The Smets-Wouters Model
Monetary and Fiscal Policy

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1. Introduction

2. The Environment and Markets
   - Household
   - Firms
   - Government
   - Market clearing and equilibrium

3. Analysis
   - Households
   - Intermediate goods firms

4. The linearized model
   - A list of equations
   - Calibration
Source and Impact


- **Impact:** The Smets-Wouters model have become a modern workhorse and benchmark model for analyzing monetary and fiscal policy in European central banks, and is spreading to policy institutions in the US as well.
Overview

- This is an elaborate New Keynesian model.
- There is a continuum of households, who supply household-specific labor in monopolistic competition. They set wages. Wages are Calvo-sticky.
- There is a continuum of intermediate good firms, who supply intermediate goods in monopolistic competition. They set prices. Prices are Calvo-sticky.
- Final goods use intermediate goods and are produced in perfect competition.
- There is habit formation, adjustment costs to investment, variable capital utilization.
- The monetary authority follows a Taylor-type rule.
- There are many sources of shocks - enough to make sure the data can be matched to the model.
Introduction
The Environment and Markets
Analysis
The linearized model

Outline

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Utility of household $\tau$:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t U^T_t$$

where

$$U^T_t = \epsilon^b_t \left( \frac{(C^T_t - H_t)^{1-\sigma_c}}{1 - \sigma_c} - \epsilon^L_t \frac{\ell^T_t)^{1+\sigma_c}}{1 + \sigma_c} \right)$$

- $C^T_t$: consumption.
- $H_t$: external habit / catching up with the Joneses.
- $\ell^T_t$: labor
- $\epsilon^b_t$: intertemporal substitution shock
- $\epsilon^L_t$: labor supply shock
Preference Shocks:

\[ \epsilon^b_t = \rho_b \epsilon^b_{t-1} + \eta^b_t \]

\[ \epsilon^L_t = \rho_L \epsilon^L_{t-1} + \eta^L_t \]

Habits:

\[ H_t = hC_{t-1} \]

where \( C_{t-1} \) is aggregate consumption in \( t - 1 \).
... is left unmodelled, but implicitly assumed to be there.

Easiest solution: assume that households have money in the utility, i.e. enjoy holding real balances,...

... and the monetary authority influences nominal rates per helicopter drops of money on households,...

... but that otherwise money does not influence budget constraints etc.

See Woodford for details on how this can be done.

Later on, we shall formulate an interest-rate setting rule for the monetary authority. Thus money does not need to be modelled explicitly (hopefully... but subtle and possibly crucial issues may be overlooked this way!!)
Intertemporal budget constraint and income

- Intertemporal budget constraint:
  \[ b_t \frac{B^T_t}{P_t} = \frac{B^T_{t-1}}{P_t} + Y^T_t - C^T_t - I^T_t \]

  where \( B^T_t \) are nominal discount bonds with market price \( b_t \).

- Real income
  \[ Y^T_t = (w^T_t \ell^T_t + A^T_t) + (r^K_t z^T_t K^T_{t-1} - \Psi(z^T_t)K^T_{t-1}) + \text{Div}^T_t - \text{tax}_t \]

- \( w^T_t \ell^T_t + A^T_t \): Labor income plus state contingent security payoffs.

- \( r^K_t z^T_t K^T_{t-1} - \Psi(z^T_t)K^T_{t-1} \): return on real capital stock minus costs from capital utilization \( z^T_t \). Assume \( \Psi(1) = 0 \).

- \( \text{Div}^T_t \): dividends from imperfectly competitive firms.

- \( \text{tax}_t \): real lump-sum tax.
Imperfect substitutability of labor

- Individual households supply different types of labor, which is not perfectly substitutable,

\[ L_t = \left( \int_0^1 (\ell_t^\tau)^{1/(1+\lambda_{w,t})} d\tau \right)^{1+\lambda_{w,t}} \]

- The degree of substitutability is random,

\[ \lambda_{w,t} = \lambda_w + \eta_t^w \]

- In the flexible-wage economy, \( 1 + \lambda_{w,t} \) will be the markup of real wages over the usual ratio of the marginal disutility of labor to the marginal utility of consumption. Thus, \( \eta_t^w \) is a wage markup shock.
Wage setting

