25}$$

$$= \phi\hat{\varepsilon}_t^a + \phi\alpha\psi\hat{r}_t^k + \phi(1-\alpha)\hat{L}_t \tag{26}$$

$$\hat{R}_t = \rho\hat{R}_{t-1} + (1-\rho)\left\{r_\pi\hat{\pi}_{t-1} + r_Y\left(\hat{Y}_t - \hat{Y}_t^P\right)\right\} \tag{27}$$

$$r_{d\pi}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + r_{dy}\left(\hat{Y}_t - \hat{Y}_t^P - (\hat{Y}_{t-1} - \hat{Y}_{t-1}^P)\right) + \eta_t^R \tag{28}$$

Here, $\varphi \equiv 1/\bar{S}''$ is the inverse of the second derivative of the investment adjustment cost function evaluated at the deterministic steady state. $\psi \equiv \psi'(1)/\psi''(1)$ is the inverse of the elasticity of capital utilization cost function at the steady state. c_y, k_y, g_y are steady-state shares of consumption, capital and government spending in total output, respectively. ϕ is one plus the share of fixed cost in production.

We next turn to the wage and price setting block of the model. In the Smets and Wouters (2003) specification, wage and price setting is described by the following two log-linear equations

$$\hat{\pi}_t = \frac{\beta}{1+\beta\gamma_p}E_t\hat{\pi}_{t+1} + \frac{\gamma_p}{(1+\beta\gamma_p)}\hat{\pi}_{t-1}$$
$$+ \frac{1}{1+\beta\gamma_p}\frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}\left(\alpha\hat{r}_t^k + (1-\alpha)\hat{w}_t - \hat{\varepsilon}_t^a + \eta_t^p\right) \tag{29}$$

$$\begin{aligned} \hat{w}_t \quad = \quad & \left(\frac{1}{1+\beta}\right)\hat{w}_{t-1} + \frac{\beta\xi_w}{1-\xi_w}\left(\frac{\lambda_w}{1-\lambda_w}\sigma_L - 1\right)\hat{w}_{t+1} \\ & + \left(\frac{\gamma_w\xi_w}{1-\xi_w}\right)\left(\frac{\lambda_w}{1-\lambda_w}\sigma_L - 1\right)\hat{\pi}_{t-1} + \frac{\beta\xi_w}{1-\xi_w}\left(\frac{\lambda_w}{1-\lambda_w}\sigma_L - 1\right)\hat{\pi}_{t+1} \\ & + \xi_w\left(\frac{-\gamma_w\beta\xi_w + 1 + \beta\xi_w}{1-\xi_w} + \right)\left(\frac{\lambda_w}{1-\lambda_w}\sigma_L - 1\right)\hat{\pi}_t \\ & + (1-\beta\xi_w)\left(\hat{w}_t - \hat{\varepsilon}_t^l - \sigma_L\hat{L}_t - \sigma_c\left(\frac{1}{1-h}\right)(\hat{C}_t - h\hat{C}_{t-1} - \eta_t^w)\right) \end{aligned} \tag{30}$$

4 Empirical analysis

We apply the system-based Bayesian approach which allows to incorporate prior information from micro-studies or other sources into the estimation. This approach has been discussed by many authors in the literature in the last few years, e.g. Schorfheide (2000), Smets and Wouters (2003) as well as Fernandez-Villaverde and Rubio-Ramirez (2004).

4.1 The data

The models considered here are estimated with quarterly Euro area data for the period 1970:Q1-2003:Q4.[7] The data set we employ was first constructed by Fagan, Henry, and Mestre (2001) for the Area Wide Model database. The time series from this database have been used by Smets and Wouters (2003) and Adolfson, Laseen, Linde, and Villani (2005), to mention only a few of the wide range of estimated DSGE models for the euro area. Adolfson, Laseen, Linde, and Villani (2005) assume a common trend in the real variables while estimating the model. This assumption is, however, not satisfied empirically, see Del Negro, Schorfheide, Smets, and Wouters (2004). To address this issue we eliminate the trend in both real and nominal variables by applying HP filter with a high smoothing parameter ($\lambda = 10,000$) as advocated by Juillard, Karam, Laxtan, and Pesenti (2004) or Detken and Smets (2004).[8] Using detrended data becomes also important as some nominal variables trend up or downward over the whole sample period, which could additionally bias the estimates. Since there is no consistent euro area measure of hours worked, the model is estimated on employment E_t which is likely to respond more sluggishly to shocks. As in Smets and Wouters (2003) we work with the following auxiliary equation for employment

$$\hat{E}_t = \beta \hat{E}_{t+1} + \frac{(1-\beta\xi_e)(1-\xi_e)}{\xi_e}\left(\hat{E}_t - \hat{L}_t\right)$$

In each period, only a fraction ξ_e of firms can adjust employment to the desired total labor input and the difference is take up by unobserved hours per worked per employer. A derivation of this equation can be found in Adolfson, Laseen, Linde, and Villani (2005). Our models explain the same variables as Smets and Wouters (2003) and the vector of observables $[\hat{Y}_t, \hat{C}_t, \hat{I}_t, \hat{\pi}_t, \hat{w}_t, \widehat{E}_t, \hat{R}_t]$ includes: real GDP, consumption, investment, CPI inflation, the real wage, employment and the nominal interest rate.[9]

We apply Bayesian estimation methods using the software package DYNARE. An optimization algorithm csminwel is used to obtain an initial estimate of the mode of the posterior parameter distribution. To check that the optimization routine converges to the same value we start it from a number of various initial values before launching the MCMC chains. The latter is based on two chains of 50.000 - 100.000 draws. Convergence of the algorithm (not reported in the paper) is checked via CUMSUM statistics and appears by and large satisfactory.[10]

[7] The data from the 1970's are used as a training sample for initialization of the Kalman Filter.

[8] Smets and Wouters (2003) remove a linear trend from the data.

[9] Note that Smets and Wouters (2003) allow for a unit root in the inflation target which has the similar effect on model dynamics as a direct detrending of inflation series.

[10] As in any applied work with MCMC chains, there is always a chance that convergence appears to have occurred when in fact it has not.

4.2 Calibrated parameters and priors

The Bayesian approach facilitates the incorporation of prior information from other macro as well as micro studies in a formalized way. In specifying the prior density $p(\theta)$ we assume that all parameters are independently distributed of each other, i.e. $p(\theta) = \prod_{i=1}^{N} p_i(\theta_i)$, which allows for a straightforward evaluation of the posterior. The set of priors is heavily influenced by Smets and Wouters (2003). Prior to the estimation we have checked whether the models simulated with the mean of the prior distribution can roughly match the volatility and persistence of the data. As the estimation is based on HP-detrended series, which are slightly less volatile than linearly detrended series employed in Smets and Wouters (2003), the priors for the standard deviations of structural shocks have been in general scaled down.

The full set of priors can be found in table 1. In particular, the Calvo parameters ξ_p, ξ_w are assumed to be beta distributed with the mean of 0.75 and standard deviation of 0.05. The parameters standing for the degree of indexation γ_p, γ_w are set to be beta distributed with the mean of 0.75 and standard deviation of 0.15.

The sticky information model is characterized by $J+1$ structural parameters, corresponding to the shares of agents $\omega_j \quad j = 0, ..., J$ using information sets outdated by j periods.[11] Estimating all of these parameters would imply deterioration of model's out-of-sample fit and would result in penalizing the whole class of sticky information models. Therefore, we reduce the dimensionality of the parameter space by imposing some functional forms on the relation between the ω_j for $j = 0, ...J$. In the baseline model we assume that the fraction of agents using information outdated by j periods decays geometrically, i.e $\omega_j = c(1 - \tilde{\xi})\tilde{\xi}^j$ for $j = 0, 1, ..., J$. Here, $\tilde{\xi} \in (0, 1)$ is the single parameter to be estimated and c ensures that the shares add up to unity.[12] This specification is analogous to the Calvo wage and price setting model, where the share of agents whose price was last updated j periods ago also declines geometrically. Furthermore, Reis (2005, Proposition 7) has shown that under certain assumptions the share of agents not having planned for j periods follows the exponential distribution. For large J this parameterization approximates the distribution advocated by Reis (2005). For the prior distribution of the information structure we choose fairly loose densities defined on the interval $(0, 1)$, leaving an important role for the data. In particular, the parameter $\tilde{\xi}$ is assumed to be prior beta distributed with the mean of 0.8 and standard deviation of 0.15. The prior distributions of the all parameters are presented in the table 1 below.

[11] In the subsequent paragraphs we drop the distinction between the ω_j^p describing price setting and ω_j^w describing wage setting and use the simpler notation ω_j to refer to both.

[12] I.e. $c^{-1} = \sum_{i=0}^{J} (1 - \tilde{\xi})\tilde{\xi}^j$.

parameter	symbol	type	mean	std/df
investment adj. cost	S''	norm	4	1.5
consumption utility	σ_c	norm	1	0.375
habit persistence	h	beta	0.7	0.1
Calvo wage stickiness	ξ_w	beta	0.75	0.05
Calvo price stickiness	ξ_p	beta	0.75	0.05
information rigidity prices	$\tilde{\xi}_p$	beta	0.8	0.15
information rigidity wages	$\tilde{\xi}_w$	beta	0.8	0.15
labor utility	σ_l	norm	2	0.75
indexation wages	γ_w	beta	0.75	0.15
indexation prices	γ_p	beta	0.75	0.15
capital utilization adj. cost	ϕ	norm	0.2	0.075
fixed cost	ψ	norm	1.45	0.125
Calvo employment stickiness	ξ_L	beta	0.5	0.15
response to inflation	r_π	norm	1.7	0.1
response to diff. inflation	$r_{d\pi}$	norm	0.3	0.1
interest rate smoothing	ρ	beta	0.8	0.1
response to output gap	r_y	norm	0.125	0.05
response to diff. output gap	r_{dy}	norm	0.063	0.05
persistence tech. shock	ρ_a	beta	0.85	0.1
persistence preference shock	ρ_b	beta	0.85	0.1
persistence gov. spending. shock	ρ_g	beta	0.85	0.1
persistence labor supply shock	ρ_L	beta	0.85	0.1
persistence investment shock	ρ_I	beta	0.85	0.1
stdv. productivity shock	σ_a	invg	0.4	2
stdv. preference shock	σ_b	invg	0.2	2
stdv. gov. spending shock	σ_g	invg	0.3	2
stdv. labor supply shock	σ_L	invg	1	2
stdv. equity premium shock	σ_q	invg	0.4	2
stdv. monetary shock	σ_R	invg	0.1	2
stdv. investment shock	σ_I	invg	0.1	2
stdv. inflation equation shock	σ_π	invg	13	2
stdv. wage equation shock	σ_w	invg	80	2

Table 1: Prior parameter distribution

As in Smets and Wouters (2003) some of the structural parameters are calibrated, as they mainly influence the steady state and are not or only weakly identified from log-linearized equations. Following Smets and Wouters (2003) we calibrate $\beta = 0.99$, $\tau = 0.025$, $\alpha = 0.3$ and $\lambda_w = 0.5$.

4.3 Results for the baseline model

In this section we discuss the estimation results. In order to compare the fit of the models, we report Bayes factor, root mean squared in sample error as well as the match of the models autocorrelations with those of the data.

In a Bayesian framework, model comparisons are typically based on the marginal likelihood, denoted by $p(Y|M_i) = \int p(Y|\theta_i, M_i)p(\theta|M_i)d\theta_i$ for some model M_i with parameter vector θ_i. Hence, the model's parameters are integrated out from the density using the prior as a weighting function.[13] Given alternative models M_i and M_j with prior probabilities p_i and p_j, the posterior odds ratio is given by $PO_{i,j} = \frac{p(Y|M_i)p(M_i)}{p(Y|M_j)p(M_j)}$. When all models are assigned equal prior probabilities, i.e. $p(M_j) = p(M_i)$, then the posterior odds boil down to the ratios of the marginal likelihood, i.e. the Bayes factor. The Bayes factor summarizes the evidence contained in the data in favor of one model as opposed to another. Fernandez-Villaverde and Rubio-Ramirez (2004) provide an extensive discussion of the advantages of the Bayes factor for model comparison over likelihood ratio. They also specify the sense in which the Bayes factor is a consistent selection device even when the models are non-nested or misspecified.

Table 2 reports marginal densities of the Calvo model and versions of the sticky information model.

Model	description	log of marginal density
Calvo	with indexation	-307.8
Calvo	no indexation	-304.1
Sticky information	J = 12	-416.5
Sticky information	J = 24	-412.0^*

Table 2: Log of marginal densities: baseline models. The asterisks * denotes that the marginal density has been calculated via the Laplace Approximation.

The model with the highest marginal density is the Calvo model without indexation. Compared with the standard sticky information model with $J = 12$ quarters of information lags, there is overwhelming evidence in favor of the Calvo model. Since the difference in log-marginal likelihood is 112.4 one would require a prior probability for the sticky information model that is $\exp(112.4) = 6.52 \times 10^{48}$ larger than the prior for the Calvo model to favor the sticky information model based on posterior odds. Fernandez-Villaverde and Rubio-Ramirez (2004) point out that a log-difference of 7 is often used as bound for DNA testing in forensic science. Hence, there is overwhelming evidence in favor of the Calvo model.

Summary statistics for the posterior distribution of the parameters can be found in table 3. The table shows that the structural parameters not related to wage and price setting are estimated at similar posterior modes and within similar 90% posterior intervals. This finding has also been obtained by Andres, Lopez-Salido, and Nelson (2005) in their comparison of sticky prices and sticky information models. Notable differences are found in the estimated volatility of the disturbances entering the wage and price setting equations, i.e the standard deviations of the labor supply shock, the wage markup shock and the price markup shock. This issue is interpreted later on.

[13]It is important to note that the marginal likelihood is a predictive density based on the prior distribution as a summary of the parameter uncertainty. No data is consumed to estimate the parameters of the model when computing the marginal likelihood. This makes it possible to interpret the marginal likelihood as a measure of out-of-sample predictive performance, rather than in-sample fit.

parameter		Calvo mode	Calvo 90% post. interval	Mankiw-Reiss J=12 mode	Mankiw-Reiss J=12 90% post. interval
investment adj. cost	S''	4.054	(0.562, 2.954, 4.724)	5.615	(3.806, 5.691, 7.547)
consumption utility	σ_c	0.954	(0.750, 1.179, 1.599)	1.446	(0.987, 1.423, 1.889)
habit persistence	h	0.476	(0.358, 0.491,0.625)	0.516	(0.422, 0.545, 0.658)
labor utility	σ_l	2.386	(1.854, 2.741, 3.690)	2.635	(1.856, 2.868, 3.893)
indexation wages	γ_w	0.482	(0.201, 0.409, 0.604)		
indexation prices	γ_p	0.548	(0.257, 0.393, 0.544)		
Calvo wages	ξ_w	0.714	(0.624, 0.699, 0.771)		
Calvo prices	ξ_p	0.875	(0.878, 0.899, 0.923)		
information rigidity prices	$\tilde{\xi}_p$			0.998	(0.998, 0.998, 0.998)
information rigidity wages	$\tilde{\xi}_w$			0.856	(0.802, 0.853, 0.904)
capital util. adj. cost	ϕ	0.346	(0.252, 0.358, 0.471)	0.370	(0.269, 0.370, 0.477)
fixed cost	ψ	1.778	(1.384, 1.558, 1.723)	1.735	(1.575, 1.741, 1.897)
Calvo employment	ξ_L	0.200	(0.628, 0.689, 0.752)	0.159	(0.081, 0.208, 0.329)
response to inflation	r_π	1.683	(1.503, 1.681, 1.853)	1.660	(1.482, 1.650, 1.818)
response to diff. inflation	$r_{d\pi}$	0.150	(0.076, 0.146, 0.215)	0.145	(0.100, 0.159, 0.222)
interest rate smoothing	ρ	0.927	(0.939, 0.959, 0.981)	0.948	(0.908, 0.936, 0.965)
response to output gap	r_y	0.051	(0.040, 0.109, 0.176)	0.043	(0.013, 0.046, 0.081)
response to diff. output gap	r_{dy}	0.136	(0.164, 0.197, 0.227)	0.103	(0.075, 0.118, 0.158)
persistence techn. shock	ρ_a	0.926	(0.874, 0.910, 0.948)	0.845	(0.799, 0.843, 0.891)
persistence preference shock	ρ_b	0.745	(0.361, 0.493, 0.623)	0.712	(0.545, 0.669, 0.792)
persistence gov. spending. shock	ρ_g	0.976	(0.851, 0.898, 0.943)	0.979	(0.931, 0.965, 0.999)
persistence labor supply shock	ρ_L	0.725	(0.980, 0.988, 0.997)	0.833	(0.785, 0.864, 0.947)
persistence investment shock	ρ_I	0.267	(0.090, 0.308, 0.715)	0.325	(0.190, 0.309, 0.435)
stdv. productivity shock	σ_a	0.277	(0.339, 0.422, 0.504)	0.285	(0.250, 0.299, 0.339)
stdv. preference shock	σ_b	0.088	(0.116, 0.148, 0.185)	0.098	(0.075, 0.109, 0.143)
stdv. gov. spending shock	σ_g	0.321	(0.277, 0.321, 0.361)	0.320	(0.284, 0.321, 0.360)
stdv. labor supply shock	σ_L	2.399	(0.852, 1.229, 1.597)	4.547	(2.463, 4.242, 5.903)
stdv. equity premium shock	σ_q	0.093	(0.046, 0.279, 0.848)	0.093	(0.046, 0.192, 0.364)
stdv. monetary shock	σ_R	0.066	(0.037, 0.057, 0.077)	0.052	(0.039, 0.060, 0.080)
stdv. investment shock	σ_I	0.514	(0.173, 0.504, 0.729)	0.517	(0.441, 0.529, 0.619)
stdv. inflation equation shock	σ_π	0.461	(0.392, 0.692, 0.962)	0.036	(0.025, 0.037, 0.050)
stdv. wage equation shock	σ_w	0.630	(0.287, 0.713, 1.152)	0.936	(0.647, 1.034, 1.396)

Table 3: Posterior distribution: Calvo model with indexation and truncated Mankiw-Reiss model with $J = 12$.

We now turn to what the estimated model implies for information rigidity in price and wage setting. The estimated population shares of agents working with information outdated by j periods, denoted by ω_j, are proportional to the parameter $\tilde{\xi}$ to the power j. Here $\tilde{\xi}$ is the only estimated parameter of the truncated sticky information scheme governing the speed with which the shares decline in age. For $\tilde{\xi}$=0, all firms act with current information, for larger $\tilde{\xi}$ the shares decline more slowly over time indicating the presence of more information rigidity. Figure 1 plots the age distribution of information sets used by price and wage setters according to the prior of the $\tilde{\xi}$ parameter and according to posterior mode of $\tilde{\xi}$.

