# 822 Accompanying materials

# **Appendix A**



Figure A.1: Pointwise 68 percent real wage responses intervals to monetary shocks, only monetary shocks identified.



Figure A2: Pointwise 68 percent real wage response intervals to monetary shocks, all shocks identified.



Figure A.3: Pointwise 68 percent real wage response intervals to monetary shocks, VAR chosen with BIC.

	Flexible price					Sticky price			
	sticky wage model						flexible price model		
	Standard deviation of Standard deviation of					Basic			
	monetary shocks 10			markup shocks 10					
	times larger			times larger					
Horizon	T=80	T=160	T = 500	T=80	T = 160	T = 500	T=80	T=160	T = 500
0	90	90	90	50	50	49	100	100	100
1	80	86	88	64	74	77	75	85	94
2	78	80	86	64	73	81	68	76	83
3	72	76	83	62	73	80	61	69	78
4	68	72	81	59	72	83	59	63	70

Table A.1: Percentages of correctly signed real wage responses to monetary shocks; median value across 200 Monte Carlo replications. In all panels the VAR has two lags and includes output, real wages, hours, inflation and the nominal rate.

	2 lags			4 lags			10 lags		
Horizon	T = 80	T = 160	T = 500	T = 80	T = 160	T = 500	T = 80	T = 160	T = 500
0	100	100	100	100	100	100	100	100	100
1	82	89	97	78	86	95	76	87	96
2	75	78	90	63	66	85	60	71	83
3	65	69	84	53	59	70	52	57	72
4	60	61	76	59	55	63	47	54	59

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Table A.2: Percentages of correctly signed real wage responses to monetary shocks; median value across 200 Monte Carlo replications. The DGP is the sticky prices, flexible wage model; the VAR includes output, inflation, nominal rate and hours. The correct representation of the DGP is a VAR(2).

#### Appendix B 835

The Smets and Wouter's (2003) class of models features nominal frictions (sticky nominal 836 wage and price setting, backward wage and inflation indexation), real frictions (habit for-837 mation in consumption, investment adjustment costs, variable capital utilization and fixed 838 costs in production). The class has three blocks and its log-linearized representation (around 839 the steady state) is as follows. The aggregate demand block is: 840

$$y_t = c_y c_t + i_y i_t + g_y e_t^g \tag{24}$$

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$$c_t = \frac{h}{1+h}c_{t-1} + \frac{1}{1+h}E_tc_{t+1} - \frac{1-h}{(1+h)\sigma_c}(R_t - E_t\pi_{t+1}) + \frac{1-h}{(1+h)\sigma_c}(e_t^b - E_te_{t+1}^b)$$
(25)

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$$i_{t} = \frac{1}{1+\beta}i_{t-1} + \frac{\beta}{1+\beta}E_{t}i_{t+1} + \frac{\phi}{1+\beta}q_{t} - \frac{\beta E_{t}e_{t+1}^{I} - e_{t}^{I}}{1+\beta}$$
(26)

$$q_t = \beta(1-\delta)E_t q_{t+1} - (R_t - E_t \pi_{t+1}) + (1 - \beta(1-\delta))E_t r_{t+1}$$
(27)

Equation (24) is the aggregate resource constraint. Total output,  $y_t$ , is absorbed by con-844 sumption,  $c_t$ , investment,  $i_t$ , and exogenous government spending,  $e_t^g$ . Equation (25) is a 845 dynamic IS curve:  $e_t^b$  is a preference shock,  $\sigma_c$  the coefficient of relative risk aversion and 846 h the coefficient of external habit formation. The dynamics of investment are in equation 847 (26);  $\phi$  represents the elasticity of the costs of adjusting investments,  $q_t$  the value of existing 848 capital,  $e_t^I$  a shock to the investment's adjustment cost function and  $\beta$  the discount factor. 849 Equation (27) characterizes Tobin's q: the current value of the capital stock positively de-850 pends on its expected future value and its expected return, and negatively on the ex-ante 851 real interest rate. The aggregate supply block is: 852

$$y_t = \omega(\alpha k_{t-1} + \alpha \psi r_t + (1 - \alpha)n_t + e_t^z)$$
(28)