- Households are monopolistically competitive suppliers of labor and wage setters, offering their labor in the quantity demanded at their current wage $W^T_t$.
- Wages are Calvo-sticky.
- Each period, the household has probability $1 - \xi_w$ that it is allowed to freely adjust its wage, choosing a new nominal wage
  \[
  W^T_t = \tilde{W}^T_t
  \]
- If not, wages are adjusted according to the indexation rule
  \[
  W^T_t = \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_w} W^T_{t-1}
  \]
- $\gamma_w = 0$: no indexation. $\gamma_w = 1$: perfect indexation.
Perfect insurance markets

Perfect insurance:

- labor income of an individual household equals aggregate labor income.
- Thus, the consumption of an individual household equals aggregate consumption, $C^T_t = C_t$, ...
- ... and marginal utility $\Lambda^T_t \equiv \Lambda_t$ of consumption is equal across households.
- As a consequence, capital holdings $K^T_t \equiv K_t$, bond holdings $B^T_t = B_t$ as well as firm dividends $\text{Div}^T_t \equiv \text{Div}_t$ will be identical across different types of households.
- Also possible: these remain in constant proportions forever across different households.
Outline

1. Introduction
2. The Environment and Markets
   - Household
   - Firms
   - Government
   - Market clearing and equilibrium
3. Analysis
   - Households
   - Intermediate goods firms
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   - A list of equations
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All sectors

- **Final goods production**: homogenous final good, produced with a continuum of imperfectly substitutable intermediate goods.

- A continuum of **intermediate goods**, produced with capital and labor.

- **Labor**, in turn, is a “composite” of individual household labor.

- New **capital** is produced with old capital and investment, subject to an **investment adjustment cost**.

- Depreciation varies with **capital utilization**.
Final goods production

\[ Y_t = \left( \int_0^1 (y_{j,t})^{1/(1+\lambda_{p,t})} \, dj \right)^{1+\lambda_{p,t}} \]

The degree of substitutability is random,

\[ \lambda_{p,t} = \lambda_p + \eta_t^p \]

It will turn out that \( 1 + \lambda_{p,t} \) is the markup of prices over marginal costs at the intermediate goods level. Thus, \( \eta_t^p \) is a goods markup shock or a cost-push shock.
Intermediate goods production

- Intermediate goods production is
  \[ y_{j,t} = \epsilon^a_t \tilde{K}_{j,t} \alpha L_{j,t}^{1-\alpha} - \Phi \]

- \( \Phi \): a fixed cost.
- \( \tilde{K}_{j,t} \): effective utilization of the capital stock,
  \[ \tilde{K}_{j,t} = z_t K_{j,t-1} \]
- \( \epsilon^a_t \): aggregate productivity shock,
  \[ \epsilon^a_t = \rho a \epsilon^a_{t-1} + \eta^a_t \]

- The profits of intermediate goods firms are paid as dividends \( \text{Div}_t \).
Intermediate good firms are monopolistically competitive, offering their good in the quantity demanded at their current price $P_{j,t}$.

Prices are Calvo-sticky.

Each period, the firm has probability $1 - \xi_p$ that it is allowed to freely adjust its price, choosing a new nominal price

$$P_{j,t} = \tilde{P}_{j,t}$$

If not, prices are adjusted according to the indexation rule

$$P_{j,t} = \left( \frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} P_{j,t-1}$$

$\gamma_p = 0$: no indexation. $\gamma_p = 1$: perfect indexation.
Capital evolution

- New capital is produced from old capital and investment goods,

\[ K_t = (1 - \tau)K_{t-1} + \left(1 - S\left(\frac{\epsilon_t}{l_t}ight)\right) l_t \]

- \( l_t \): gross investment
- \( \tau \): depreciation rate
- \( S(\cdot) \): cost for changing the level of investment, with \( S(1) = 0, S'(1) = 0, S''(1) > 0 \).
- \( \epsilon_t^I \): shock to investment cost,

\[ \epsilon_t^I = \rho \epsilon_{t-1}^I + \eta_t^I \]
Outline

1. Introduction

2. The Environment and Markets
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   - Government
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Government

- Government consumption: $G_t$, following government spending rule, financed by lump sum taxation,
  \[ G_t = \text{tax}_t \]

- Monetary authority: sets nominal interest rate
  \[ R_t = 1 + i_t = 1/b_t \]
  following some interesting setting rule.