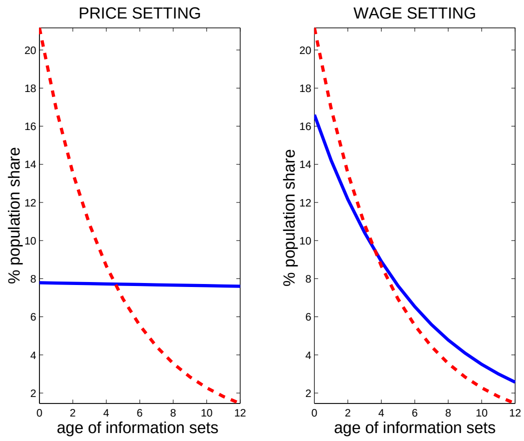

Figure 1: Age distributions of information sets $J = 12$. Broken line - distribution according to prior. Solid line - distribution according to posterior.

For price setting, the posterior mode of ξ_p is 0.998. As can be seen from the graph, this implies that the age distribution of information sets follows a Taylor type pattern with age invariant shares rather a Calvo type pattern with geometrically declining shares. For wage setting, the posterior mode of ξ_w is 0.856, generating a Calvo type pattern. Apparently, the data favors the maximum possible amount of information rigidity for price setting.

Next, we analyze the impulse responses generated from the models with the parameters evaluated at the posterior mode. Figure 2 shows that the estimated sticky information model is capable of generating a delayed and hump shaped response of output and inflation to monetary shocks that is a stylized fact from identified VARs. The work of Christiano, Eichenbaum, and Evans (2005) finds that inflation takes as much as 3 years to reach its peak response to a monetary shock. As noted by Trabandt (2005), the Calvo model with indexation in price setting can also generate this basic pattern. The sticky information model generates the strongest response of inflation 12 quarters after the shock when all agents have updated their information set. Due to the endogenous propagation mechanism in the model, the effect of the monetary shock on inflation is propagated beyond the duration of information rigidities.

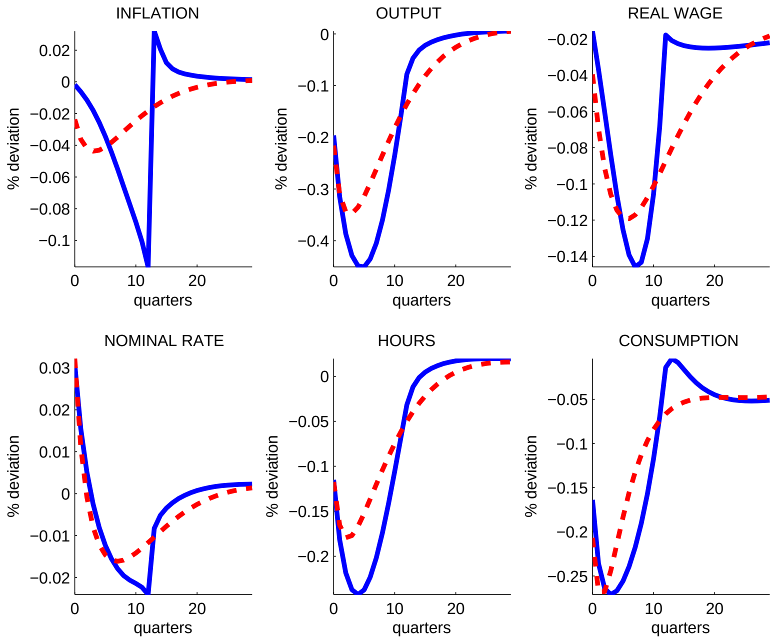

Figure 2: Impulse response to monetary shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model with indexation. Impulse responses are calculated at the posterior mode.

The full set of impulse responses as well as forecast error variance decomposition can be found in the appendix. The impulse responses to most other shocks do not add much more insight into the difference between sticky information models and sticky price models except for the price and wage markup shocks. For these shocks the impulse response are drastically different. Figure 3 displays the response to price markup shock, i.e. a stochastic variation in the elasticity of substitution of differentiated goods in the CES aggregator.

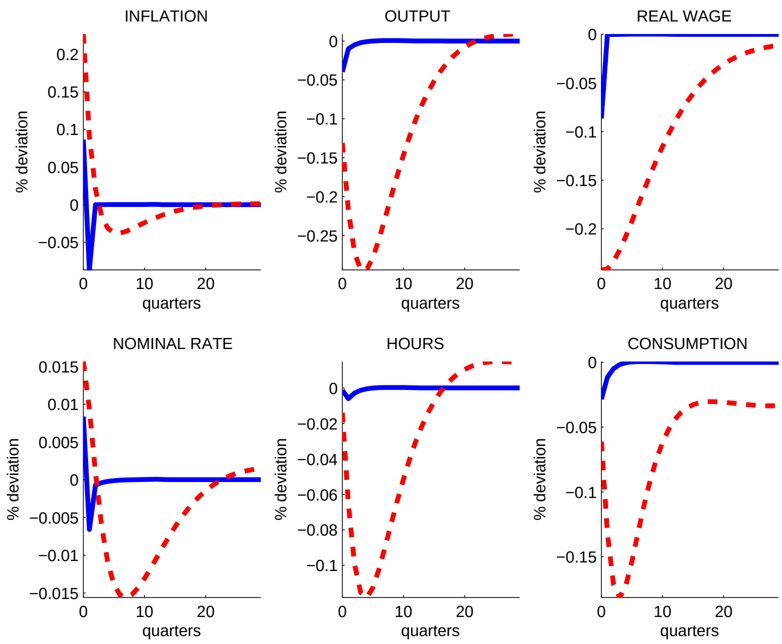

Figure 3: Impulse response to markup shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

Two observations emerge. First, the uncorrelated markup shock induces a persistent decline in most variables for the Calvo model. However, in the sticky information model these variables return to their steady state values very rapidly. Second, inflation and the nominal rate oscillate for two periods following the shock, inducing a negative first-order autocorrelation of inflation conditional on this shock. It is well known from Smets and Wouters (2003) that the price markup shock is the dominant shock driving inflation in their model. This is confirmed in table 12 on page 38 in the appendix for our estimation of the Calvo model. At horizon 1 and 4 quarters, markup shocks account for 95 and 70 percent, respectively, of the variance in the forecast error of inflation. Note further from table 2 that estimating a restricted Calvo model without the markup shock reduces the marginal likelihood drastically.

Inflation is empirically a volatile process, but responds sluggishly to marginal cost in the model. Hence, significant markup shocks are needed to match the volatility of inflation. This, however, creates problems for the sticky information model.[14] More volatile price markup shocks help to match the standard deviation of inflation in the data, but come at the cost of reducing the persistence of inflation and the real wage - as can be seen from the impulse responses in figure 3. The following table summarizes the the match of the model with respect to standard deviation and autocorrelation of inflation and the real wage.

[14]These issues do not arise when one compares the Calvo model with the Mankiw Reis model only along a few selected dimension. Our likelihood based method considers all model implications in an environement with many shocks as opposed to say matching inflation persistence.

variable	data	Calvo	SI J=12	SI J=24
stdv inflation	0.33	0.31	0.3	0.4
stdv wage	1.09	1.27	1.19	1.84
AR(1) inflation	0.63	0.59	0.46	0.17
AR(1) wage	0.92	0.93	0.35	0.67

Table 4: Standard deviations and autocorrelation of the models and the data.

The table shows that both version of the estimated sticky information models fail to match the persistence present in the inflation and real wage series, which the Calvo model matches reasonably well. Furthermore, the sticky information model with $J = 24$ implies much to volatile real wage series. Furthermore, we report how well the different models replicate the autocorrelations of other times series used for estimation. Figure 4 displays the autocorrelations $corr(X_t, X_{t-j})$ for a generic variable X. where the abscissa denotes the displacement $j = 0, ..., 8$. The figure shows that the sticky information model replicates the autocorrelations of the data roughly as well as the Calvo model with one major exception: It fails dramatically to generate the serial correlation of the real wage series.

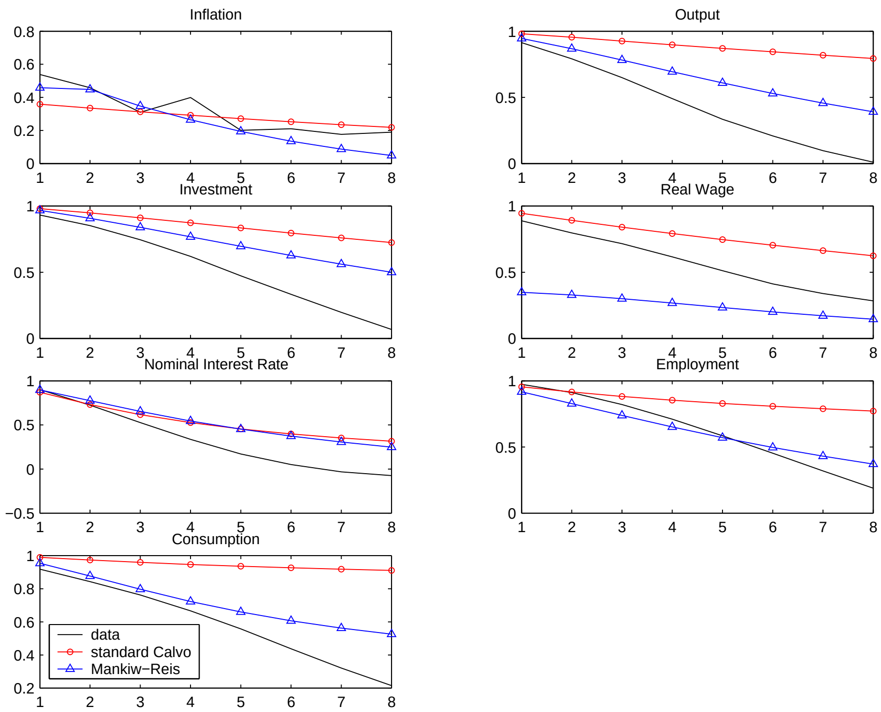

Figure 4: Replicated autocorrelations

This inadequate match of the real wage series is further confirmed by comparing the mean squared in sample error that is displayed in table 5.

Root mean squarred error	$\hat{C}_t$	$\hat{Y}_t$	$\hat{I}_t$	$\widehat{E}_t$	$\hat{R}_t$	$\hat{W}_t$	$\hat{\pi}_t$
VAR(1)	0.41	0.41	1.07	0.12	0.11	0.38	0.22
Calvo SW	0.52	0.51	1.26	0.25	0.11	0.41	0.25
sticky information J=12	0.52	0.52	1.27	0.29	0.11	0.86	0.24
sticky information J=24	0.52	0.53	1.26	0.22	0.11	1.00	0.25

Table 5: Root mean squared error (RMSE): Calvo, standard sticky information, VAR(1)

As a reference model, we report the in-sample fit of a vector-autoregression of order one. The structural models perform somewhat worse than the atheoretical VAR.[15] The sticky information models have a similar RMSE than the Calvo model for all variables accept for the real wage. The RMSE of the real wage series is roughly twice as high for the sticky information model than for the Calvo model.

Finally one may ask whether there is support for sticky information schemes in price setting while wage setting is modeled as following the Calvo scheme and vice versa. In other words, is it sticky information in wages or sticky information in prices that accounts for the bad fit? To this end, table 6 presents the marginal density of so called mixed models. In these mixed models only price setters follow sticky information and wage setters Calvo or vice versa.

Model	description	log of marginal density
Calvo	without price markup shock	-359.9
Calvo	without wage markup shock	-361.9
mixed: Calvo Wages, SI prices		-348.1
mixed: Calvo Wages, SI prices	without price markup shock	-361.0
mixed: SI Wages, Calvo prices		-320.7
mixed: SI Wages, Calvo prices	without wage markup shock	-344.5

Table 6: Log of marginal densities: mixed models

As can be seen from that table, the mixed models per se do not attain higher marginal densities than the Calvo model. However, once one estimates the Calvo model without price or wage markup shocks and compares this model to mixed models without these markup shocks, the picture looks more favorable for sticky information. For instance, the pure Calvo model without price markup shocks attains roughly the same marginal density as the model with Calvo wage setting and sticky information price setting absent markup shocks. Hence, it appears that including or excluding markup shocks is an important decision for the relative model performance. Another important decision is whether to allow these shocks to be autocorrelated or not. We proceed by estimating models with price and wage markup shocks as they are important sources of inflation dynamics and overall model fit.

[15] The Smets and Wouters (2003) DSGE model fares slightly better against the VAR, which might be due to the fact that we omit the inflation objective shock from the exogenous stochastic processes.

4.4 Extension I: Increasing the truncation point

We have further examined whether the remarkably weak performance of the standard sticky information model is caused by choosing the truncation point $J = 12$ too small. For $J = 12$ the average age of information sets for price setting implied by $\tilde{\xi}_p = 0.998$ is roughly 7 quarters.[16] This compares to an estimated average age of price contracts of 8 quarters in the Calvo model. Hence, one may want to allow more outdated information in the Mankiw-Reis type model.[17] Therefore, the model is re-estimated with $J = 24$. Trabandt (2005) has shown that the recursive equilibrium law of motion in his sticky information model does not change by more than an arbitrarily small tolerance criterion if further lags are added beyond the 20th lag. Hence, the choice of $J = 24$ is expected to be a reasonable approximation to the infinite lag inherent in Mankiw and Reis original sticky information model. Note that we include many more lags in the model than other studies that also need to decide about a truncation point. For instance, Andres, Lopez-Salido, and Nelson (2005) truncate after 3 periods. Laforte (2005) considers information sets that are outdated by at most 9 quarters. With such a large number of lags it becomes infeasible to perform a full blown Bayesian analysis on a desktop PC. Therefore, no MCMC chains are run and we restrict ourselves to characterizing the posterior mode via optimization algorithms.

Increasing the maximum lag for outdated information sets from $J = 12$ to $J = 24$ improves the fit of the sticky information model only slightly. The log of the marginal density now increases from -416 to -412 as computed via the Laplace approximation, but is still far off from the marginal density of for the Calvo model with indexation of -307.

The estimation results are presented in table 7, for comparison we again provide the estimates of the Calvo model with indexation. Again the estimates of the structural parameters unrelated to price and wage setting are by and large similar across models. The posterior mode of the parameters describing information rigidity in the sticky information model are now estimated at 0.90 for price setting and 0.52 for wage setting. This gives rise to the age distribution of information sets as depicted in figure 5.

[16] This is easy to see: Note that $\tilde{\xi} \sim 1$ implies that the 13 age cohorts have roughly equal population share. Hence the average age is roughly similar to the average age formula for Taylor pricing: $1/n \sum_{i=1}^{N} i = (N+1)/2$. For $N = 13$ this yields 7.

[17] Another possible way to compare the models is to also truncate the Calvo sticky price and wage model at $J = 12$ thereby leveling the playing field.

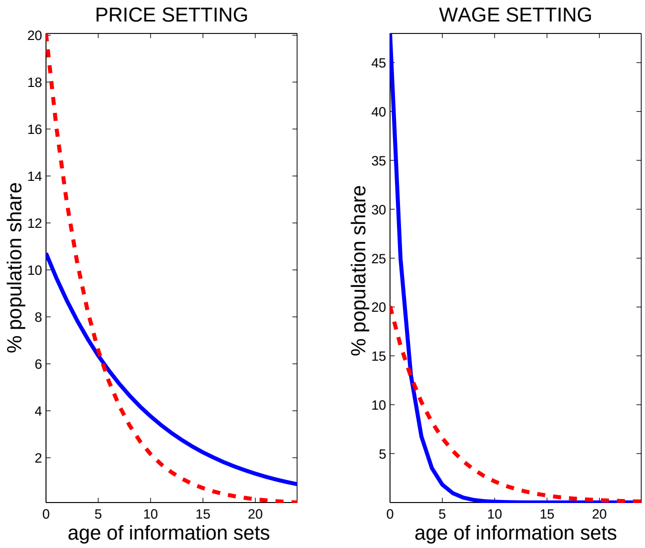

Figure 5: Age distributions of information sets $J = 24$. Broken line - distribution according to prior. Solid line - distribution according to posterior.

Inspecting the figure shows that the truncation point is clearly sufficient for wage setting, since the estimated age distribution converge to zero. For price setting there remains a nonzero mass at age 24, indicating that a further increase in the number of lags might provide a slightly better approximation to the infinite lag structure.

parameter		Calvo		Mankiw-Reiss J=24	
		mode	90% post. interval	mode	90% post. interval
investment adj. cost	S''	4.054	(0.562, 2.954, 4.724)	3.983	( )
consumption utility	σ_c	0.954	(0.750, 1.179, 1.599)	1.187	( )
habit persistence	h	0.476	(0.358, 0.491,0.625)	0.472	( )
labor utility	σ_l	2.386	(1.854, 2.741, 3.690)	2.735	( )
indexation wages	γ_w	0.482	(0.201, 0.409, 0.604)		
indexation prices	γ_p	0.548	(0.257, 0.393, 0.544)		
Calvo wages	ξ_w	0.714	(0.624, 0.699, 0.771)		
Calvo prices	ξ_p	0.875	(0.878, 0.899, 0.923)		
information rigidity prices	$\tilde{\xi}_p$			0.901	( )
information rigidity wages	$\tilde{\xi}_w$			0.520	( )
capital util. adj. cost	ϕ	0.346	(0.252, 0.358, 0.471)	0.345	( )
fixed cost	ψ	1.778	(1.384, 1.558, 1.723)	1.563	( )
Calvo employment	ξ_L	0.200	(0.628, 0.689, 0.752)	0.680	( )
response to inflation	r_π	1.683	(1.503, 1.681, 1.853)	1.653	( )
response to diff. inflation	$r_{d\pi}$	0.150	(0.076, 0.146, 0.215)	0.131	( )
interest rate smoothing	ρ	0.927	(0.939, 0.959, 0.981)	0.975	( )
response to output gap	r_y	0.051	(0.040, 0.109, 0.176)	0.107	( )
response to diff. output gap	r_{dy}	0.136	(0.164, 0.197, 0.227)	0.219	( )
persistence techn. shock	ρ_a	0.926	(0.874, 0.910, 0.948)	0.904	( )
persistence preference shock	ρ_b	0.745	(0.361, 0.493, 0.623)	0.534	( )
persistence gov. spending. shock	ρ_g	0.976	(0.851, 0.898, 0.943)	0.898	( )
persistence labor supply shock	ρ_L	0.725	(0.980, 0.988, 0.997)	0.989	( )
persistence investment shock	ρ_I	0.267	(0.090, 0.308, 0.715)	0.261	( )
stdv. productivity shock	σ_a	0.277	(0.339, 0.422, 0.504)	0.397	( )
stdv. preference shock	σ_b	0.088	(0.116, 0.148, 0.185)	0.146	( )
stdv. gov. spending shock	σ_g	0.321	(0.277, 0.321, 0.361)	0.313	( )
stdv. labor supply shock	σ_L	2.399	(0.852, 1.229, 1.597)	1.305	( )
stdv. equity premium shock	σ_q	0.093	(0.046, 0.279, 0.848)	0.094	( )
stdv. monetary shock	σ_R	0.066	(0.037, 0.057, 0.077)	0.038	( )
stdv. investment shock	σ_I	0.514	(0.173, 0.504, 0.729)	0.557	( )
stdv. inflation equation shock	σ_π	0.461	(0.392, 0.692, 0.962)	0.058	( )
stdv. wage equation shock	σ_w	0.630	(0.287, 0.713, 1.152)	0.253	( )

Table 7: Posterior distribution: Calvo model with indexation and truncated Mankiw-Reiss model with $J = 24$.