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$$k_t = (1 - \delta)k_{t-1} + \delta i_t \tag{29}$$

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$$\pi_t = \frac{\beta}{1+\beta\mu_p} E_t \pi_{t+1} + \frac{\mu_p}{1+\beta\mu_p} \pi_{t-1} + \kappa_p m c_t \tag{30}$$

$$w_{t} = \frac{\beta}{1+\beta} E_{t} w_{t+1} + \frac{1}{1+\beta} w_{t-1} + \frac{\beta}{1+\beta} E_{t} \pi_{t+1} - \frac{1+\beta\mu_{w}}{1+\beta} \pi_{t} + \frac{\mu_{w}}{1+\beta} \pi_{t-1} - \kappa_{w} \mu_{t}^{W}$$
(31)

$$n_t = -w_t + (1+\psi)r_t^k + k_{t-1} \tag{32}$$

Equation (28) is the aggregate production function. In equilibrium  $\psi r_t$  equals the capital 857 utilization rate and  $e_t^z$  is a total factor productivity (TFP) shock. Fixed costs of production 858 are given by  $\omega - 1$  and  $\alpha$  is the capital share. The law of motion of capital accumulation is in 859 equation (29). Equation (30) links inflation to marginal costs,  $mc_t = \alpha r_t^k + (1-\alpha)w_t - e_t^z + e_t^{\mu_p}$ and  $e_t^{\mu_p}$  is a markup shock. The parameter  $\kappa_p = \frac{1}{1+\beta\mu_p} \frac{(1-\beta\zeta_p)(1-\zeta_p)}{\zeta_p}$ , is the slope of the Phillips 860 861 curve and depends on  $\zeta_p$ , the probability that firms face for not being able to change prices 862 in the Calvo setting. The parameter  $\mu_p$  determines the degree of price indexation. Equation 863 (31) links the real wage to expected and past wages, to inflation and to the marginal rate 864 of substitution between consumption and leisure,  $\mu_t^W = w_t - \sigma_l n_t - \frac{\sigma_c}{1-h}(c_t - hc_{t-1}) - e_t^{\mu_w}$ 865 where  $\sigma_l$  is the inverse of the elasticity of hours to the real wage,  $e_t^{\mu_w}$  a labor supply shock 866 and  $\kappa_w = \frac{1}{1+\beta} \frac{(1-\beta\zeta_w)(1-\zeta_w)}{(1+\frac{(1+\varepsilon^w)\sigma_l}{\varepsilon^w})\zeta_w}$ . Equation (32) follows from the equalization of marginal costs. 867 The monetary rule is 868

$$R_{t} = \rho_{R}R_{t-1} + (1 - \rho_{R})(\gamma_{\pi}\pi_{t} + \gamma_{y}y_{t}) + e_{t}^{R}$$
(33)

where  $\varepsilon_t^R$  is a monetary policy shock.

Equations (24) to (33) define a system of 10 equations in ten unknowns,  $(\pi_t, y_t, c_t, i_t, q_t, l_t, w_t, k_t, r_t, R_t)$ . The model features seven exogenous disturbances: TFP,  $e_t^z$ , investment-specific,  $e_t^I$ , preference,  $e_t^b$ , government spending,  $e_t^g$ , monetary policy,  $e_t^R$ , price markup  $e_t^{\mu_p}$  and labor supply,  $e_t^{\mu_w}$  shocks. The vector of disturbances  $S_t = [e_t^z, e_t^I, e_t^b, e_t^g, e_t^R, e_t^{\mu_p}, e_t^{\mu_w}]'$ , satisfies:

$$\log(S_t) = (I - \boldsymbol{\varrho})\log(\overline{S}) + \boldsymbol{\varrho}\log(S_{t-1}) + V_t$$
(34)

where  $V \sim iid(0', \Sigma_v)$ ,  $\boldsymbol{\varrho}$  is diagonal with roots less than one in absolute value and  $\overline{S} = E(S)$ . In table B.1 we present the intervals used to compute robust restrictions presented in table 5 together with the parameters for the DGP used in section 4.4.