- We shall specify these rules in the log-linearized version of the model.
Outline

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2. The Environment and Markets
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   - Government
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   - Calibration
Market clearing

- Labor market:
  $$\int_0^1 L_{j,t} dj = L_t = \left( \int_0^1 (\ell_t^\tau)^{1/(1+\lambda_{w,t})} d\tau \right)^{1+\lambda_{w,t}}$$

- Final goods market:
  $$C_t + I_t + G_t + l_t + \psi(z_t)K_{t-1} = Y_t$$

- Capital rental market:
  $$\int K_{j,t-1} dj = K_{t-1}$$
Wage and price aggregation

Dixit-Stiglitz aggregation:
- Aggregate wages are
  \[ W_t = \left( \int_0^1 (W_t^T)^{-1/\lambda_{w,t}} d\tau \right)^{-\lambda_{w,t}} \]
- Aggregate prices are
  \[ P_t = \left( \int_0^1 (P_{j,t})^{-1/\lambda_{p,t}} d\tau \right)^{-\lambda_{p,t}} \]
- One can derive these formulas from first-order conditions of producing aggregate output or aggregate labor.
Equilibrium

**Definition**

Given policy rules for $G_t$ and $R_t$ and thus tax$_t$, an equilibrium is an allocation $(B_t, C_t, H_t, (\ell^\tau_t)_{\tau \in [0,1]}, (L_i,t)_{i \in [0,1]}, L_t, (\tilde{K}_i,t)_{i \in [0,1]}, (K_i,t)_{i \in [0,1]}, K_t, z_t, I_t, (y_i,t)_{i \in [0,1]}, Y_t, \text{Div}_t)$ and prices $(b_t, r^k_t, (W^\tau_t)_{\tau \in [0,1]}, W_t, (P_i,t)_{i \in [0,1]})$, so that

1. Given prices and the demand function for labor $\ell^\tau_t$, the allocation maximizes the utility of the household, subject to the Calvo-sticky wages.

2. Given prices and the demand function for $y_{t,i}$, the allocation maximizes the profits of the firms, subject to the Calvo-sticky prices.


4. The policy rules are consistent with allocation and prices.

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Money and Fiscal: the NK Model
Outline

1. Introduction

2. The Environment and Markets
   - Household
   - Firms
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4. The linearized model
   - A list of equations
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Intertemporal optimization 1

- Lucas asset pricing equation for bonds:

\[
E_t \left[ \beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{R_t}{P_{t+1}} \right] = 1
\]

where

\[
\Lambda_t = U_{C,t} = \epsilon^b_t (C_t - H_t)^{-\sigma_c}
\]

- Lucas asset pricing equation for capital:

\[
Q_t = E_t \left[ \beta \frac{\Lambda_{t+1}}{\Lambda_t} \left( Q_{t+1}(1 - \tau) + Z_{t+1}r^k_{t+1} - \psi(Z_{t+1}) \right) \right]
\]
Intertemporal optimization 2

- Optimal investment:

\[ Q_t \left( 1 - S \left( \frac{\epsilon_l l_t}{l_{t-1}} \right) \right) = Q_t S' \left( \frac{\epsilon_l l_t}{l_{t-1}} \right) \frac{\epsilon_l l_t}{l_{t-1}} + 1 \]

\[-E_t \left[ \beta \frac{\Lambda_{t+1}^{t+1}}{\Lambda_t} Q_{t+1} S' \left( \frac{\epsilon_{l+1} l_{t+1}}{l_t} \right) \left( \frac{\epsilon_{l+1} l_{t+1}}{l_t} \right) \frac{l_{t+1}}{l_t} \right] \]

copied from Smets-Wouters, equation (16). Is it correct?

- For capital utilization:

\[ r^k_t = \psi'(Z_t) \]
Wage setting

- Demand curve for labor:

$$\ell^T_t = \left( \frac{W^T_t}{W_t} \right)^{-\left(1 + \lambda_{W,t}\right)/\lambda_{W,t}} L_t$$

- Optimality condition for setting a new wage $\tilde{w}_t$:

$$\frac{\tilde{w}_t}{P_t} E_t \left[ \sum_{i=0}^{\infty} \beta^i \xi^i_w \left( \frac{P_t}{P_{t-1}} \right)^{\gamma_w} \frac{\ell^T_{t+i} U_{C,t+i}}{1 + \lambda_{W,t+i}} \right]$$

$$= E_t \left[ \sum_{i=0}^{\infty} \beta^i \xi^i_w \ell^T_{t+i} U_{l,t+i} \right]$$

where $U_{C,t}, U_{l,t}$ denote marginal utility of consumption and marginal disutility of labor.
Evolution of wages