We next turn to a description of impulse responses of this sticky information model. Again the parameters are evaluated at the posterior mode for plotting responses.

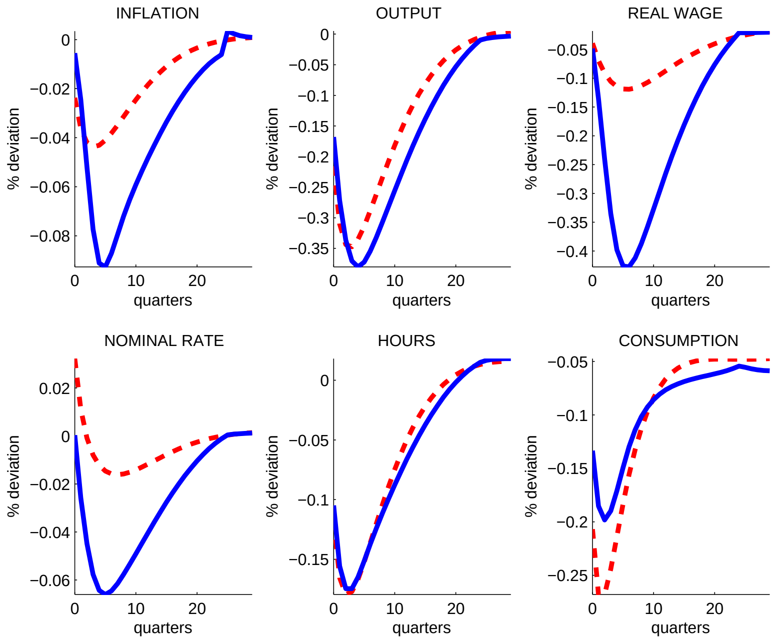

Figure 6: Impulse response to monetary shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

The monetary shock brings about a qualitatively very similar delayed and hump-shaped responses of the observable variables in the Calvo model as in the sticky information model, see figure 6. The real wage, inflation and the nominal rate react stronger in the sticky information model. This may be due to the fact that the the estimated information rigidity $\tilde{\xi}_w = 0.52$ in wage setting is smaller than the Calvo wage setting parameter $\xi_w = 0.71$. This similarity between the models is confirmed when considering further shocks. Here, we only show some selected responses. Figure 7 displays the impulse responses to the technology shock.

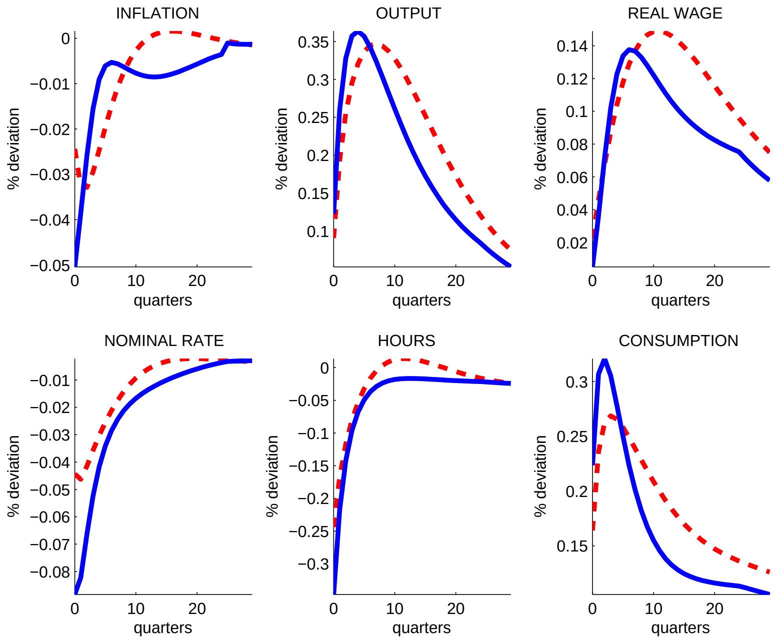

Figure 7: Impulse response to technology shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

The impulse response to the technology shock and most other shocks displayed in the appendix do not point to obvious differences between the models. However, sharp discrepancies arise from the impulse responses to the price (and similarly wage) markup shock displayed in figure 8.

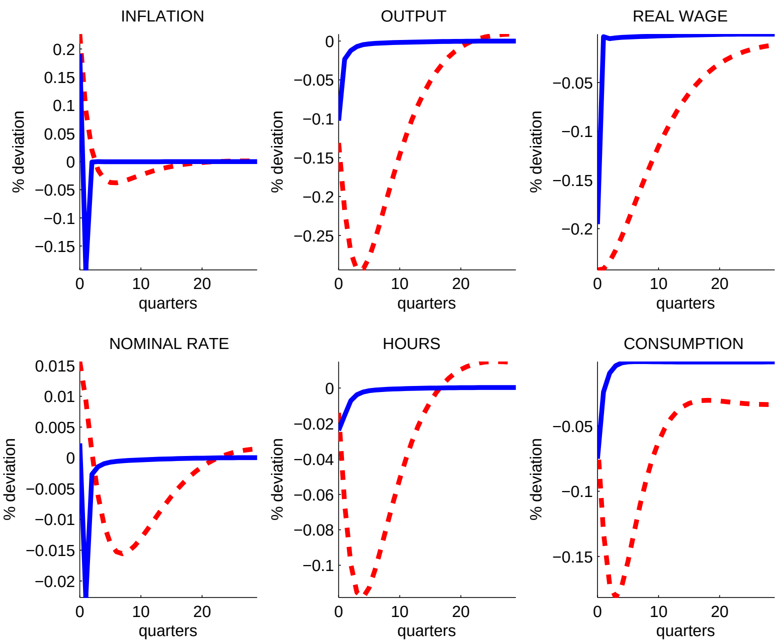

Figure 8: Impulse response to price markup shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

As for the case of $J = 12$, the markup shock induces persistent response in most variables for the Calvo model, but very different dynamics for the sticky information model. As indicated by the modest improvement in the marginal likelihood extending the truncation does not improve the overall fit of the sticky information model by much. This finding is confirmed by inspecting the RMSE for the extended model, displayed in the last row of table 5 on page 20. For most series there is not much of a change in the RMSE relative to the model with $J = 12$. The root-mean-squared for the employment and investment improves, but the real wage series is now matched even worse.

Finally, it is worthwhile to compare our estimated degree of information rigidity to what is reported in other studies. Carroll (2003) finds that the average U.S. household updates inflation expectations roughly once per year. A study by Döpke, Dovern, Fritsche, and Slacalek (2005) has reported a similar frequency of updating information sets for 5 major European countries. In the baseline model with $J = 12$ the average age of information sets relevant for price setting is roughly seven quarters and for wage setting 5 quarters. For $J = 24$ the average age is roughly 8 quarters for price setting, but only 2 quarters for wage setting. Compared to the micro studies, a very high degree of information stickiness in price setting is needed for the DSGE models to match the data. One should bear in mind though that the estimated average age of the reset price in the Calvo model is also very high. Given the estimate of $\xi_p = 0.875$, on average prices are a roughly two years old in the Calvo model. Estimating version of this model with firm specific input factors is likely to decrease both the estimated average age of prices and of information sets.

4.5 Extension II: Departing from exponential decay

Next, we explore another avenue that can potentially provide a better fit of sticky information models. That is, we relax the assumption that the age distribution of information sets follows the exponential decay. This modification is motivated by Laforte (2005), who has shown that the fit of sticky price models and sticky information models can be improved by allowing for a more general pattern of price adjustment in the spirit of Wolman (1999).

First, we estimate a rich parameterization where all J parameters ω_j are estimated freely. The purpose of estimating the rich parameterization is to obtain more insights regarding the information distribution in the data and use this knowledge for parameterizing more parsimonious models. Therefore, we do not compute the marginal density for this richly parameterized model and thus do not include it in the set of models to be compared via posterior-odds ratios.

As will be shown below, the estimates from the rich parameterization do not support the idea that population shares that are strictly declining in age as suggested by Reis (2005). Rather, the age distribution of information sets appears to be hump shaped. We therefore introduce two intermediate parameterizations, which can capture this hump shaped pattern while estimating only a small number of parameters. In the intermediate specification I, we estimate only the share of agents using the current and yesterday's information set, i.e. ω_0 and ω_1. This specification allows the age distribution of information sets to be hump-shaped. The current information set may now have very little weight and the peak is allowed to be at lag 1. Further lags have geometrically decaying weights. In intermediate parameterization I, the parameter ω_0 is beta distributed with the mean of 0.2 and standard deviation of 0.15. The parameter ω_1 which imposes geometrically decreasing relationship for the remaining information sets is prior beta distributed with mean 0.8 and standard deviation of 0.15.

The intermediate parameterization II allows for a more general hump shaped pattern. Under this specification, we estimate directly parameters the $\{\omega_0, \omega_1, \omega_5\}$ and linearly interpolate the values for the remaining shares assuming that $\omega_J = 0$. The priors assumed for estimated parameters ω_0, ω_1, ω_5 in the intermediate parameterization II are also beta distributed with the mean of 0.2 and standard deviation of 0.15. This pattern allows for at most two peaks in the age distribution or for a plateau at intermediate lags.

The estimated age distributions are summarized in figures 9 and 10. The estimated share of agents working with current information is small. Hence, that data favor a specification where the age distribution of information sets of price and wage setter follows a hump-shaped pattern. However, these modification improve the fit of sticky information models only mildly. The marginal density of the sticky information with intermediate parameterization I and a maximum of 12 information lags is -404.7. For the intermediate parameterization II the marginal density is -409.2. Hence, the improvement over the baseline model is large enough to reject geometric decay. However, relative to the sticky price model whose marginal density is -307, this modified sticky information model still fares far worse.

5 Alternative model comparison method

The analysis so far has shown overwhelming dominance of the sticky price model relative to the sticky information model based on the Bayes factor as the model comparison criterion. Sims (2003) has pointed out that Bayesian model comparison methods can misbehave. He notes that results may be sensitive to the prior distributions of parameters, to seemingly minor aspects of model specification and tend to be implausibly sharp. He cites Gelman, Carlin, Stern, and Rubin (1995) who note that posterior probabilities are useful, when "each of the discrete models make scientific sense and there are no obvious scientific models in between". Sims expands on this point by noting that overwhelming favor for one model against an alternative model based on posterior odds may be an indication that the selection of models is simply too sparse. He advocates to expand the range of models or to vary the model specification.

We address these potential pitfalls of applying Bayesian model selection criteria in the following way. We address the requirement of Gelman, Carlin, Stern, and Rubin (1995) and form an obvious in between model: This is a nested model, where an estimated fraction of firms follows the Calvo apparatus and the remaining fraction follows the sticky information approach. Our structural interpretation of such a nested model is based on the idea that for some firms menu costs may be a more important source of nominal rigidities, whereas for other firms it may be information acquisition costs.

5.1 The nested Calvo - sticky information model

In order to validate the empirical relevance of Calvo and Sticky Information scheme within the same model we introduce a nested Calvo - Sticky Information model. In this model a fraction α of firms operates according to the Calvo Model. The remaining fraction $1-\alpha$ sets prices according to the sticky information scheme. Within the sticky information scheme, we allow the information set to be outdated by at most J periods. In the following exposition, we aim to keep the notation simple and assume that all sticky information agents set their price based on yesterdays information set. At the expense of notation, the model can easily be expanded to arbitrary information lags $j = 0, 1, ..., J$. In fact, we estimate a model with $J = 12$. For empirical analysis we use the nested models with parsimoniously as well as with rich parameterized sticky information part.

Let P_t^* denote the optimal price of the Calvo price setters that re-optimize their price in period t and let $P_{t,t-1}$ denote the price that the sticky information agents chooses today based on information yesterday. ξ_p stands for the probability that Calvo agents cannot re-optimize their price.

The aggregate price index P_t is defined as[18]

$$P_t^{-1/\lambda_{pt}} = \alpha \left\{ (1-\xi_p)\left(P_t^*\right)^{-1/\lambda_{pt}} + \sum_{j=1}^{\infty}(1-\xi_p)\xi_p^j \left(P_{t-j}^*\right)^{-1/\lambda_{pt}} \right\} + (1-\alpha) P_{t,t-1}^{-1/\lambda_{pt}} \tag{31}$$

In order to eliminate the infinite sum, we define an auxiliary index X_t via the relation $X_t^{-1/\lambda_{pt}} \equiv \sum_{j=0}^{\infty}(1-\xi_p)\xi_p^j \left(P_{t-j}^*\right)^{-1/\lambda_{pt}}$. Note that the infinite sum above is $\xi_p X_{t-1}^{-1/\lambda_{pt}}$. X_t evolves as

$$X_t^{-1/\lambda_{pt}} = (1-\xi_p)\left(P_t^*\right)^{-1/\lambda_{pt}} + \xi_p X_{t-1}^{-1/\lambda_{pt}} \tag{32}$$

Our price index is therefore

$$P_t^{-1/\lambda_{pt}} = \alpha \left\{ (1-\xi_p)\left(P_t^*\right)^{-1/\lambda_{pt}} + \xi_p X_{t-1}^{-1/\lambda_{pt}} \right\} + (1-\alpha) P_{t,t-1}^{-1/\lambda_{pt}} \tag{33}$$

[18] Note that the term $\sum_{j=1}^{\infty}(1-\xi_p)\xi_p^j \; P_{t-j}^* \; {}^{-1/\lambda_{pt}}$ does not equal $\xi_p P_{t-1}^{-1/\lambda_{pt}}$ as in the Calvo model, due to the presence of sticky information agents. This fact requires us to introduce the auxiliary variable X_t.

Thus, price setting in the mixed model is described by (11) defining P_t^* and by (15) defining the optimal $P_{t,t-1}$ as well as the two equations (32) and (33).

In order to solve the model with standard methods, a stationary version of above two equations is needed. This is obtained as follows: Equation (33) is divided by P_t and the stationary variables $x_t \equiv X/P_t, p_{t,t-1} \equiv P_{t,t-1}/P_t$ and $p_t^* \equiv P_t^*$ are defined.

$$1^{-1/\lambda_{pt}} = \alpha \left\{ (1-\xi_p)\,(p_t^*)^{-1/\lambda_{pt}} + \xi_p \left(\frac{x_{t-1}}{\pi_t} \right)^{-1/\lambda_{pt}} \right\} + (1-\alpha) \left(\frac{p_{t,t-1}}{\pi_t} \right)^{-1/\lambda_{pt}} \tag{34}$$

Here, π_t is price inflation between period $t-1$ and period t. Divide (32) by P_t to arrive at

$$x_t^{-1/\lambda_{pt}} = (1-\xi_p)\,(p_t^*)^{-1/\lambda_{pt}} + \xi_p \left(\frac{x_{t-1}}{\pi_t} \right)^{-1/\lambda_{pt}} \tag{35}$$

The same logic applied to the wage setting scheme yields:

$$1^{-1/\lambda_{wt}} = \alpha \left\{ (1-\xi_w)\,(w_t^*)^{-1/\lambda_{wt}} + \xi_w \left(\frac{x_{t-1}}{\pi_t^w} \right)^{-1/\lambda_{wt}} \right\} + (1-\alpha) \left(\frac{w_{t,t-1}}{\pi_t^w} \right)^{-1/\lambda_{wt}} \tag{36}$$

$$(x_t^w)^{-1/\lambda_{wt}} = (1-\xi_w)\,(w_t^*)^{-1/\lambda_{wt}} + \xi_w \left(\frac{x_{t-1}^w}{\pi_t} \right)^{-1/\lambda_{wt}} \tag{37}$$

where $\pi_t^w = W_t/W_{t-1}$ denotes wage inflation.

5.2 Estimation results for nested model

The prior distribution of the parameters that are specific to the nested model, α^P, α^w, is assumed to be the beta distribution with mean of 0.5 and standard deviation of 0.2.

Table 8 collects the log marginal densities as our summary statistics for the overall model evaluation.

Model	parameterization	log marginal density
Calvo	with indexation	-307.8
Calvo	without indexation	-304.1
Nested Calvo-SI model	parsimonious, J=12	-322.6
Nested Calvo-SI model	intermediate I, J=12	-323.2
Nested Calvo-SI model	intermediate II, J=12	-317.4

Table 8: Comparison of marginal densities for nested models

The log marginal densities indicate that the data fit of the nested models is much better than that of the pure sticky information models whose marginal likelihood is roughly -400. However, the nested models do not attain a higher marginal density than the standard Calvo model. In fact, based on the Bayes factor the standard Calvo model again dominates any of the nested models.

We now turn to the estimated shares of sticky information agents. Table 9 summarizes these shares for the different models we estimate. For the parsimoniously parameterized models, we estimate the share of Calvo agents for price setting very close to unity. In other words, the data ascribes almost zero mass to sticky information price setters. For wage setting the share of agents following sticky information schemes is estimated at 7%. This is consistent with the finding that the Calvo model overwhelmingly dominates the parsimoniously parameterized sticky information model in terms of posterior odds. Hence, one can conclude that the overwhelming evidence against the sticky information model based on Bayes factor is also confirmed by the evidence in the nested model.

model	parsimonious	intermediate I	intermediate II
price setting	0.01	0.15	0.15
wage setting	0.07	0.30	0.35

Table 9: Estimated shares of sticky information agents

For the other estimated parameterizations, we estimate the share of sticky information price setters at roughly 15%. For wage setting the share of sticky information households is estimated between 30% and 35%. In other words, there seems to be little evidence for sticky information considerations in price setting, but more in wage setting.

Next, the estimated age distribution of information sets is discussed. Figure 9 on the next page and figure 10 on page 32 show the posterior distribution of ω_j - the shares of agents working with information outdated by j periods- for wage and price setting. The blue starred line shows the age distribution under the unrestricted estimation where all ω_j are estimated freely. This age distribution is highly irregular. It does not follow either one of the two typically employed schemes in the sticky information literature: Geometrically declining weights as in Calvo or equal weights as in Taylor type models.[19]

[19]See Coiboin (2006) and Dupor and Tsuraga (2005) for the use of sticky information models that employ these types of age distributions.