Parameter	Description	Support	DGP
$\sigma_c$	Risk aversion coefficient	[1,6]	2
$\sigma_l$	Inverse Frish labor supply elasticity	[0.5, 4.0]	1.9
h	Consumption habit	[0.1, 0.8]	0.7
ω	Fixed cost	[1.0, 1.80]	1.2
$\phi$	Adjustment cost parameter	[0.0001, 0.02]	0.018
δ	Capital depreciation rate	[0.015, 0.03]	0.025
$\alpha$	Capital share	[0.15, 0.35]	0.3
$\psi$	Capacity utilization elasticity	[0.1, 0.6]	0.5
$\zeta_p$	Degree of price stickiness	[0.4, 0.9]	0.7
$\mu_p$	Price indexation	[0.2, 0.8]	0.2
$\zeta_w$	Degree of wage stickiness	[0.4, 0.9]	0.8
$\mu_w$	Wage indexation	[0.2, 0.8]	0.5
$\varepsilon^w$	Steady state markup in labor market	[0.1, 1.8]	1.0
$g_y$	Share of government consumption	[0.10, 0.25]	0.2
$ ho_R$	Lagged interest rate coefficient	[0.2, 0.95]	0.74
$\gamma_{\pi}$	Inflation coefficient on interest rate rule	[1.1, 3.0]	1.18
$\gamma_y$	Output coefficient on interest rate rule	[0.0, 1.0]	0.0
$ert arrho_i$	Persistence of shocks $i = z, b, I, \mu_p, \mu_w$	[0,0.9]	0.8
β	Discount factor	0.99	0.99
$\pi^s$	Steady state inflation	1.016	1.016
$s_g$	Standard deviation expenditure shock		0.1
$ s_b $	Standard deviation preference shock		0.066
$s_z$	Standard deviation technology shock		0.0064
$ s_i $	Standard deviation investment shock		0.557
$ s_p $	Standard deviation price markup shock		0.221
$s_w$	Standard deviation wage markup shock		0.135
$s_m$	Standard deviation monetary shock		0.0026

Table B.1: Supports for the structural parameters and parameters of the DGP, Smets and Wouters model.

## **Appendix C**

In this appendix we show that failute to impose the uniqueness condition in identification could lead to large biases. For this purpose, we generate density estimates of the unconstrained (4, 4) element of the matrix

$$D = \begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix}$$

in a static four variable VAR, y = De, where e has diagonal variance with elements [1,1,1,2], identifying the last shock only using restrictions on the (j, 4) > 0, j = 1, 2, 3 elements of the matrix (scheme 1), identifying the last shock only using the same restrictions and the restriction that the other three shocks can not generate a similar pattern of responses (scheme 2) and identifying all the shocks using the restrictions on the (j, i), j = 1, 2, 3; i = 1, ..., 4elements of the matrix.



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Figure C.1: Density of the response under different identification schemes. Scheme 1 sign restrictions, one shock; Scheme 2 sign plus uniqueness restrictions, on shock; Scheme 3 sign restrictions all shocks. Vertical bar: true value.

Figure C.1 shows that the distribution of responses in scheme 1 (dotted line) and in scheme 2 (solid line) looks very different: 30 percent of the mass of the estimated distribution

is above zero in scheme 1 and only 9 percent is above zero when the additional uniqueness restrictions are imposed; the median of the distribution is a better estimator of the true value in scheme 2. Thus, while not a substitute for identifying all the shocks, which can be seen gives very precise information about the sign and the magnitude of the unrestricted element, imposing the uniqueness condition may help to sharpen inference when only a subset of the shocks is identified.