Per aggregation of wages,

\[(W_t)^{-1/\lambda_{w,t}} = \xi_w \left( W_{t-1} \left( \frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} \right)^{-1/\lambda_{w,t}} + (1 - \xi_w)(\tilde{w}_t)^{-1/\lambda_{w,t}}\]
Outline

1. Introduction
2. The Environment and Markets
   - Household
   - Firms
   - Government
   - Market clearing and equilibrium
3. Analysis
   - Households
   - Intermediate goods firms
4. The linearized model
   - A list of equations
   - Calibration
Cost minimization gives

\[ \frac{W_t L_{j,t}}{r_t K_{j,t}} = \frac{1 - \alpha}{\alpha} \]

Thus, marginal costs for producing one extra unit of intermediate goods output is

\[ MC_t = \frac{1}{\epsilon_t^a} W_t^{1-\alpha} \left( r_t^K \right)^{\alpha} \left( \alpha^{-\alpha} (1 - \alpha)^{-(1-\alpha)} \right) \]
Demand and profits

- The demand function \( y^j_t = D(P_j,t; P_t, Y_t) \) is given by
  \[
y_j,t = \left( \frac{P_{j,t}}{P_t} \right)^{-(1-\lambda_{p,t})/\lambda_{p,t}} Y_t
  \]

- Nominal profits are
  \[
  \pi_{j,t} = (P_{j,t} - MC_t) \left( \frac{P_{j,t}}{P_t} \right)^{-(1-\lambda_{p,t})/\lambda_{p,t}} Y_t - MC_t \Phi
  \]
Optimality condition for setting a new price $\tilde{p}_t$:

$$
E_t \left[ \sum_{i=0}^{\infty} \beta^i \xi^i_{p} \Lambda_{t+i} y_{j,t+i} \left( \frac{\tilde{p}_t}{P_t} \left( \frac{P_{t-1+i}/P_{t-1}}{P_{t+i}/P_t} \right)^{\gamma_p} \right) \right]
$$

$$
= E_t \left[ \sum_{i=0}^{\infty} \beta^i \xi^i_{p} \Lambda_{t+i} y_{j,t+i} (1 + \lambda_{p,t+i}) \text{mc}_{t+i} \right]
$$

where

$$
\text{mc}_t = \frac{\text{MC}_t}{P_t}
$$

are the real marginal costs.
Per aggregation of prices,

\[
(P_t)^{-1/\lambda_{p,t}} = \xi_p \left( P_{t-1} \left( \frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} \right)^{-1/\lambda_{p,t}} + (1 - \xi_p) (\tilde{\rho}_t)^{-1/\lambda_{p,t}}
\]
Outline

1. Introduction
2. The Environment and Markets
   - Household
   - Firms
   - Government
   - Market clearing and equilibrium
3. Analysis
   - Households
   - Intermediate goods firms
4. The linearized model
   - A list of equations
   - Calibration
Remark

- The equations in the published version of the paper do not appear to be entirely correct (this can easily happen), ...
- ... and they do not appear to be consistent with the code either, even once corrected.
- We therefore spent considerable time clarifying the differences.
- We believe we got everything correct now.
- Very special thanks go to Wenjuan Chen and Matthieu Droumaguet for doing this and to Stefan Ried for supervising it! This was a lot of work...
- Details are in a "SmetsWouters-"Manual.
Equations 1, 2 and 3

- The capital accumulation equation:
  \[
  \hat{K}_t = (1 - \tau)\hat{K}_{t-1} + \tau\hat{l}_{t-1}
  \]  
  (1)

- The labour demand equation:
  \[
  \hat{L}_t = -\hat{w}_t + (1 + \psi)\hat{r}_t^k + \hat{K}_{t-1}
  \]  
  (2)

- The goods market equilibrium condition:
  \[
  \hat{Y}_t = (1 - \tau k_y - g_y)\hat{C}_t + \tau k_y\hat{l}_t + \epsilon_t^G
  \]  
  (3)
Equations 4,5

- The production function:
  \[ \hat{Y}_t = \phi \epsilon_t^a + \phi \alpha \hat{K}_{t-1} + \phi \alpha \psi \hat{r}^k_t + \phi (1 - \alpha) \hat{L}_t \]  