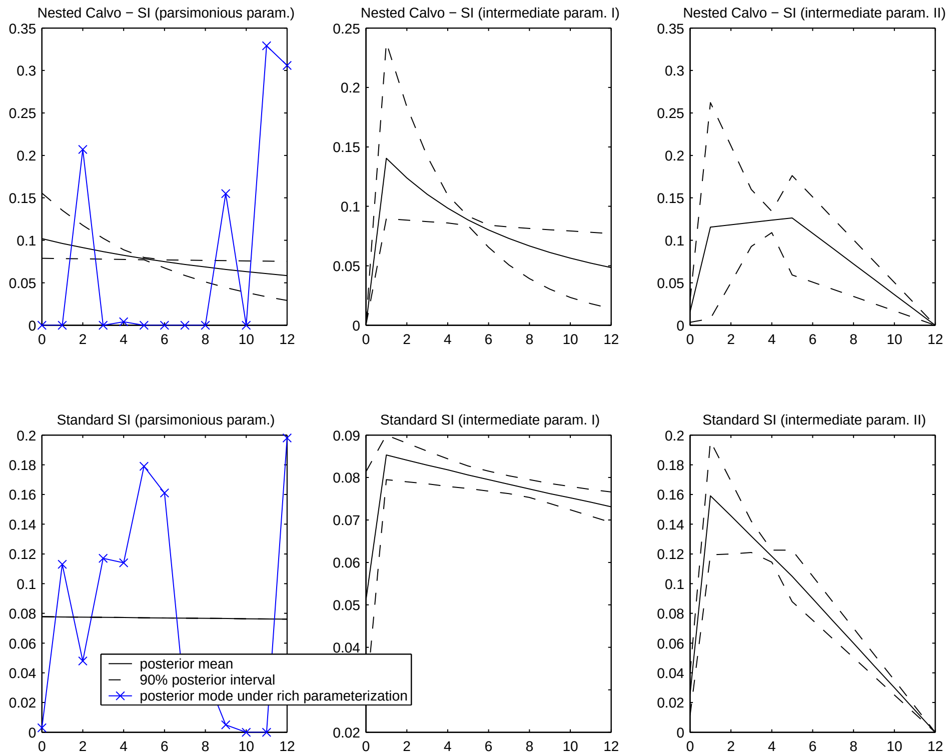

Figure 9: Age distribution of information sets: price setting

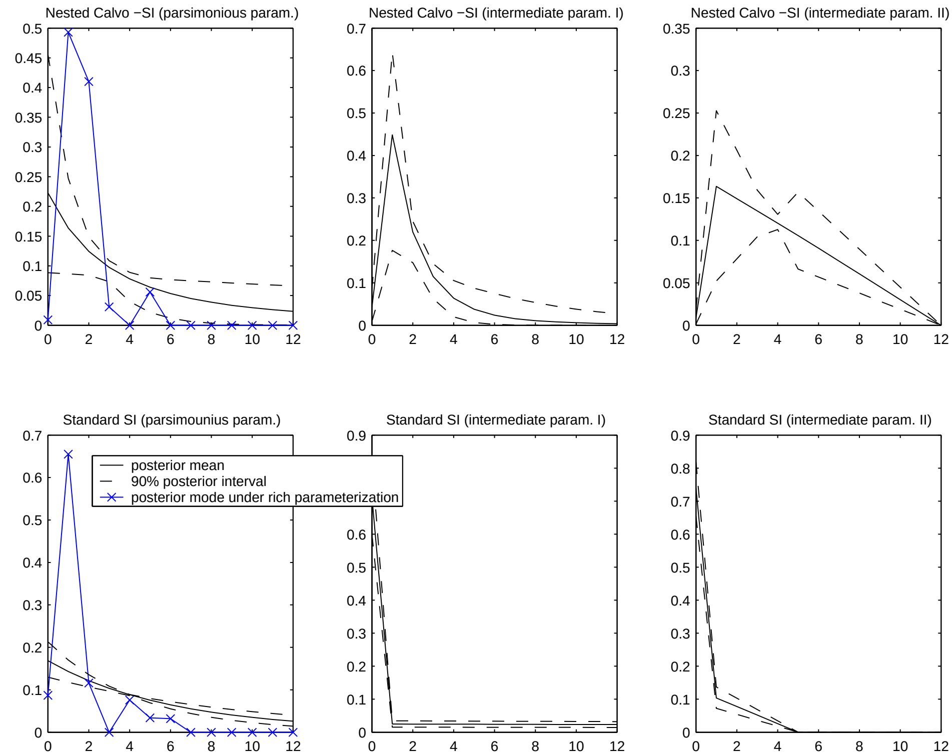

Figure 10: Age distribution of information sets: wage setting

For wage setting, the estimated unrestricted age distribution appears to be well approximated by hump shaped pattern with a peak at lag 1.

6 Conclusion

This paper has evaluated the empirical performance of sticky information models in wage and price setting relative the Calvo model. Our primary finding is that the baseline sticky information model is strongly dominated as measured via the Bayes factor by the Calvo model. This finding holds for both considered truncation points $J = 12$ and $J = 24$ and for all considered age distribution of information sets. One potential explanation for this finding is the inability of sticky information models to match the persistence and volatility in real wages and inflation. Thus, the standard sticky information model is *hard to square with the facts* once we let likelihood based methods decide what the facts are rather than matching a few selected stylized facts.

As a second method for comparing sticky information and sticky price model we form a nested model. A share of agents is assumed to follow the Calvo apparatus whereas the remaining agents sets prices according to sticky information model. This method also delivers strong evidence against sticky information ideas. When the age distribution follows a truncated exponential decay, the posterior mode indicates that only 1% of agents follows sticky information schemes in price setting and only 7% in wage setting. Hence, the nested model also suggest that the data does not offer much support sticky information schemes. Finally, we show that there is little evidence in Euro area data for the arrival of information to follow a Poisson process as suggested by Reis (2005). Such a poisson process implies that the largest share of firms uses current information, which is not what we estimate in our framework. On the contrary, our estimates suggest that the share of agents using current information is typically very small.

In comparing sticky information models to the Calvo model we have made a number of choices that could be relaxed in future work. First, we have only considered sticky information in wage and price setting. This natural choice implies a form of dichotomy: Household make consumption decisions based on full information, but wage decision base on outdated information. A similar dichotomy holds for investment and pricing decisions of firms. Future work could empirically evaluate the whole sticky information paradigm by incorporating it into all decisions of economic agents.[20] In order to allow for a fair comparison with the Calvo model we have chosen not pursue this avenue in the current work. Second, future work could investigate to what extent our findings are sensitive to the specification of the real side of the economy by incorporating real rigidities in the form of firm specific factor markets. We leave these issues for future work.

Finally, a note on our methodology is in order. We view likelihood based methods such as the Bayesian model comparison employed in this paper as the appropriate way to compare models to the data. In our view, this is preferable over selecting a few stylized facts from the vast range of implications that a model has for observable variables. Essentially, we let the data decide how to weigh all the different moments that one may potentially decide to match. However, some may criticize this approach because the so-called structural shocks are not regarded as truly structural. For instance, Schmitt-Grohe and Uribe (2005) view some of the shocks employed in recent DSGE models as “a reflection of the fact that theory lags behind business cycle”, i.e. as misspecification errors rather than structural shocks. They further criticize that these non-structural errors often explain a majority of observed business-cycle fluctuations. In principle, this criticism also applies to this paper. For instance, we have argued that the difference in marginal likelihood between sticky information models and sticky price models may in part be attributable to how markup shocks affect the dynamics in the respective models. These markup shocks are viewed by some in the profession as non-structural shocks reflecting a host of issues neglected in the model. In our view, this is not an argument against the methodology per se. If these shocks are found to be important for model comparison purposes, this only highlights the need to further explore the interpretation and foundation of these shocks.

[20]See Coiboin (2006) for an analysis of the interactions between sticky information in consumption and in price setting.

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Appendix A: Variance decomposition

Model	H	technology	discount	government	investment	labor	monetary	price markup	risk premium	wage markup
	1	(1.6, 5.5, 17.3)	(8.6, 17.8, 24.1)	(22.6, 29.9, 38.2)	(0.0, 22.1, 27.9)	(5.5, 8.9, 15.2)	(5.9, 10.3, 18.4)	(0.6, 1.6, 3.4)	(0.0, 0.0, 13.2)	(1.2, 1.8, 2.9)
Calvo (SW)	4	(13.1, 23.8, 39.3)	(2.5, 7.9, 12.7)	(7.7, 12.4, 17.7)	(0.0, 14.2, 20.0)	(12.1, 17.7, 24.4)	(11.3, 18.7, 28.3)	(1.5, 3.2, 6.9)	(0.0, 0.0, 3.7)	(0.4, 0.7, 1.3)
	8	(18.1, 31.9, 45.5)	(1.2, 3.9, 6.7)	(4.1, 7.1, 10.8)	(0.0, 8.4, 13.1)	(15.6, 22.7, 31.2)	(12.0, 20.9, 30.9)	(1.7, 3.7, 8.1)	(0.0, 0.0, 1.9)	(0.2, 0.4, 0.7)
	20	(17.0, 32.3, 48.0)	(0.7, 2.1, 3.7)	(2.3, 4.0, 6.3)	(0.0, 4.6, 7.6)	(23.0, 33.8, 45.8)	(9.8, 18.2, 29.5)	(1.4, 3.1, 6.7)	(0.0, 0.0, 1.0)	(0.2, 0.3, 0.8)
	1	(2.6, 6.4, 12.7)	(12.0, 17.4, 23.7)	(22.3, 28.8, 36.0)	(18.2, 22.6, 28.5)	(5.6, 8.9, 13.7)	(6.2, 10.1, 15.2)	(1.6, 2.6, 4.6)	(0.0, 0.0, 0.4)	(0.9, 1.4, 2.1)
Standard Calvo	4	(15.5, 24.5, 35.4)	(4.4, 8.0, 13.1)	(8.4, 12.4, 17.1)	(10.4, 15.2, 21.2)	(12.3, 17.5, 24.2)	(11.7, 17.9, 24.8)	(1.2, 2.3, 5.0)	(0.0, 0.0, 0.2)	(0.3, 0.5, 0.8)
	8	(20.6, 31.1, 43.9)	(2.1, 4.1, 7.2)	(4.7, 7.4, 10.8)	(5.8, 9.4, 14.2)	(16.2, 22.8, 31.1)	(13.5, 20.7, 29.1)	(1.0, 2.0, 4.6)	(0.0, 0.0, 0.1)	(0.2, 0.3, 0.4)
	20	(17.5, 29.1, 44.5)	(1.2, 2.2, 4.0)	(2.6, 4.3, 6.5)	(3.1, 5.3, 8.5)	(24.5, 34.2, 46.3)	(12.3, 20.5, 30.9)	(0.8, 1.6, 3.9)	(0.0, 0.0, 0.1)	(0.1, 0.2, 0.4)
	1	(0.0, 0.0, 0.4)	(17.3, 22.4, 28.2)	(20.7, 26.1, 31.3)	(20.5, 25.4, 31.4)	(3.6, 8.2, 14.6)	(5.8, 9.0, 13.6)	(0.1, 0.4, 0.8)	(0.0, 0.0, 0.1)	(5.4, 7.2, 10.2)
Standard SI	4	(0.3, 1.3, 3.6)	(12.6, 18.9, 26.7)	(11.2, 14.9, 19.4)	(16.5, 23.4, 32.0)	(5.6, 15.9, 31.5)	(14.5, 21.6, 31.8)	(0.0, 0.1, 0.2)	(0.0, 0.0, 0.0)	(1.0, 1.4, 2.2)
	8	(0.5, 2.2, 5.6)	(7.2, 12.6, 19.9)	(8.3, 12.5, 17.3)	(11.1, 18.4, 26.8)	(5.2, 18.7, 41.4)	(20.3, 31.1, 45.7)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.0)	(0.5, 0.8, 1.2)
	20	(0.7, 2.8, 8.2)	(4.1, 9.2, 15.0)	(5.5, 11.8, 20.8)	(6.8, 13.7, 23.0)	(5.5, 28.8, 63.8)	(13.5, 28.8, 45.1)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.0)	(0.4, 0.6, 0.9)
	1	(2.3, 6.1, 13.0)	(12.4, 18.0, 23.9)	(22.1, 28.5, 35.5)	(18.3, 23.0, 28.2)	(4.8, 8.1, 13.1)	(6.0, 10.0, 15.1)	(2.0, 3.0, 5.5)	(0.0, 0.0, 0.2)	(1.0, 1.6, 2.1)
Calvo-SI	4	(14.9, 25.8, 36.8)	(4.4, 8.3, 13.3)	(8.0, 11.9, 16.4)	(9.7, 15.0, 21.0)	(11.6, 16.4, 23.3)	(12.5, 17.8, 25.0)	(1.2, 2.4, 4.8)	(0.0, 0.0, 0.1)	(0.3, 0.5, 0.8)
	8	(19.8, 33.7, 45.5)	(2.1, 4.3, 7.4)	(4.5, 7.0, 10.3)	(5.7, 9.2, 13.3)	(15.1, 21.6, 30.0)	(13.9, 20.5, 29.5)	(0.9, 2.0, 4.3)	(0.0, 0.0, 0.0)	(0.1, 0.2, 0.4)
	20	(16.7, 32.6, 46.7)	(1.1, 2.4, 4.0)	(2.5, 4.1, 6.3)	(3.1, 5.2, 8.0)	(23.1, 33.7, 45.7)	(12.7, 19.4, 29.6)	(0.7, 1.4, 3.5)	(0.0, 0.0, 0.0)	(0.1, 0.2, 0.3)

Table 10: Variance decomposition: Output **SW** refers to the Calvo specification with indexation. **Standard Calvo** refers to the model without indexation.**standard SI** refers to the baseline sticky information model with J=12. **Calvo-SI** is the nested Calvo - sticky information model.

Model	H	technology	discount	government	investment	labor	monetary	price markup	risk premium	wage markup
Calvo (SW)	1	(42.8, 53.9, 63.7)	(20.0, 26.9, 35.0)	(2.2, 3.6, 5.8)	(0.0, 3.3, 4.8)	(1.4, 3.1, 5.6)	(0.0, 1.6, 8.7)	(0.1, 2.3, 7.4)	(0.0, 0.0, 11.5)	(1.4, 2.1, 3.8)
	4	(43.7, 55.2, 64.6)	(16.0, 21.5, 30.4)	(2.7, 4.1, 6.5)	(0.0, 6.4, 9.8)	(1.1, 2.9, 5.8)	(1.7, 3.8, 11.9)	(0.5, 1.4, 3.5)	(0.0, 0.0, 8.0)	(1.0, 2.0, 4.0)
	8	(36.7, 51.2, 62.8)	(12.2, 16.8, 25.1)	(2.7, 3.9, 6.5)	(0.0, 6.7, 10.4)	(0.9, 2.8, 5.9)	(4.3, 10.3, 27.6)	(1.4, 2.9, 5.8)	(0.0, 0.0, 6.1)	(0.9, 1.8, 3.8)
	20	(28.6, 44.5, 57.9)	(9.7, 14.2, 21.4)	(2.3, 3.6, 6.1)	(0.0, 6.0, 9.4)	(0.8, 2.7, 6.2)	(7.9, 19.4, 41.4)	(2.3, 4.4, 7.9)	(0.0, 0.0, 4.5)	(0.8, 1.6, 3.5)
Standard Calvo	1	(45.7, 56.3, 65.8)	(19.6, 26.9, 35.3)	(2.2, 3.6, 5.8)	(2.3, 3.7, 5.7)	(1.5, 3.2, 6.3)	(0.0, 1.2, 6.5)	(0.1, 1.5, 5.1)	(0.0, 0.0, 0.3)	(1.1, 1.9, 3.0)
	4	(44.7, 55.3, 65.1)	(15.3, 22.4, 32.8)	(2.7, 4.1, 6.3)	(4.8, 7.2, 10.9)	(1.3, 3.0, 6.4)	(1.7, 3.3, 8.1)	(0.6, 1.4, 2.8)	(0.0, 0.0, 0.2)	(0.8, 1.4, 2.5)
	8	(41.1, 51.8, 62.6)	(12.3, 18.3, 28.1)	(2.8, 4.1, 6.3)	(5.2, 7.8, 11.4)	(1.1, 2.9, 6.3)	(4.3, 9.4, 20.2)	(1.0, 2.0, 3.5)	(0.0, 0.0, 0.2)	(0.7, 1.2, 2.3)
	20	(33.9, 45.5, 57.9)	(9.9, 15.5, 24.1)	(2.5, 3.8, 5.9)	(4.4, 6.9, 10.4)	(1.0, 2.8, 6.5)	(9.0, 19.1, 36.8)	(1.3, 2.4, 4.2)	(0.0, 0.0, 0.2)	(0.6, 1.0, 2.0)
Standard SI	1	(6.3, 13.9, 26.4)	(10.2, 16.9, 26.2)	(0.2, 0.7, 1.5)	(0.6, 1.4, 3.0)	(22.9, 45.4, 68.2)	(3.4, 10.4, 25.5)	(0.1, 0.6, 2.0)	(0.0, 0.0, 0.0)	(3.8, 7.1, 12.5)
	4	(6.3, 12.8, 24.9)	(11.5, 19.2, 29.3)	(0.3, 0.9, 1.9)	(1.7, 3.4, 7.0)	(32.6, 55.2, 72.5)	(1.5, 3.7, 11.2)	(0.0, 0.2, 0.9)	(0.0, 0.0, 0.0)	(1.0, 1.9, 3.8)
	8	(6.0, 12.1, 22.3)	(10.2, 16.8, 26.3)	(0.4, 1.2, 2.3)	(2.3, 4.4, 8.5)	(37.7, 57.2, 72.5)	(2.5, 4.6, 10.4)	(0.0, 0.2, 0.6)	(0.0, 0.0, 0.0)	(0.7, 1.3, 2.7)
	20	(5.7, 11.3, 19.7)	(8.9, 15.1, 23.6)	(0.7, 1.6, 2.8)	(2.5, 4.3, 8.4)	(39.2, 57.7, 70.7)	(4.5, 7.4, 13.9)	(0.0, 0.1, 0.5)	(0.0, 0.0, 0.0)	(0.6, 1.1, 2.3)
Calvo-SI	1	(45.3, 56.3, 65.2)	(19.5, 26.9, 36.4)	(2.1, 3.6, 5.9)	(2.2, 3.7, 5.9)	(1.3, 2.6, 5.0)	(0.0, 1.4, 6.6)	(0.0, 1.7, 5.6)	(0.0, 0.0, 0.1)	(1.2, 1.9, 2.8)
	4	(42.2, 55.1, 65.4)	(15.5, 23.5, 34.1)	(2.6, 4.1, 6.3)	(4.7, 7.3, 11.4)	(1.0, 2.5, 5.2)	(1.8, 3.0, 7.6)	(0.7, 1.5, 3.3)	(0.0, 0.0, 0.1)	(0.7, 1.2, 2.1)
	8	(38.6, 51.8, 62.9)	(13.0, 19.6, 30.1)	(2.7, 4.1, 6.1)	(5.2, 7.8, 11.8)	(0.9, 2.4, 5.1)	(4.8, 9.0, 20.6)	(1.1, 2.0, 3.9)	(0.0, 0.0, 0.1)	(0.6, 1.0, 1.9)
	20	(33.0, 46.2, 58.7)	(10.9, 16.6, 26.7)	(2.4, 3.9, 5.8)	(4.6, 7.1, 10.5)	(0.8, 2.3, 5.2)	(9.6, 17.7, 33.1)	(1.3, 2.3, 4.3)	(0.0, 0.0, 0.1)	(0.5, 0.9, 1.7)

Table 11: Variance decomposition: Nominal interest rate

Model	H	technology	discount	government	investment	labor	monetary	price markup	risk premium	wage markup
Calvo (SW)	1	(0.7, 1.5, 3.1)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.1)	(0.9, 2.0, 4.1)	(92.4, 95.6, 97.4)	(0.0, 0.0, 0.0)	(0.3, 0.5, 1.4)
	4	(2.7, 5.5, 9.9)	(0.1, 0.2, 0.7)	(0.1, 0.2, 0.4)	(0.0, 0.2, 0.5)	(0.0, 0.1, 0.5)	(6.1, 11.4, 20.2)	(70.3, 79.3, 86.4)	(0.0, 0.0, 0.0)	(0.8, 1.8, 4.7)
	8	(3.1, 6.3, 11.2)	(0.1, 0.2, 0.9)	(0.1, 0.3, 0.6)	(0.0, 0.2, 0.7)	(0.0, 0.2, 0.8)	(11.5, 20.1, 33.4)	(57.5, 69.4, 79.1)	(0.0, 0.0, 0.0)	(0.8, 1.9, 5.1)
	20	(2.7, 5.8, 10.5)	(0.1, 0.3, 1.0)	(0.1, 0.3, 0.7)	(0.0, 0.2, 0.7)	(0.0, 0.4, 1.3)	(16.3, 27.5, 43.8)	(48.4, 62.1, 73.7)	(0.0, 0.0, 0.0)	(0.7, 1.7, 4.8)
Standard Calvo	1	(1.3, 2.7, 5.2)	(0.0, 0.1, 0.3)	(0.0, 0.1, 0.2)	(0.0, 0.1, 0.2)	(0.0, 0.1, 0.2)	(2.4, 4.3, 7.9)	(87.2, 91.5, 94.6)	(0.0, 0.0, 0.0)	(0.3, 0.7, 1.6)
	4	(2.7, 5.6, 10.2)	(0.1, 0.3, 0.9)	(0.1, 0.2, 0.5)	(0.1, 0.2, 0.6)	(0.0, 0.2, 0.6)	(8.0, 13.7, 23.2)	(67.9, 77.6, 84.6)	(0.0, 0.0, 0.0)	(0.6, 1.3, 2.9)
	8	(2.8, 6.1, 11.4)	(0.1, 0.4, 1.2)	(0.1, 0.3, 0.7)	(0.1, 0.3, 0.8)	(0.0, 0.3, 1.0)	(12.8, 21.4, 34.1)	(56.3, 69.0, 77.7)	(0.0, 0.0, 0.0)	(0.5, 1.3, 2.9)
	20	(2.5, 5.7, 11.2)	(0.1, 0.4, 1.4)	(0.1, 0.4, 0.9)	(0.1, 0.3, 0.9)	(0.1, 0.5, 1.5)	(18.0, 29.4, 45.1)	(45.9, 61.1, 71.7)	(0.0, 0.0, 0.0)	(0.5, 1.1, 2.7)
Standard SI	1	(3.2, 5.6, 9.3)	(0.1, 0.1, 0.2)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.1)	(0.0, 0.1, 0.3)	(0.0, 0.0, 0.1)	(37.7, 61.4, 75.9)	(0.0, 0.0, 0.0)	(19.9, 32.5, 53.2)
	4	(2.8, 5.4, 8.7)	(0.3, 0.8, 1.9)	(0.0, 0.1, 0.2)	(0.2, 0.3, 0.7)	(0.6, 2.1, 5.4)	(0.9, 1.6, 3.9)	(35.5, 58.1, 73.4)	(0.0, 0.0, 0.0)	(18.5, 30.5, 50.0)
	8	(2.5, 4.3, 6.8)	(0.3, 1.2, 3.5)	(0.2, 0.5, 1.0)	(0.4, 0.9, 2.0)	(3.6, 10.0, 19.4)	(9.6, 17.7, 33.5)	(20.6, 41.2, 60.0)	(0.0, 0.0, 0.0)	(13.5, 21.5, 31.7)
	20	(1.4, 2.4, 4.3)	(0.5, 1.8, 4.6)	(0.5, 1.2, 2.0)	(0.6, 1.5, 3.3)	(5.5, 17.4, 35.2)	(30.6, 48.8, 66.9)	(5.6, 16.3, 30.9)	(0.0, 0.0, 0.0)	(5.8, 8.4, 11.2)
Calvo-SI	1	(1.5, 2.7, 4.5)	(0.0, 0.1, 0.3)	(0.0, 0.1, 0.2)	(0.0, 0.1, 0.2)	(0.0, 0.0, 0.1)	(2.4, 4.1, 7.0)	(88.1, 92.0, 94.9)	(0.0, 0.0, 0.0)	(0.3, 0.6, 1.2)
	4	(3.0, 5.3, 8.4)	(0.1, 0.3, 0.8)	(0.1, 0.2, 0.5)	(0.0, 0.2, 0.6)	(0.0, 0.1, 0.4)	(8.2, 13.2, 21.1)	(70.6, 78.9, 85.7)	(0.0, 0.0, 0.0)	(0.4, 1.0, 2.0)
	8	(3.0, 5.4, 9.1)	(0.1, 0.3, 1.0)	(0.1, 0.3, 0.6)	(0.0, 0.2, 0.8)	(0.0, 0.2, 0.6)	(13.2, 20.5, 31.9)	(60.6, 70.5, 79.4)	(0.0, 0.0, 0.0)	(0.4, 1.0, 2.0)
	20	(2.7, 5.1, 8.8)	(0.1, 0.3, 1.1)	(0.1, 0.3, 0.8)	(0.1, 0.2, 0.8)	(0.0, 0.3, 1.1)	(17.4, 27.5, 41.5)	(50.4, 63.8, 74.7)	(0.0, 0.0, 0.0)	(0.4, 0.9, 1.9)

Table 12: Variance decomposition: Inflation

Model	H	technology	discount	government	investment	labor	monetary	price markup	risk premium	wage markup
Calvo (SW)	1	(0.0, 0.0, 0.3)	(0.2, 0.6, 2.2)	(0.0, 0.1, 0.4)	(0.0, 0.2, 0.8)	(0.0, 0.2, 0.6)	(1.3, 3.3, 7.9)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.1)	(88.5, 95.3, 98.2)
	4	(0.0, 0.1, 1.0)	(0.2, 0.7, 2.4)	(0.1, 0.2, 0.7)	(0.0, 0.5, 1.5)	(0.1, 0.3, 1.0)	(5.4, 11.6, 22.4)	(1.1, 3.8, 8.4)	(0.0, 0.0, 0.1)	(69.6, 81.6, 89.4)
	8	(0.0, 0.2, 1.1)	(0.2, 0.6, 2.2)	(0.1, 0.3, 0.7)	(0.0, 0.5, 1.4)	(0.1, 0.3, 1.0)	(8.2, 16.9, 29.7)	(1.2, 3.8, 8.4)	(0.0, 0.0, 0.1)	(62.9, 76.2, 86.4)
	20	(0.1, 0.3, 1.3)	(0.2, 0.6, 2.2)	(0.1, 0.3, 0.7)	(0.0, 0.5, 1.4)	(0.1, 0.4, 1.1)	(9.4, 19.4, 33.5)	(1.2, 3.9, 8.3)	(0.0, 0.0, 0.1)	(59.1, 73.4, 84.9)
Standard Calvo	1	(0.0, 0.1, 0.8)	(0.3, 1.0, 2.6)	(0.1, 0.2, 0.6)	(0.1, 0.4, 1.0)	(0.1, 0.3, 0.8)	(2.4, 5.5, 10.8)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.0)	(84.8, 92.2, 96.7)
	4	(0.0, 0.1, 1.0)	(0.3, 1.1, 3.1)	(0.1, 0.4, 0.9)	(0.2, 0.7, 1.8)	(0.1, 0.5, 1.3)	(7.0, 14.3, 25.1)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.0)	(69.9, 82.2, 91.2)
	8	(0.0, 0.2, 1.2)	(0.3, 1.1, 2.9)	(0.1, 0.4, 0.9)	(0.2, 0.7, 1.8)	(0.1, 0.5, 1.3)	(9.8, 18.7, 31.2)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.0)	(64.1, 77.7, 87.9)
	20	(0.1, 0.5, 1.8)	(0.3, 1.0, 2.8)	(0.1, 0.3, 0.8)	(0.2, 0.7, 1.7)	(0.1, 0.5, 1.3)	(11.5, 21.1, 34.9)	(0.0, 0.1, 0.3)	(0.0, 0.0, 0.0)	(60.7, 75.0, 85.6)
Standard SI	1	(0.0, 0.0, 0.0)	(0.1, 0.1, 0.3)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(0.1, 0.4, 1.2)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(98.4, 99.3, 99.8)
	4	(0.0, 0.0, 0.0)	(0.1, 0.1, 0.3)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.1)	(0.1, 0.5, 1.1)	(0.1, 0.2, 0.4)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(98.2, 99.2, 99.7)
	8	(0.0, 0.0, 0.1)	(0.1, 0.1, 0.3)	(0.0, 0.0, 0.0)	(0.0, 0.1, 0.1)	(0.2, 0.6, 1.3)	(0.3, 0.7, 1.6)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(96.8, 98.4, 99.2)
	20	(0.0, 0.0, 0.1)	(0.1, 0.1, 0.4)	(0.0, 0.0, 0.1)	(0.0, 0.1, 0.2)	(0.4, 0.8, 1.6)	(0.9, 1.6, 2.9)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(95.4, 97.2, 98.3)
Calvo-SI	1	(0.0, 0.1, 0.8)	(0.4, 1.2, 3.2)	(0.1, 0.2, 0.6)	(0.2, 0.4, 1.2)	(0.1, 0.2, 0.7)	(2.7, 5.2, 9.7)	(0.0, 0.0, 0.1)	(0.0, 0.0, 0.0)	(84.9, 92.2, 95.9)
	4	(0.0, 0.2, 0.8)	(0.4, 1.3, 3.5)	(0.1, 0.4, 0.9)	(0.3, 0.8, 1.9)	(0.1, 0.4, 1.0)	(7.4, 13.6, 23.3)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.0)	(71.3, 82.8, 90.3)
	8	(0.0, 0.2, 0.9)	(0.4, 1.2, 3.4)	(0.1, 0.3, 0.9)	(0.2, 0.7, 1.9)	(0.1, 0.4, 1.0)	(10.1, 18.2, 30.1)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.0)	(65.6, 78.5, 87.2)
	20	(0.2, 0.5, 1.5)	(0.4, 1.2, 3.3)	(0.1, 0.3, 0.9)	(0.3, 0.7, 1.9)	(0.1, 0.4, 1.0)	(11.6, 20.2, 33.3)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.0)	(62.5, 75.7, 85.6)

Table 13: Variance decomposition: Wage inflation

Model	H	technology	discount	government	investment	labor	monetary	price markup	risk premium	wage markup
	1	(0.0, 0.3, 0.7)	(0.1, 0.4, 1.3)	(0.0, 0.1, 0.2)	(0.0, 0.1, 0.4)	(0.0, 0.1, 0.3)	(0.3, 1.0, 2.6)	(16.6, 23.3, 31.6)	(0.0, 0.0, 0.0)	(65.1, 74.3, 81.6)
Calvo (SW)	4	(0.7, 2.7, 6.1)	(0.3, 0.9, 3.1)	(0.1, 0.2, 0.7)	(0.0, 0.6, 2.0)	(0.1, 0.4, 1.2)	(2.4, 6.6, 14.9)	(15.3, 24.4, 37.2)	(0.0, 0.0, 0.1)	(46.0, 62.6, 75.8)
	8	(2.6, 8.4, 17.6)	(0.3, 0.9, 3.1)	(0.1, 0.3, 1.0)	(0.0, 1.1, 3.0)	(0.2, 0.6, 1.8)	(6.6, 15.6, 30.3)	(14.1, 23.4, 36.2)	(0.0, 0.0, 0.2)	(29.4, 46.9, 63.8)
	20	(7.0, 20.0, 40.2)	(0.2, 0.6, 2.2)	(0.1, 0.2, 0.7)	(0.0, 1.2, 3.0)	(0.3, 0.7, 1.8)	(12.2, 26.4, 45.9)	(10.7, 18.6, 30.3)	(0.0, 0.0, 0.2)	(15.4, 27.9, 44.0)
	1	(0.0, 0.3, 0.8)	(0.1, 0.6, 1.6)	(0.0, 0.1, 0.3)	(0.1, 0.2, 0.5)	(0.0, 0.1, 0.4)	(0.4, 1.2, 2.8)	(17.2, 23.9, 31.9)	(0.0, 0.0, 0.0)	(64.5, 73.1, 80.4)
Standard Calvo	4	(0.8, 2.9, 6.4)	(0.4, 1.4, 4.1)	(0.1, 0.3, 0.9)	(0.3, 1.0, 2.4)	(0.2, 0.6, 1.5)	(3.0, 8.2, 17.2)	(17.3, 23.4, 31.3)	(0.0, 0.0, 0.0)	(47.8, 60.7, 72.0)
	8	(2.8, 8.6, 17.7)	(0.4, 1.5, 4.5)	(0.1, 0.4, 1.2)	(0.6, 1.7, 3.8)	(0.3, 0.9, 2.2)	(8.0, 19.3, 34.6)	(14.4, 20.3, 28.2)	(0.0, 0.0, 0.0)	(31.0, 44.9, 59.6)
	20	(6.0, 17.5, 35.4)	(0.3, 1.0, 3.2)	(0.1, 0.3, 1.0)	(0.8, 1.9, 4.3)	(0.4, 0.9, 2.1)	(17.0, 34.1, 53.4)	(9.0, 14.6, 22.5)	(0.0, 0.0, 0.0)	(15.9, 26.2, 41.1)
	1	(0.0, 0.0, 0.0)	(0.1, 0.1, 0.3)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(0.1, 0.4, 1.2)	(0.0, 0.0, 0.1)	(0.3, 0.8, 1.6)	(0.0, 0.0, 0.0)	(97.2, 98.5, 99.3)
Standard SI	4	(0.1, 0.3, 0.6)	(0.5, 1.2, 3.1)	(0.0, 0.0, 0.1)	(0.1, 0.3, 0.6)	(1.6, 5.1, 11.6)	(0.5, 1.0, 2.5)	(0.3, 0.7, 1.4)	(0.0, 0.0, 0.0)	(83.2, 90.9, 95.8)
	8	(0.3, 1.0, 2.2)	(0.6, 2.0, 4.7)	(0.0, 0.1, 0.3)	(0.5, 0.9, 1.8)	(4.6, 11.6, 21.4)	(3.2, 5.7, 12.4)	(0.2, 0.6, 1.2)	(0.0, 0.0, 0.0)	(61.2, 77.2, 87.9)
	20	(0.8, 2.6, 7.4)	(0.6, 1.9, 4.7)	(0.1, 0.2, 0.4)	(1.0, 1.8, 3.0)	(5.7, 12.6, 22.6)	(5.4, 8.9, 17.1)	(0.2, 0.6, 1.1)	(0.0, 0.0, 0.0)	(54.1, 69.5, 81.0)
	1	(0.0, 0.3, 0.8)	(0.2, 0.7, 1.9)	(0.0, 0.1, 0.3)	(0.1, 0.2, 0.6)	(0.0, 0.1, 0.3)	(0.4, 1.1, 2.4)	(18.4, 24.7, 35.3)	(0.0, 0.0, 0.0)	(60.4, 72.5, 79.0)
Calvo-SI	4	(1.1, 3.8, 7.8)	(0.6, 1.9, 5.2)	(0.1, 0.4, 1.0)	(0.5, 1.2, 2.6)	(0.2, 0.5, 1.3)	(3.9, 8.6, 17.5)	(18.6, 25.1, 35.2)	(0.0, 0.0, 0.0)	(40.7, 56.5, 68.9)
	8	(3.7, 11.5, 20.4)	(0.5, 1.8, 4.7)	(0.1, 0.5, 1.2)	(0.8, 2.0, 4.0)	(0.3, 0.8, 1.8)	(9.9, 20.4, 35.9)	(15.4, 21.1, 31.4)	(0.0, 0.0, 0.0)	(24.6, 39.6, 54.4)
	20	(6.8, 22.8, 39.4)	(0.3, 1.2, 3.2)	(0.1, 0.3, 0.9)	(0.8, 1.9, 3.9)	(0.4, 0.8, 1.8)	(18.8, 34.8, 51.9)	(9.4, 14.4, 21.8)	(0.0, 0.0, 0.0)	(13.0, 21.9, 36.1)