- The monetary policy reaction function: a Taylor-type rule
  \[ \hat{R}_t = \rho \hat{R}_{t-1} + (1 - \rho) \left\{ \tilde{\pi}_t + r_{\pi} (\hat{\pi}_{t-1} - \hat{\pi}_t) + r_Y (\hat{Y}_t - \hat{Y}_t^P) \right\} \]
  \[ + r_{\Delta \pi} (\hat{\pi}_t - \hat{\pi}_{t-1}) + r_{\Delta Y} \left[ \hat{Y}_t - \hat{Y}_t^P - (\hat{Y}_{t-1} - \hat{Y}_{t-1}^P) \right] + \eta_t^R \]  

where \( Y_t^P \) refers to a hypothetical “frictionless economy” and potential output. The difference \( \hat{Y}_t - \hat{Y}_t^P \) is the output gap.
Equation 6

The consumption equation:

\[
\hat{C}_t = \frac{h}{1 + h} \hat{C}_{t-1} + \frac{1}{1 + h} E_t \hat{C}_{t+1} - \frac{1 - h}{(1 + h)\sigma_c} (\hat{R}_t - E_t \hat{\pi}_{t+1}) + \frac{1 - h}{(1 + h)\sigma_c} \hat{\varepsilon}_t^b
\]

(6)
Equations 7, 8

- **The investment equation:**

\[
\hat{l}_t = \frac{1}{1 + \beta} \hat{l}_{t-1} + \frac{\beta}{1 + \beta} E_t \hat{l}_{t+1} + \frac{\varphi}{1 + \beta} \hat{Q}_t + \hat{e}_t \tag{7}
\]

- **The Q equation:**

\[
\hat{Q}_t = - (\hat{R}_t - E_t \hat{\pi}_{t+1}) + \frac{1 - \tau}{1 - \tau + \bar{r}^k} E_t \hat{Q}_{t+1} + \frac{\bar{r}^k}{1 - \tau + \bar{r}^k} E_t \hat{r}^k_{t+1} + \eta_t^Q \tag{8}
\]
The inflation equation:

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

Equation 9
The wage equation is given as follows. Pay attention that the sign before the labour supply shock shall be positive instead of negative, which is confirmed by the authors.

\[
\hat{w}_t = \frac{\beta}{1 + \beta} E_t \hat{w}_{t+1} + \frac{1}{1 + \beta} \hat{w}_{t-1} + \frac{\beta}{1 + \beta} E_t \hat{\pi}_{t+1} - \frac{1 + \beta \gamma_w}{1 + \beta} \hat{\pi}_t + \frac{\gamma_w}{1 + \beta} \hat{\pi}_{t-1} - \frac{1}{1 + \beta} \left(1 - \beta \xi_w\right) \left(1 - \xi_w\right) \left(1 + \frac{(1 + \lambda_w)\sigma_L}{\lambda_w}\right) \xi_w \]

\[
\left[\hat{w}_t - \sigma_L \hat{L}_t - \frac{\sigma_c}{1 - h} (\hat{C}_t - h\hat{C}_{t-1}) + \hat{\epsilon}_t^L\right] + \eta_t^w
\]
### Differences to published version

<table>
<thead>
<tr>
<th>Equation in Smets-Wouters (2003)</th>
<th>Here</th>
</tr>
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<tbody>
<tr>
<td>28</td>
<td>take out $\epsilon_{t+1}^b$</td>
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<tr>
<td>29</td>
<td>take out $\epsilon_{t+1}^l$</td>
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<td>29</td>
<td>$\epsilon_t^b$ rescaled to equal 1</td>
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<tr>
<td>35a</td>
<td>$\epsilon_t^G$ rescaled to equal 1</td>
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<td>32</td>
<td>$\eta_t^p$ rescaled to equal 1</td>
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<tr>
<td>33</td>
<td>$\eta_t^w$ rescaled to equal 1</td>
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</table>
Calculating results

- In order to calculate results, we have to create two systems. One is the flexible system where there is no price stickiness, wage stickiness or three cost-push shocks.

- The other one is the sticky system where prices and wages are set following a Calvo mechanism.

- We use the potential output produced in the flexible system to calculate the output gap in the Taylor rule.