Table 14: Variance decomposition: Real wage

Model	H	technology	discount	government	investment	labor	monetary	price markup	risk premium	wage markup
	1	(38.2, 49.8, 62.3)	(5.5, 8.7, 12.5)	(11.9, 16.6, 22.5)	(0.0, 11.6, 15.6)	(2.8, 5.4, 11.4)	(2.3, 4.6, 11.4)	(0.0, 0.1, 0.4)	(0.0, 0.0, 9.6)	(0.6, 1.1, 2.0)
Calvo (SW)	4	(16.5, 29.5, 42.8)	(3.1, 6.9, 10.4)	(9.2, 12.2, 16.7)	(0.0, 13.1, 17.7)	(12.9, 19.9, 32.2)	(7.9, 14.2, 29.2)	(0.2, 0.6, 2.1)	(0.0, 0.0, 5.4)	(0.6, 1.2, 2.0)
	8	(9.5, 19.6, 30.5)	(1.8, 4.5, 7.2)	(6.5, 9.1, 12.9)	(0.1, 9.7, 13.8)	(23.9, 33.9, 46.0)	(10.6, 18.7, 33.5)	(0.5, 1.4, 3.6)	(0.0, 0.0, 3.2)	(0.7, 1.2, 2.0)
	20	(5.6, 11.7, 19.3)	(1.1, 2.7, 4.4)	(3.9, 5.8, 8.5)	(0.1, 5.9, 8.8)	(42.6, 54.8, 65.6)	(8.2, 15.7, 28.7)	(0.5, 1.3, 3.2)	(0.0, 0.0, 1.8)	(0.6, 1.1, 2.0)
	1	(37.4, 49.7, 62.1)	(6.0, 8.9, 13.0)	(11.6, 16.4, 21.5)	(9.0, 12.5, 16.7)	(2.9, 5.7, 10.0)	(2.6, 4.7, 8.2)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.2)	(0.6, 1.1, 1.9)
Standard Calvo	4	(17.8, 28.5, 41.3)	(4.3, 7.1, 11.2)	(9.1, 12.4, 16.1)	(10.8, 14.3, 19.5)	(13.2, 20.5, 29.7)	(8.3, 13.9, 21.8)	(0.0, 0.3, 1.2)	(0.0, 0.0, 0.2)	(0.7, 1.2, 2.0)
	8	(11.0, 18.9, 29.5)	(2.7, 4.7, 7.5)	(6.7, 9.4, 12.7)	(7.7, 10.8, 15.4)	(24.7, 34.4, 45.3)	(11.2, 18.5, 28.4)	(0.1, 0.4, 1.7)	(0.0, 0.0, 0.1)	(0.7, 1.1, 1.9)
	20	(6.4, 11.3, 18.9)	(1.6, 2.8, 4.7)	(4.1, 6.0, 8.6)	(4.4, 6.5, 9.6)	(42.8, 53.9, 63.9)	(9.8, 16.8, 27.1)	(0.1, 0.4, 1.5)	(0.0, 0.0, 0.1)	(0.5, 0.9, 1.5)
	1	(30.0, 38.0, 47.5)	(8.6, 11.2, 14.9)	(11.0, 14.7, 18.5)	(10.7, 14.0, 18.8)	(3.4, 6.1, 10.5)	(2.9, 4.8, 7.2)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(6.2, 9.2, 14.7)
Standard SI	4	(15.2, 21.4, 29.2)	(8.5, 12.6, 17.9)	(8.7, 11.4, 15.0)	(12.2, 17.1, 24.3)	(8.3, 17.1, 31.7)	(10.0, 15.0, 22.3)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(1.6, 2.6, 4.3)
	8	(9.8, 14.6, 21.5)	(5.4, 9.4, 14.5)	(7.3, 10.8, 15.1)	(8.9, 14.2, 22.2)	(8.9, 23.7, 46.6)	(13.6, 22.1, 34.1)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(1.0, 1.6, 2.6)
	20	(6.1, 11.5, 17.3)	(3.2, 7.3, 12.3)	(5.2, 11.5, 20.2)	(5.8, 11.3, 19.2)	(8.9, 32.5, 64.9)	(9.2, 20.8, 34.1)	(0.0, 0.0, 0.0)	(0.0, 0.0, 0.0)	(0.7, 1.2, 2.1)
	1	(36.3, 51.3, 63.9)	(6.0, 9.1, 13.1)	(11.9, 15.8, 20.0)	(8.8, 12.3, 16.1)	(2.8, 4.9, 9.6)	(2.4, 4.7, 9.1)	(0.0, 0.1, 0.5)	(0.0, 0.0, 0.1)	(0.3, 0.6, 1.1)
Calvo-SI	4	(15.9, 29.5, 43.6)	(4.4, 7.5, 10.8)	(9.3, 12.1, 15.1)	(10.7, 14.4, 18.6)	(12.6, 18.8, 28.1)	(8.8, 14.4, 24.6)	(0.1, 0.4, 1.4)	(0.0, 0.0, 0.1)	(0.3, 0.6, 1.1)
	8	(9.8, 19.7, 32.1)	(2.9, 5.0, 7.7)	(6.7, 9.3, 12.0)	(7.7, 10.8, 14.0)	(23.6, 32.0, 43.6)	(12.5, 19.4, 30.8)	(0.1, 0.5, 1.8)	(0.0, 0.0, 0.1)	(0.3, 0.6, 1.0)
	20	(6.0, 12.5, 21.1)	(1.7, 3.1, 4.9)	(4.4, 6.1, 8.1)	(4.5, 6.8, 9.1)	(41.7, 52.1, 63.4)	(10.4, 16.8, 27.7)	(0.1, 0.5, 1.5)	(0.0, 0.0, 0.0)	(0.3, 0.5, 0.8)

Table 15: Variance decomposition: Employment

Appendix B: Impulse responses for baseline model J=12

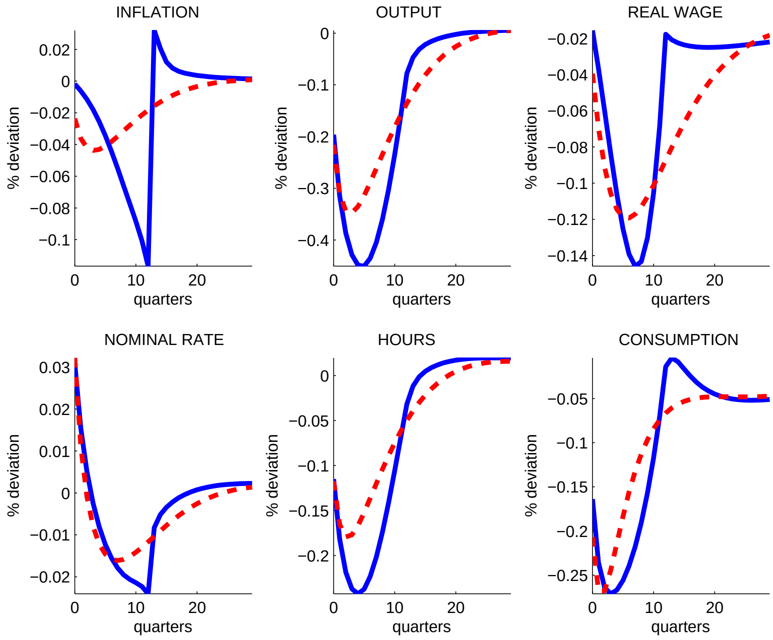

Figure 11: Impulse response to monetary shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

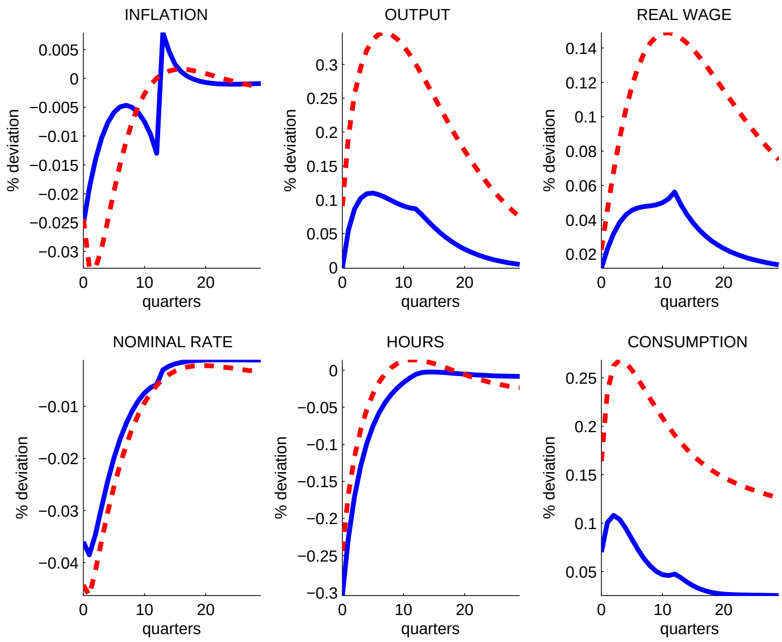

Figure 12: Impulse response to technology shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

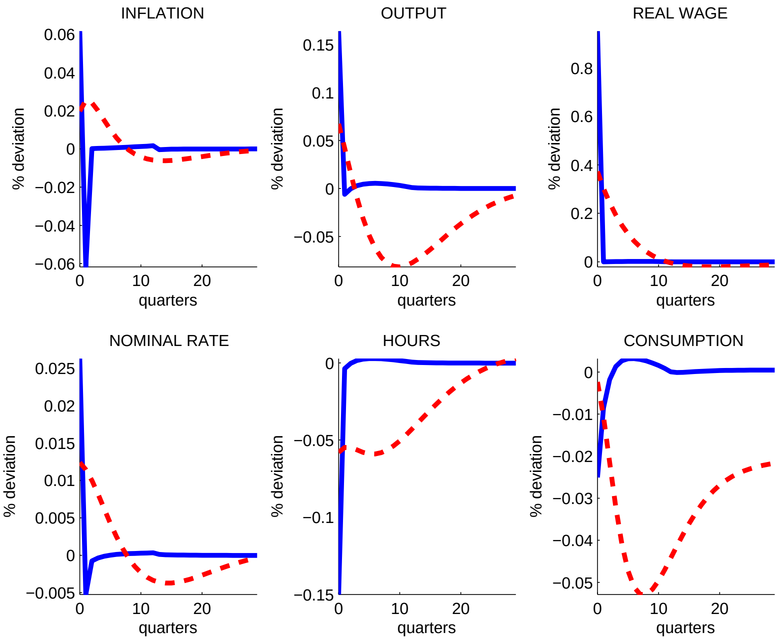

Figure 13: Impulse response to wage markup shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

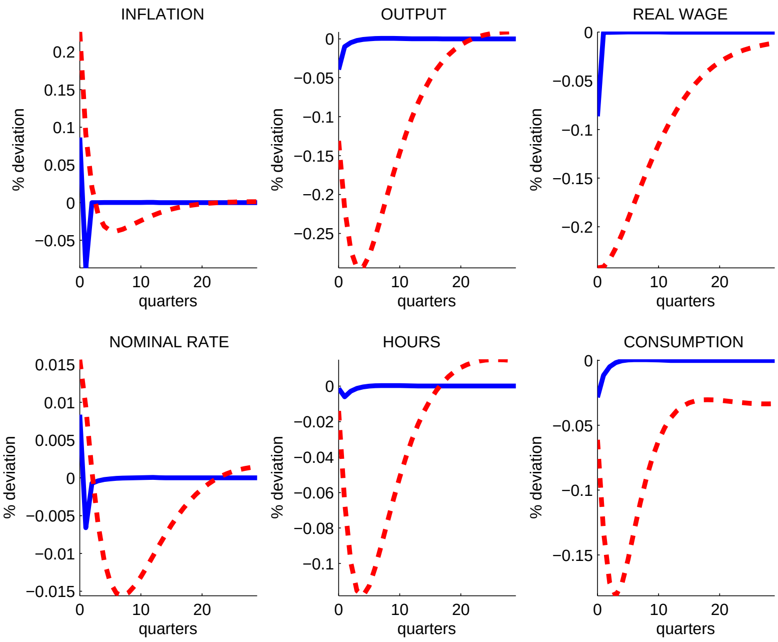

Figure 14: Impulse response to price markup shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

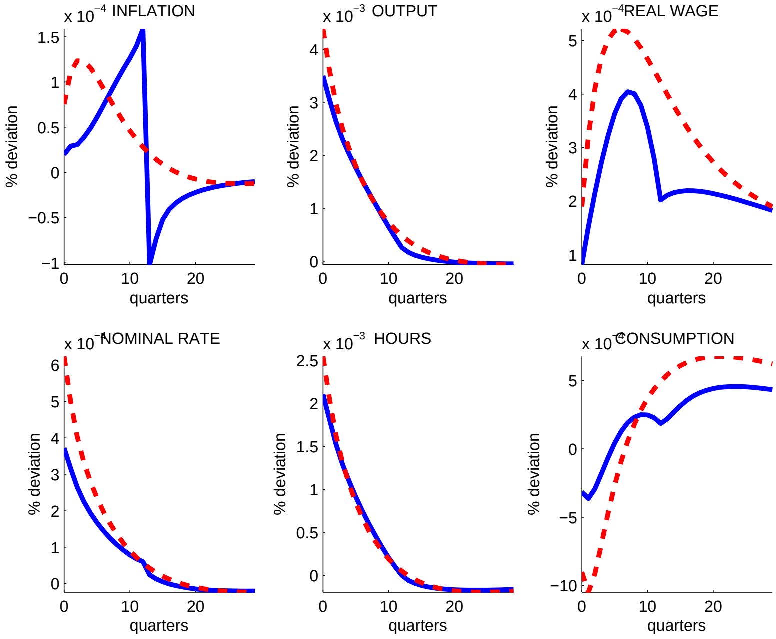

Figure 15: Impulse response to equity price shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

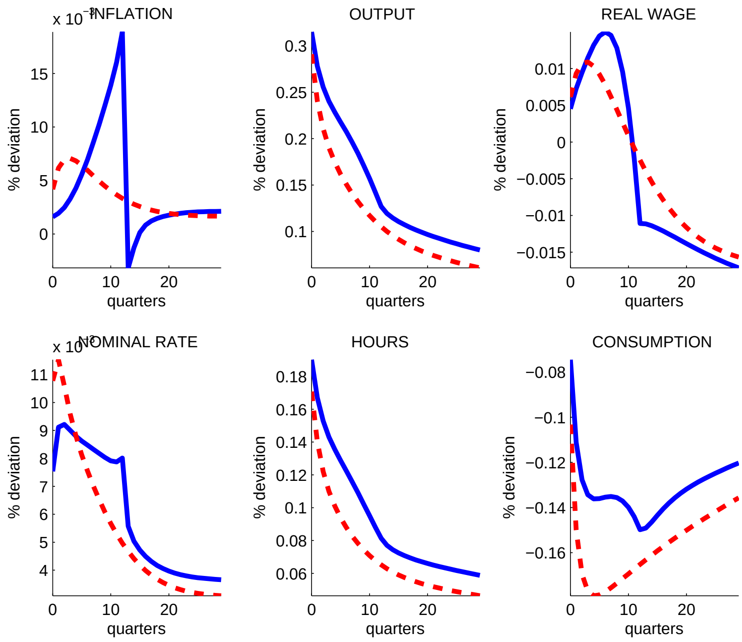

Figure 16: Impulse response to government spending shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

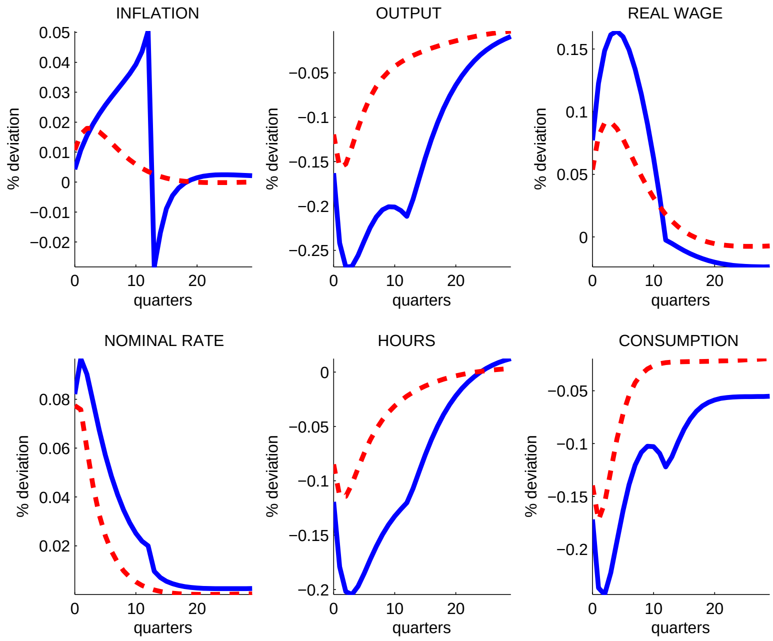

Figure 17: Impulse response to labor supply shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

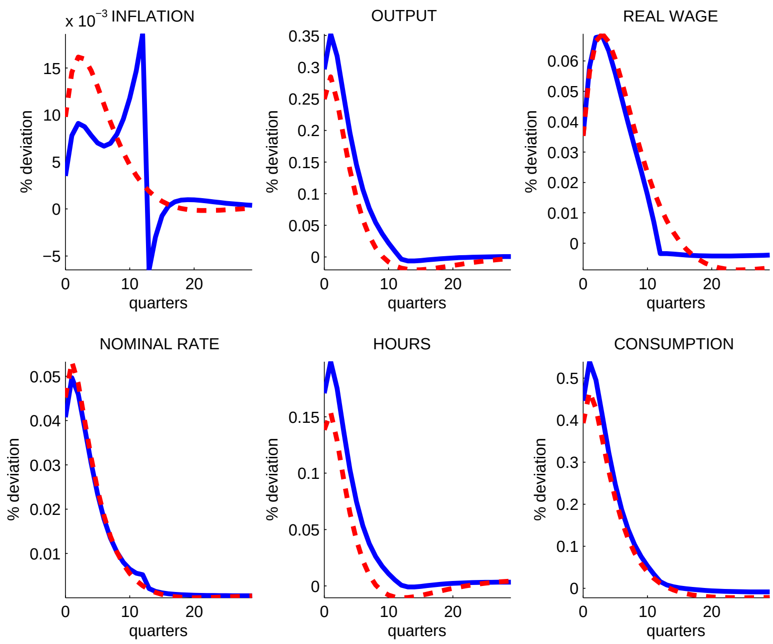

Figure 18: Impulse response to preference shock. Blue solid line - sticky information model J=12, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

Appendix C: Impulse responses for baseline model J=24

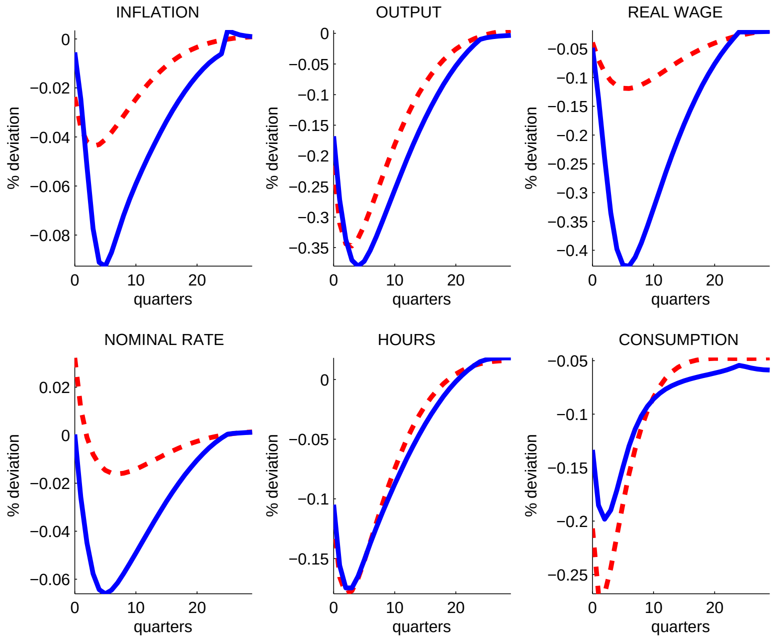

Figure 19: Impulse response to monetary shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

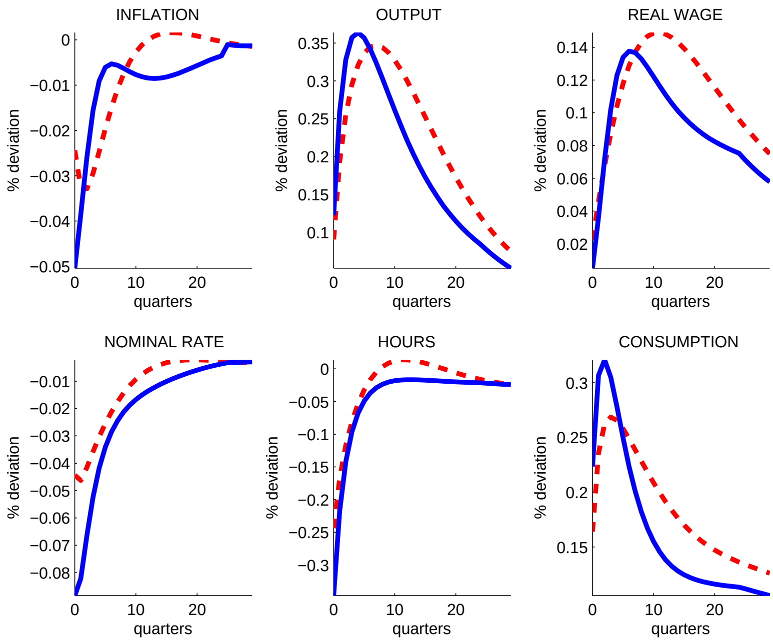

Figure 20: Impulse response to technology shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

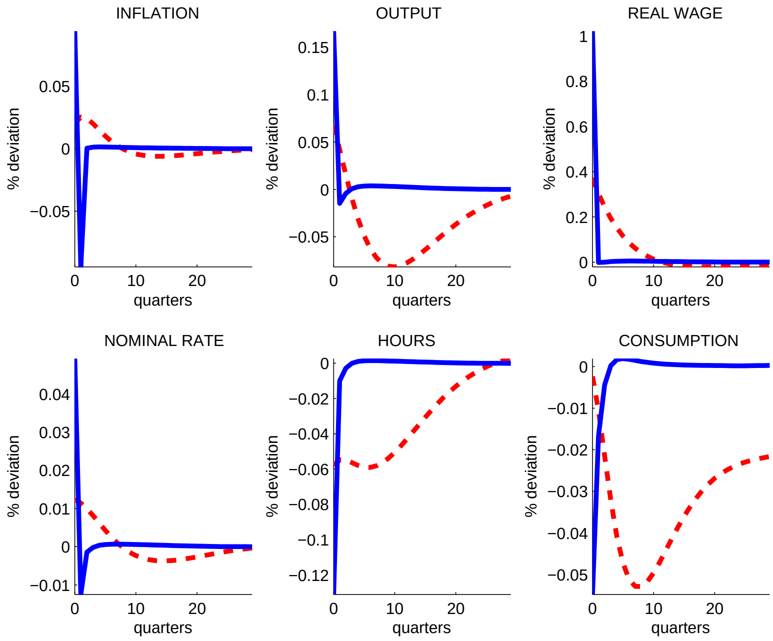

Figure 21: Impulse response to wage markup shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

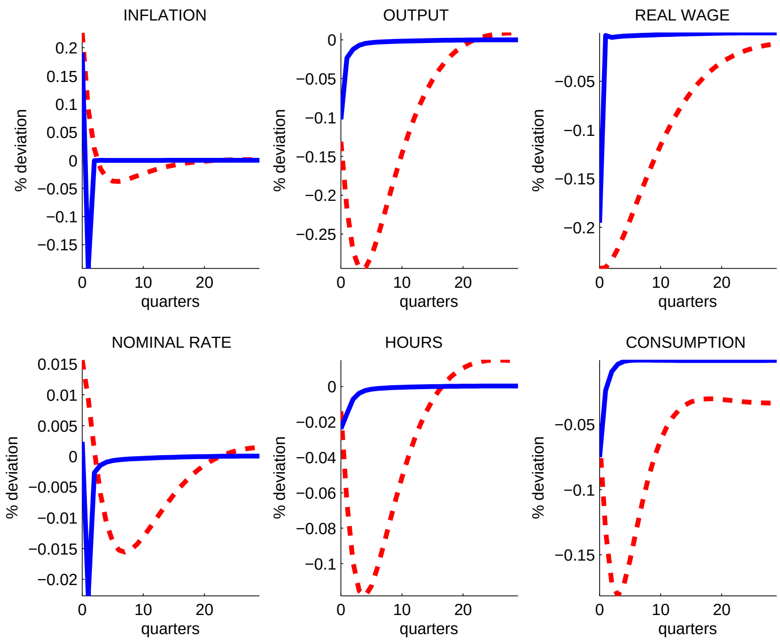

Figure 22: Impulse response to price markup shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

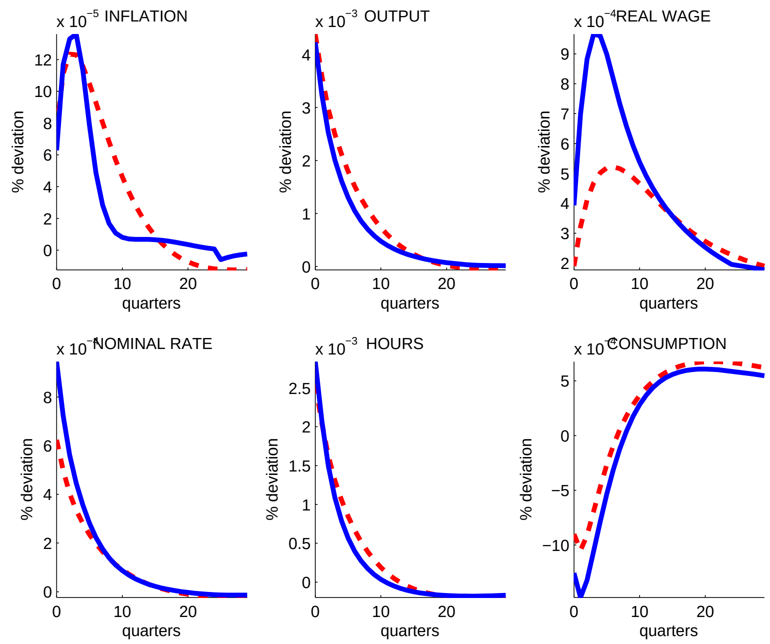

Figure 23: Impulse response to equity price shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

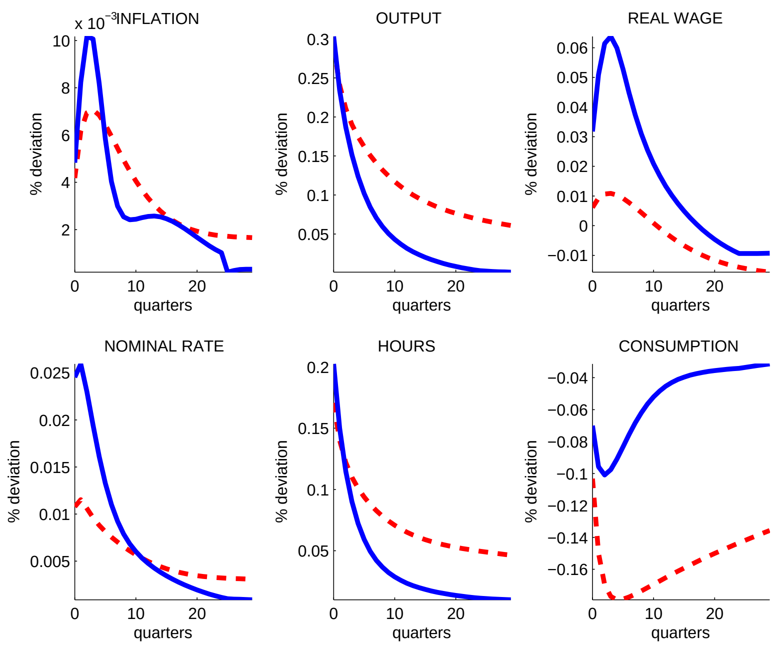

Figure 24: Impulse response to government spending shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

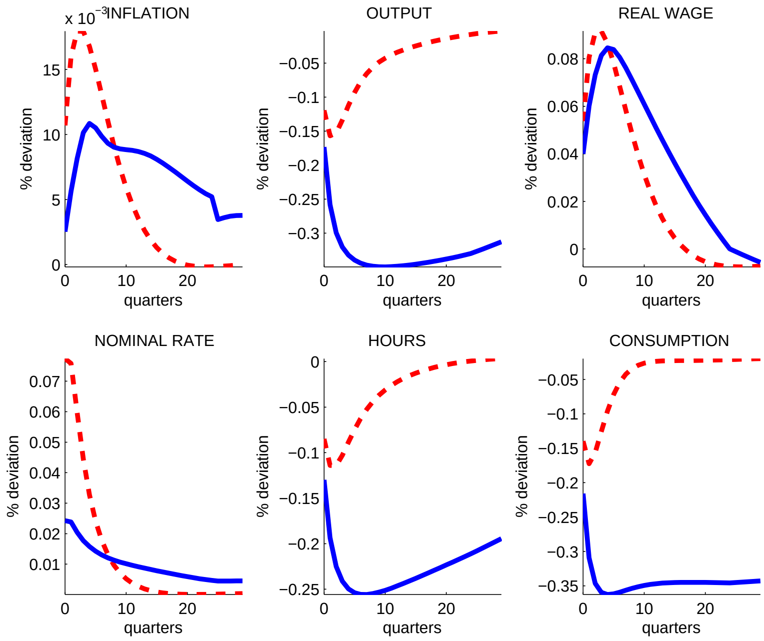

Figure 25: Impulse response to labor supply shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

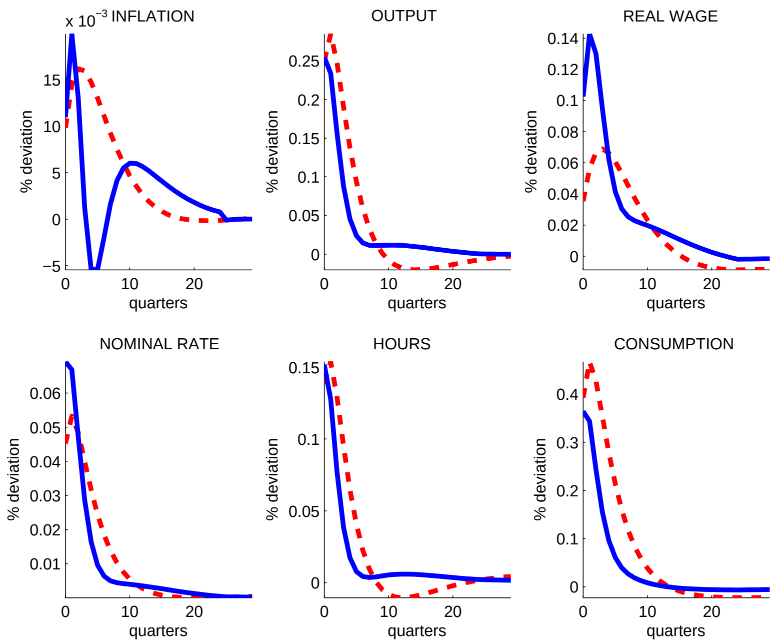

Figure 26: Impulse response to preference shock. Blue solid line - sticky information model J=24, red dashed line - Calvo model. Impulse responses are calculated at the posterior mode.

Appendix D: Posterior parameter distribution

		Standard Calvo	
parameter		mode	90% post. interval
investment adj. cost	S''	2.295	(1.064, 2.794, 4.382)
consumption utility	σ_c	1.169	(0.755, 1.187, 1.572)
habit persistence	h	0.459	(0.337, 0.473, 0.608)
Calvo wages	ξ_w	0.668	(0.617, 0.686, 0.764)
labor utility	σ_l	2.485	(1.790, 2.699, 3.641)
Calvo prices	ξ_p	0.887	(0.869, 0.889, 0.911)
capital util. adj. cost	ϕ	0.351	(0.242, 0.353, 0.460)
fixed cost	ψ	1.476	(1.327, 1.502, 1.671)
Calvo employment	ξ_L	0.711	(0.646, 0.706, 0.760)
response to inflation	r_π	1.680	(1.510, 1.674, 1.850)
response to diff. inflation	$r_{d\pi}$	0.143	(0.085, 0.154, 0.222)
interest rate smoothing	ρ	0.964	(0.933, 0.958, 0.982)
response to output gap	r_y	0.088	(0.012, 0.084, 0.157)
response to diff. output gap	r_{dy}	0.194	(0.164, 0.198, 0.232)
persistence techn. shock	ρ_a	0.900	(0.866, 0.904, 0.942)
persistence preference shock	ρ_b	0.517	(0.373, 0.518, 0.666)
persistence gov. spending. shock	ρ_g	0.903	(0.862, 0.903, 0.946)
persistence labor supply shock	ρ_L	0.990	(0.978, 0.987, 0.997)
persistence investment shock	ρ_I	0.246	(0.153, 0.252, 0.355)
productivity shock	σ_a	0.439	(0.360, 0.439, 0.524)
preference shock	σ_b	0.142	(0.106, 0.144, 0.181)
gov. spending shock	σ_g	0.311	(0.281, 0.319, 0.356)
labor supply shock	σ_L	1.112	(0.855, 1.217, 1.558)
equity premium shock	σ_q	0.093	(0.046, 0.177, 0.336)
monetary shock	σ_R	0.051	(0.038, 0.057, 0.076)
investment shock	σ_I	0.568	(0.488, 0.573, 0.661)
inflation equation shock	σ_π	0.514	(0.347, 0.565, 0.764)
wage equation shock	σ_w	0.456	(0.275, 0.607, 0.988)

Table 16: Posterior distribution: Standard Calvo model without indexation

		Calvo no price markup shock		Calvo no wage markup shock	
parameter		mode	90% post. interval	mode	90% post. interval
investment adj. cost	S''	5.495	(3.804, 5.707, 7.645)	6.143	(4.430, 6.403, 8.251)
consumption utility	σ_c	0.986	(0.662, 1.108, 1.538)	1.180	(0.812, 1.308, 1.762)
habit persistence	h	0.692	(0.484, 0.661, 0.850)	0.777	(0.604, 0.746, 0.866)
Calvo wages	ξ_w	0.770	(0.725, 0.773, 0.821)	0.639	(0.512, 0.620, 0.720)
labor utility	σ_l	1.385	(0.897, 2.030, 3.128)	1.595	(0.844, 1.929, 3.006)
Calvo prices	ξ_p	0.619	(0.573, 0.618, 0.665)	0.854	(0.835, 0.857, 0.880)
indexation wages	γ_w	0.946	(0.754, 0.871, 0.996)	0.418	(0.195, 0.428, 0.654)
indexation prices	γ_p	0.087	(0.035, 0.109, 0.174)	0.507	(0.374, 0.515, 0.662)
capital util. adj. cost	ϕ	0.365	(0.269, 0.371, 0.473)	0.332	(0.234, 0.341, 0.445)
fixed cost	ψ	1.187	(0.993, 1.183, 1.369)	1.827	(1.667, 1.824, 1.987)
Calvo employment	ξ_L	0.849	(0.820, 0.846, 0.873)	0.115	(0.047, 0.132, 0.214)
response to inflation	r_π	1.665	(1.477, 1.661, 1.827)	1.608	(1.436, 1.609, 1.780)
response to diff. inflation	$r_{d\pi}$	0.304	(0.227, 0.305, 0.384)	0.222	(0.151, 0.227, 0.302)
interest rate smoothing	ρ	0.873	(0.826, 0.867, 0.908)	0.856	(0.803, 0.856, 0.905)
response to output gap	r_y	0.105	(0.041, 0.108, 0.172)	-0.012	(-0.047, 0.000, 0.043)
response to diff. output gap	r_{dy}	0.006	(-0.036, 0.002, 0.035)	0.041	(0.015, 0.045, 0.074)
persistence techn. shock	ρ_a	0.898	(0.794, 0.878, 0.960)	0.900	(0.852, 0.897, 0.943)
persistence preference shock	ρ_b	0.438	(0.295, 0.463, 0.624)	0.522	(0.339, 0.532, 0.730)
persistence gov. spending. shock	ρ_g	0.886	(0.834, 0.883, 0.935)	0.953	(0.899, 0.945, 0.991)
persistence labor supply shock	ρ_L	0.999	(0.998, 0.998, 0.999)	0.539	(0.344, 0.568, 0.787)
persistence investment shock	ρ_I	0.349	(0.228, 0.354, 0.472)	0.456	(0.278, 0.452, 0.622)
productivity shock	σ_a	0.449	(0.389, 0.484, 0.579)	0.268	(0.239, 0.279, 0.314)
preference shock	σ_b	0.169	(0.126, 0.166, 0.208)	0.144	(0.094, 0.144, 0.193)
gov. spending shock	σ_g	0.294	(0.265, 0.302, 0.339)	0.320	(0.284, 0.326, 0.364)
labor supply shock	σ_L	1.036	(0.852, 1.365, 1.877)	8.595	(3.413, 9.714, 16.718)
equity premium shock	σ_q	0.093	(0.045, 0.293, 0.844)	0.093	(0.048, 0.169, 0.335)
monetary shock	σ_R	0.126	(0.111, 0.129, 0.147)	0.115	(0.103, 0.119, 0.134)
investment shock	σ_I	0.501	(0.429, 0.512, 0.597)	0.438	(0.343, 0.449, 0.547)
inflation equation shock	σ_π			0.326	(0.242, 0.351, 0.453)
wage equation shock	σ_w	0.900	(0.552, 1.327, 2.063)		