- In each system, there are 8 endogenous variables and 2 state variables. The 8 endogenous variables are capital, consumption, investment, inflation, wages, output, interest rate, and real capital stock. The 2 state variables are labour and return on capital.
Outline

1. Introduction
2. The Environment and Markets
   - Household
   - Firms
   - Government
   - Market clearing and equilibrium
3. Analysis
   - Households
   - Intermediate goods firms
4. The linearized model
   - A list of equations
   - Calibration
## Calibration 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
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<tr>
<td>$\tau$</td>
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<td>$\alpha$</td>
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<td>capital output ratio</td>
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<tr>
<td>$\psi$</td>
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<td>inverse elasticity of cap. util. cost</td>
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<tr>
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<td>degree of partial indexation of price</td>
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<td>$\gamma_w$</td>
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<td>degree of partial indexation of wage</td>
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<td>mark up in wage setting</td>
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<td>Calvo price stickiness</td>
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<td>$\xi_s$</td>
<td>0.737</td>
<td>Calvo wage stickiness</td>
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<td>$\sigma_L$</td>
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<td>inverse elasticity of labor supply</td>
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</tbody>
</table>
## Calibration 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_c$</td>
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<td>coeff. of relative risk aversion</td>
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<tr>
<td>$h$</td>
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<td>habit portion of past consumption</td>
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<tr>
<td>$\phi$</td>
<td>1.408</td>
<td>$1 + \text{share of fixed cost in prod.}$</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>$1/6.771$</td>
<td>inverse of inv. adj. cost</td>
</tr>
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<td>$\bar{r}_k$</td>
<td>$1/\beta - 1 + \tau$</td>
<td>steady state return on capital</td>
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<td>capital output ratio</td>
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<td>share of investment to GDP</td>
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<td>$c_y$</td>
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<td>share of consumption to GDP</td>
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<tr>
<td>$k_y$</td>
<td>$inv_y/\tau$</td>
<td>capital income share, inv. share</td>
</tr>
<tr>
<td>$g_y$</td>
<td>$1 - c_y - inv_y$</td>
<td>government expend. share in GDP</td>
</tr>
<tr>
<td>$r^\Delta_y$</td>
<td>0.14</td>
<td>inflation growth coeff.</td>
</tr>
<tr>
<td>$r_y$</td>
<td>0.099</td>
<td>output gap coeff.</td>
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</tbody>
</table>
### Calibration 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^\Delta_y$</td>
<td>0.159</td>
<td>output gap growth coefficient</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.961</td>
<td>AR for lagged interest rate</td>
</tr>
<tr>
<td>$r_\pi$</td>
<td>1.684</td>
<td>inflation coefficient</td>
</tr>
<tr>
<td>$\rho_{\epsilon_L}$</td>
<td>0.889</td>
<td>AR for labour supply shock</td>
</tr>
<tr>
<td>$\rho_{\epsilon_a}$</td>
<td>0.823</td>
<td>AR for productivity shock</td>
</tr>
<tr>
<td>$\rho_{\epsilon_b}$</td>
<td>0.855</td>
<td>AR for f preference shock</td>
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<tr>
<td>$\rho_G$</td>
<td>0.949</td>
<td>AR for government expenditure shock</td>
</tr>
<tr>
<td>$\rho_{\pi}$</td>
<td>0.924</td>
<td>AR for inflation objective shock</td>
</tr>
<tr>
<td>$\rho_{\epsilon_i}$</td>
<td>0.927</td>
<td>AR for investment shock</td>
</tr>
<tr>
<td>$\rho_{\epsilon_r}$</td>
<td>0</td>
<td>AR for interest rate shock, IID</td>
</tr>
<tr>
<td>$\rho_{\lambda_w}$</td>
<td>0</td>
<td>AR for wage markup, IID</td>
</tr>
</tbody>
</table>
### Calibration 1

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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>$\rho_q$</td>
<td>0</td>
<td>AR for return on equity, IID</td>
</tr>
<tr>
<td>$\rho_{\lambda_p}$</td>
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<td>AR for price mark-up shock, IID</td>
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<tr>
<td>$\sigma_{\epsilon_L}$</td>
<td>3.52</td>
<td>std. dev. of labour supply shock</td>
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<tr>
<td>$\sigma_{\epsilon_a}$</td>
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<td>std. dev. of productivity shock</td>
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<tr>
<td>$\sigma_{\epsilon_b}$</td>
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<td>$\sigma_G$</td>
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<tr>
<td>$\sigma_{\pi}$</td>
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<td>std. dev. of inflation objective shock</td>
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<tr>
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<tr>
<td>$\sigma_{\epsilon_q}$</td>
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<td>std. dev. of equity premium shock</td>
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