Table 17: Posterior distribution: Calvo model estimated without price markup shock, Calvo model estimated without wage markup shock

parameter		SI prices, Calvo wages		SI prices, Calvo wages without price markup shock	
		mode	90% post. interval	mode	90% post. interval
investment adj. cost	S''	4.853	(2.792, 4.613, 6.500)	5.439	(3.757, 5.701, 7.547)
consumption utility	σ_c	1.593	(1.047, 1.546, 2.003)	0.804	(0.474, 0.967, 1.422)
habit persistence	h	0.407	(0.315, 0.443, 0.553)	0.760	(0.526, 0.696, 0.876)
Calvo wages	ξ_w	0.655	(0.614, 0.696, 0.788)	0.830	(0.783, 0.830, 0.873)
labor utility	σ_l	2.268	(1.806, 2.774, 3.724)	1.331	(0.734, 1.818, 2.770)
capital util. adj. cost	ϕ	0.298	(0.203, 0.308, 0.426)	0.343	(0.242, 0.348, 0.457)
fixed cost	ψ	1.714	(1.589, 1.749, 1.912)	1.284	(1.043, 1.228, 1.417)
Calvo employment	ξ_L	0.695	(0.521, 0.645, 0.758)	0.853	(0.823, 0.849, 0.875)
response to inflation	r_π	1.634	(1.461, 1.638, 1.822)	1.642	(1.468, 1.632, 1.800)
response to diff. inflation	$r_{d\pi}$	0.142	(0.086, 0.150, 0.214)	0.275	(0.201, 0.275, 0.356)
interest rate smoothing	ρ	0.977	(0.962, 0.976, 0.988)	0.847	(0.798, 0.843, 0.891)
response to output gap	r_y	0.124	(0.052, 0.115, 0.185)	0.085	(0.037, 0.103, 0.166)
response to diff. output gap	r_{dy}	0.221	(0.183, 0.228, 0.270)	-0.025	(-0.054, -0.022, 0.008)
information rigidity prices	ω_0^p	0.999	(0.999, 0.999, 0.999)	0.603	(0.527, 0.597, 0.667)
persistence techn. shock	ρ_a	0.890	(0.855, 0.890, 0.928)	0.781	(0.705, 0.789, 0.861)
persistence preference shock	ρ_b	0.611	(0.445, 0.588, 0.728)	0.402	(0.282, 0.440, 0.601)
persistence gov. spending. shock	ρ_g	0.898	(0.858, 0.904, 0.952)	0.890	(0.835, 0.886, 0.941)
persistence labor supply shock	ρ_L	0.983	(0.970, 0.979, 0.991)	0.999	(0.999, 0.999, 0.999)
persistence investment shock	ρ_I	0.269	(0.159, 0.269, 0.366)	0.324	(0.195, 0.322, 0.447)
productivity shock	σ_a	0.415	(0.300, 0.399, 0.497)	0.483	(0.395, 0.493, 0.585)
preference shock	σ_b	0.119	(0.090, 0.127, 0.163)	0.180	(0.138, 0.175, 0.211)
gov. spending shock	σ_g	0.313	(0.279, 0.315, 0.349)	0.300	(0.268, 0.306, 0.339)
labor supply shock	σ_L	1.593	(1.345, 1.854, 2.369)	0.976	(0.670, 1.216, 1.647)
equity premium shock	σ_q	0.093	(0.049, 0.219, 0.496)	0.093	(0.051, 0.204, 0.498)
monetary shock	σ_R	0.038	(0.030, 0.042, 0.054)	0.121	(0.109, 0.125, 0.141)
investment shock	σ_I	0.547	(0.476, 0.561, 0.644)	0.516	(0.442, 0.524, 0.605)
inflation equation shock	σ_π	0.050	(0.041, 0.054, 0.067)		
wage equation shock	σ_w	0.513	(0.356, 0.936, 1.753)	1.594	(0.806, 2.164, 3.496)

Table 18: Posterior distribution: Mixed model - sticky information prices and Calvo wages, Mixed model - sticky information prices and Calvo wages estimated without price markup shock

parameter		Calvo prices, SI wages		Calvo prices, SI wages without wage markup shock	
		mode	90% post. interval	mode	90% post. interval
investment adj. cost	S''	3.476	(2.166, 3.808, 5.523)	4.847	(2.996, 4.963, 6.870)
consumption utility	σ_c	1.126	(0.675, 1.130, 1.524)	1.109	(0.745, 1.118, 1.486)
habit persistence	h	0.564	(0.444, 0.572, 0.692)	0.377	(0.291, 0.392, 0.509)
labor utility	σ_l	3.823	(3.169, 3.920, 4.721)	2.417	(1.790, 2.559, 3.306)
Calvo prices	ξ_p	0.874	(0.849, 0.874, 0.898)	0.838	(0.811, 0.838, 0.869)
capital util. adj. cost	ϕ	0.348	(0.249, 0.354, 0.462)	0.360	(0.248, 0.365, 0.478)
fixed cost	ψ	1.637	(1.493, 1.658, 1.824)	1.869	(1.716, 1.859, 2.018)
Calvo employment	ξ_L	0.671	(0.574, 0.651, 0.733)	0.213	(0.089, 0.238, 0.377)
response to inflation	r_π	1.664	(1.493, 1.665, 1.824)	1.568	(1.417, 1.587, 1.750)
response to diff. inflation	$r_{d\pi}$	0.150	(0.084, 0.158, 0.227)	0.311	(0.233, 0.313, 0.387)
interest rate smoothing	ρ	0.929	(0.893, 0.923, 0.954)	0.806	(0.758, 0.806, 0.849)
response to output gap	r_y	0.060	(0.003, 0.064, 0.126)	0.091	(0.033, 0.091, 0.142)
response to diff. output gap	r_{dy}	0.188	(0.156, 0.190, 0.221)	0.175	(0.135, 0.176, 0.218)
information rigidity wages	ω_0^w	0.530	(0.476, 0.535, 0.593)	0.076	(0.056, 0.080, 0.105)
persistence techn. shock	ρ_a	0.917	(0.880, 0.913, 0.946)	0.912	(0.864, 0.908, 0.949)
persistence preference shock	ρ_b	0.409	(0.269, 0.419, 0.554)	0.757	(0.632, 0.732, 0.832)
persistence gov. spending. shock	ρ_g	0.916	(0.875, 0.918, 0.958)	0.963	(0.920, 0.955, 0.989)
persistence labor supply shock	ρ_L	0.985	(0.969, 0.981, 0.994)	0.988	(0.973, 0.985, 0.997)
persistence investment shock	ρ_I	0.239	(0.142, 0.245, 0.352)	0.271	(0.159, 0.277, 0.396)
productivity shock	σ_a	0.406	(0.320, 0.404, 0.479)	0.270	(0.234, 0.280, 0.323)
preference shock	σ_b	0.161	(0.125, 0.164, 0.201)	0.076	(0.057, 0.085, 0.110)
gov. spending shock	σ_g	0.317	(0.284, 0.323, 0.358)	0.320	(0.285, 0.325, 0.365)
labor supply shock	σ_L	1.544	(1.270, 1.649, 2.025)	1.237	(1.000, 1.300, 1.607)
equity premium shock	σ_q	0.093	(0.055, 0.146, 0.248)	0.093	(0.051, 0.181, 0.341)
monetary shock	σ_R	0.072	(0.058, 0.078, 0.099)	0.132	(0.117, 0.135, 0.154)
investment shock	σ_I	0.553	(0.475, 0.559, 0.640)	0.532	(0.450, 0.539, 0.630)
inflation equation shock	σ_π	0.496	(0.336, 0.525, 0.707)	0.294	(0.203, 0.305, 0.408)
wage equation shock	σ_w	0.083	(0.063, 0.093, 0.121)		

Table 19: Posterior distribution: Mixed model - Calvo prices and sticky information wages, Mixed model - Calvo prices and sticky information wages estimated without wage markup shock

		Nested Calvo - SI	
parameter		mode	90% post. interval
investment adj. cost	S''	2.169	(1.024, 2.665, 4.178)
consumption utility	σ_c	1.161	(0.730, 1.142, 1.562)
habit persistence	h	0.457	(0.353, 0.490, 0.633)
Calvo wages	ξ_w	0.664	(0.598, 0.662, 0.726)
labor utility	σ_l	2.553	(1.878, 2.760, 3.597)
Calvo prices	ξ_p	0.885	(0.864, 0.883, 0.903)
capital util. adj. cost	ϕ	0.349	(0.252, 0.357, 0.460)
fixed cost	ψ	1.484	(1.337, 1.511, 1.673)
Calvo employment	ξ_L	0.707	(0.631, 0.692, 0.752)
response to inflation	r_π	1.680	(1.517, 1.677, 1.827)
response to diff. inflation	$r_{d\pi}$	0.147	(0.091, 0.159, 0.224)
interest rate smoothing	ρ	0.964	(0.936, 0.957, 0.979)
response to output gap	r_y	0.092	(0.022, 0.096, 0.163)
response to diff. output gap	r_{dy}	0.196	(0.163, 0.197, 0.229)
information rigidity prices	ω_0^p	0.984	(0.564, 0.854, 1.000)
information rigidity wages	ω_0^w	0.822	(0.601, 0.784, 0.994)
fraction of Calvo agents, prices	α^p	0.990	(0.982, 0.991, 1.000)
fraction of Calvo agents, wages	α^w	0.929	(0.830, 0.906, 0.985)
persistence techn. shock	ρ_a	0.898	(0.859, 0.898, 0.940)
persistence preference shock	ρ_b	0.511	(0.360, 0.507, 0.655)
persistence gov. spending. shock	ρ_g	0.904	(0.864, 0.904, 0.945)
persistence labor supply shock	ρ_L	0.989	(0.975, 0.986, 0.997)
persistence investment shock	ρ_I	0.243	(0.153, 0.252, 0.355)
productivity shock	σ_a	0.432	(0.361, 0.442, 0.529)
preference shock	σ_b	0.144	(0.115, 0.149, 0.189)
gov. spending shock	σ_g	0.312	(0.279, 0.316, 0.352)
labor supply shock	σ_L	1.116	(0.859, 1.208, 1.552)
equity premium shock	σ_q	0.093	(0.046, 0.133, 0.220)
monetary shock	σ_R	0.051	(0.039, 0.058, 0.077)
investment shock	σ_I	0.573	(0.496, 0.572, 0.651)
inflation equation shock	σ_π	0.485	(0.323, 0.488, 0.655)
wage equation shock	σ_w	0.439	(0.244, 0.470, 0.688)

Table 20: Posterior distribution, parsimonious parameterization: nested Calvo - sticky information model

parameter		Standard SI (J=12)		Nested Calvo - SI	
		mode	90% post. interval	mode	90% post. interval
investment adj. cost	S''	4.297	(2.916, 4.750, 6.779)	2.365	(0.906, 2.043, 3.551)
consumption utility	σ_c	1.350	(0.885, 1.307, 1.710)	1.149	(0.675, 1.110, 1.539)
habit persistence	h	0.471	(0.365, 0.492, 0.613)	0.462	(0.339, 0.478, 0.602)
Calvo wages	ξ_w			0.691	(0.619, 0.684, 0.743)
labor utility	σ_l	3.584	(2.611, 3.585, 4.470)	2.550	(1.672, 2.646, 3.563)
Calvo prices	ξ_p			0.883	(0.864, 0.890, 0.918)
capital util. adj. cost	ϕ	0.364	(0.255, 0.374, 0.476)	0.346	(0.234, 0.342, 0.453)
fixed cost	ψ	1.744	(1.605, 1.784, 1.944)	1.507	(1.373, 1.542, 1.724)
Calvo employment	ξ_L	0.625	(0.291, 0.509, 0.693)	0.702	(0.586, 0.664, 0.755)
response to inflation	r_π	1.628	(1.454, 1.642, 1.801)	1.680	(1.523, 1.686, 1.857)
response to diff. inflation	$r_{d\pi}$	0.145	(0.104, 0.157, 0.218)	0.145	(0.087, 0.161, 0.235)
interest rate smoothing	ρ	0.959	(0.922, 0.947, 0.971)	0.963	(0.941, 0.962, 0.980)
response to output gap	r_y	0.088	(0.026, 0.077, 0.127)	0.101	(0.035, 0.096, 0.165)
response to diff. output gap	r_{dy}	0.187	(0.149, 0.182, 0.218)	0.199	(0.168, 0.202, 0.236)
information rigidity prices	ω_0^p	0.004	(0.001, 0.010, 0.020)	0.000	(0.000, 0.000, 0.000)
information rigidity prices	ω_1^p	0.994	(0.970, 0.982, 0.997)	0.974	(0.800, 0.910, 0.996)
information rigidity wages	ω_0^w	0.107	(0.103, 0.272, 0.410)	0.016	(0.003, 0.031, 0.067)
information rigidity wages	ω_1^w	0.997	(0.983, 0.990, 0.996)	0.503	(0.302, 0.568, 0.820)
fraction of Calvo agents, prices	α^p			0.855	(0.696, 0.825, 0.971)
fraction of Calvo agents, wages	α^w			0.643	(0.500, 0.719, 0.967)
persistence techn. shock	ρ_a	0.881	(0.832, 0.876, 0.918)	0.901	(0.858, 0.899, 0.949)
persistence preference shock	ρ_b	0.570	(0.409, 0.580, 0.734)	0.512	(0.329, 0.485, 0.638)
persistence gov. spending. shock	ρ_g	0.911	(0.881, 0.931, 0.991)	0.903	(0.857, 0.901, 0.945)
persistence labor supply shock	ρ_L	0.975	(0.920, 0.958, 0.986)	0.989	(0.979, 0.987, 0.995)
persistence investment shock	ρ_I	0.236	(0.152, 0.245, 0.343)	0.238	(0.175, 0.535, 0.933)
productivity shock	σ_a	0.379	(0.262, 0.349, 0.432)	0.427	(0.332, 0.418, 0.495)
preference shock	σ_b	0.134	(0.091, 0.135, 0.178)	0.144	(0.111, 0.151, 0.191)
gov. spending shock	σ_g	0.311	(0.279, 0.317, 0.354)	0.313	(0.280, 0.318, 0.351)
labor supply shock	σ_L	1.935	(1.623, 2.300, 2.938)	1.146	(0.809, 1.176, 1.610)
equity premium shock	σ_q	0.093	(0.046, 0.147, 0.261)	0.093	(0.056, 0.887, 1.821)
monetary shock	σ_R	0.040	(0.033, 0.050, 0.069)	0.049	(0.038, 0.053, 0.068)
investment shock	σ_I	0.566	(0.472, 0.568, 0.646)	0.566	(0.007, 0.294, 0.610)
inflation equation shock	σ_π	0.053	(0.024, 0.063, 0.104)	0.561	(0.356, 0.744, 1.109)
wage equation shock	σ_w	0.125	(0.099, 0.151, 0.199)	0.791	(0.336, 0.723, 1.138)

Table 21: Posterior distribution, intermediate parameterization I: standard sticky information model and nested Calvo - sticky information model

		Standard SI (J=12)		Nested Calvo - SI	
parameter		mode	90% post. interval	mode	90% post. interval
investment adj. cost	S''	2.976	(1.660, 3.166, 4.717)	2.316	(0.693, 1.997, 3.680)
consumption utility	σ_c	1.355	(0.951, 1.380, 1.799)	1.157	(0.689, 1.089, 1.578)
habit persistence	h	0.489	(0.364, 0.487, 0.592)	0.462	(0.327, 0.463, 0.604)
Calvo wages	ξ_w			0.685	(0.620, 0.684, 0.755)
labor utility	σ_l	3.515	(2.687, 3.475, 4.265)	2.513	(1.656, 2.581, 3.456)
Calvo prices	ξ_p			0.884	(0.861, 0.885, 0.903)
capital util. adj. cost	ϕ	0.368	(0.273, 0.374, 0.487)	0.347	(0.256, 0.361, 0.464)
fixed cost	ψ	1.534	(1.378, 1.562, 1.746)	1.497	(1.365, 1.522, 1.701)
Calvo employment	ξ_L	0.637	(0.550, 0.625, 0.699)	0.705	(0.588, 0.672, 0.746)
response to inflation	r_π	1.639	(1.453, 1.626, 1.809)	1.680	(1.524, 1.678, 1.840)
response to diff. inflation	$r_{d\pi}$	0.163	(0.110, 0.179, 0.243)	0.146	(0.104, 0.168, 0.228)
interest rate smoothing	ρ	0.937	(0.884, 0.924, 0.965)	0.962	(0.938, 0.961, 0.983)
response to output gap	r_y	0.081	(0.011, 0.081, 0.159)	0.094	(0.031, 0.087, 0.154)
response to diff. output gap	r_{dy}	0.193	(0.161, 0.193, 0.228)	0.197	(0.168, 0.204, 0.239)
information rigidity prices	ω_0^p	0.020	(0.014, 0.050, 0.091)	0.001	(0.000, 0.018, 0.039)
information rigidity prices	ω_1^p	0.083	(0.101, 0.289, 0.482)	0.056	(0.003, 0.208, 0.445)
information rigidity prices	ω_5^p	0.057	(0.053, 0.224, 0.373)	0.100	(0.027, 0.294, 0.547)
information rigidity wages	ω_0^w	0.130	(0.142, 0.396, 0.647)	0.010	(0.000, 0.029, 0.063)
information rigidity wages	ω_1^w	0.020	(0.020, 0.077, 0.129)	0.137	(0.053, 0.343, 0.601)
information rigidity wages	ω_5^w	0.000	(0.000, 0.000, 0.000)	0.003	(0.060, 0.129, 0.206)
fraction of Calvo agents, prices	α^p			0.927	(0.860, 0.930, 0.995)
fraction of Calvo agents, wages	α^w			0.702	(0.676, 0.819, 0.975)
persistence techn. shock	ρ_a	0.863	(0.821, 0.861, 0.908)	0.898	(0.846, 0.892, 0.930)
persistence preference shock	ρ_b	0.436	(0.318, 0.441, 0.559)	0.511	(0.315, 0.474, 0.616)
persistence gov. spending. shock	ρ_g	0.922	(0.880, 0.920, 0.961)	0.903	(0.856, 0.897, 0.938)
persistence labor supply shock	ρ_L	0.983	(0.972, 0.981, 0.991)	0.989	(0.977, 0.987, 0.996)
persistence investment shock	ρ_I	0.234	(0.142, 0.235, 0.326)	0.238	(0.173, 0.505, 0.953)
productivity shock	σ_a	0.412	(0.331, 0.416, 0.497)	0.431	(0.340, 0.416, 0.483)
preference shock	σ_b	0.164	(0.129, 0.163, 0.197)	0.143	(0.119, 0.157, 0.206)
gov. spending shock	σ_g	0.313	(0.285, 0.317, 0.357)	0.313	(0.281, 0.315, 0.356)
labor supply shock	σ_L	1.618	(1.306, 1.669, 2.027)	1.135	(0.748, 1.130, 1.512)
equity premium shock	σ_q	0.093	(0.048, 0.159, 0.305)	0.093	(0.053, 0.670, 1.436)
monetary shock	σ_R	0.060	(0.046, 0.066, 0.088)	0.050	(0.035, 0.052, 0.071)
investment shock	σ_I	0.573	(0.496, 0.582, 0.666)	0.567	(0.008, 0.347, 0.620)
inflation equation shock	σ_π	0.099	(0.064, 0.166, 0.286)	0.528	(0.331, 0.555, 0.736)
wage equation shock	σ_w	0.132	(0.090, 0.163, 0.221)	0.717	(0.344, 0.704, 1.118)

Table 22: Posterior distribution, intermediate parameterization II: standard sticky information model and nested Calvo - sticky information model