DSGE Modelling at the Banco de Portugal

Ricardo Mourinho Félix
Economics and Research Department
Banco de Portugal
DSGE modelling at the Banco de Portugal

Ricardo Mourinho Félix

Economics and Research Department, Banco de Portugal

IMF Macro Modelling Workshop

Washington, DC

January 6-9, 2009
Outline

1. DSGE models at the Banco de Portugal

2. Introducing and calibrating PESSOA
   - Households and labour unions
   - Firms
   - Government
   - Rest of the world and market clearing
   - Calibration

3. Increasing competition in the domestic markets
   - Motivation of the paper
   - Simulation design and results
   - Main findings

4. Ongoing research using PESSOA

5. Directions for further research
DSGE models at the Banco de Portugal

DSGE modelling activities started in 2005

Available DSGE models


Ongoing DSGE research projects

- Available models are being used in applied research
- **EAGLE model**: joint project with ECB and Banca d’Italia
- Identification issues in DSGE models
- Credit frictions in DSGSE models
Introducing $PESSOA$

$PESSOA$

$P$ortuguese $E$conomy $S$tructural $S$mall $O$pen economy $A$nalitical model

Introducing and calibrating PESSOA

Introducing *PESSOA*: the model

**Figure 1:** Model flowchart
Introducing *PESSOA*: the model

**General features**

- SOE integrated in a monetary union (=euro area)
- 6 types of agents:
  - Households
  - Labour unions
  - Manufacturers (intermediate goods producers)
  - Distributors (final goods producers)
  - Government
  - Rest of the world (=euro area ⇒ $S = 1$)

- Labour and product differentiation

- Competition: monopolistic in output markets, perfect in input markets

- Real and nominal rigidities (quadratic adjustment costs)
Introducing *PESSOA*: the model

*PESSOA* is largely inspired on GIMF (Kumhof, M. and M. Laxton (2007))

### PESSOA
- Small-open economy model
- Exogenous monetary policy
- No role for public investment
- Trade in semi-finished goods
- Heterogeneous import contents

### GIMF
- Multi-country model
- Endogenous monetary policy
- Public investment plays a role
- Trade in intermediate and final goods
- Homogeneous import content
Households (I)

General features

- Blanchard-Yaari overlapping generations, declining lifetime productivity
- Liquidity constrained and liquidity unconstrained \((H \in \{LIQ, OLG\})\)
- Consume goods from distributors, supply labour to a union
- Pay taxes on consumption and labour income, receive transfers
- External habit persistence

OLGs’ specific features

- Own firms
- Hold domestic and foreign bonds
Households (II)

CRRA utility

\[ U_{a,t}^H(h) = \frac{1}{1 - \gamma} \left[ \left( \frac{C_{a,t}^H(h)}{H_{ab_{a,t}}^H} \right)^{\eta_H} \left( 1 - L_{a,t}^H(h) \right)^{1-\eta_H} \right]^{1-\gamma} \]

Budget constraints

- OLG:
  \[ P_tC_{a,t}^{OLG}(h) + B_a,t(h) + B^*_a,t(h) = (1 - \tau_{L,t})W_t\Phi_a L_{a,t}^{OLG}(h) + \text{Transfers}_{a,t}^{OLG}(h) + \]
  \[ \frac{1}{\theta} \left[ i_{t-1}B_{a-1,t-1}(h) + i^*_{t-1}B^*_{a-1,t-1}(h) \right] + \text{Dividends}_{a,t}(h) \]

- LIQ:
  \[ P_tC_{a,t}^{LIQ}(h) = (1 - \tau_{L,t})W_t\Phi_a L_{a,t}^{LIQ}(h) + \text{Transfers}_{a,t}^{LIQ}(h) \]

where \( P_t = P_t^C(1 + \tau_{C,t}) \) is the numeraire.
Introducing and calibrating PESSOA

Households and labour unions

Households (III)

Utility maximisation problems

- OLG:

\[
\max_{C_{a,t}^{OLG}(h), L_{a,t}^{OLG}(h), B_{a,t}(h), B_{a,t}^*(h)} E_t \sum_{s=0}^{\infty} (\beta \theta)^s U_{a,t+s}^{OLG}(h)
\]

subject to Intertemporal budget constraint OLG

- LIQ:

\[
\max_{C_{a,t}^{LIQ}(h), L_{a,t}^{LIQ}(h)} E_t \sum_{s=0}^{\infty} (\beta \theta)^s U_{a,t+s}^{LIQ}(h)
\]

subject to Intratemporal budget constraint LIQ

Wealth

\[
hw_t + fw_t = \text{human wealth} + \text{financial wealth}
\]

\[
\tilde{R}_{t+s} = \Pi_{t=1}^{s} \theta/i_{t+t-1} \quad \text{human wealth discount factor}
\]
Labour unions

General features

- Hire labour from households, rent it to manufacturers charging a markup
- Pay tax on “dividend” arising from monopolistic competition
- Quadratic wage growth adjustment costs

Dividend

\[ D^U_t(h) = (1 - \tau_{L,t}) \left[ (V_t(h) - W_t) U_t(h) - \text{Adj.costs}_t(h) \right] \]

Dividend maximisation problem

\[
\max_{V_t(h)} \quad E_t \sum_{s=0}^{\infty} \tilde{R}_{t+s} D^U_{t+s}(h) \\
\text{s.t. Adj.costs, Type h labour demand}
\]
Manufacturers (I)

General features

- Produce tradable and non-tradable goods ($J \in \{T, N\}$), using labour from unions and capital (formed with investment good from distributors)
- Pay social security contributions on wage bill, tax on dividends
- Quadratic price growth and investment adjustment costs

Production function

$$Z_t^J(j) = \left( (1 - \alpha_U^J) \frac{1}{\xi Z_J} \left( K_t^J(j) \right)^{\frac{\xi Z_J - 1}{\xi Z_J}} + (\alpha_U^J) \frac{1}{\xi Z_J} \left( T_t A_t^J U_t^J(j) \right)^{\frac{\xi Z_J - 1}{\xi Z_J}} \right)^{\frac{\xi Z_J}{\xi Z_J - 1}}$$

Capital accumulation equation

$$K_{t+1}^J(j) = (1 - \delta^J) K_t^J(j) + I_t^J(j)$$
Manufacturers (II)

Dividend

\[ D_t^J(j) = \left[ P_t^J(j)Z_t^J(j) - (1 + \tau_{SP,t})V_tU_t^J(j) - P_t^I I_t^J(j) - (\text{Fix.+Adj.\,costs})_t^J(j) \right] - \]
\[ - \tau_{K,t} \left[ P_t^J(j)Z_t^J(j) - (1 + \tau_{SP,t})V_tU_t^J(j) - P_t^I \left( q_t^J \delta^J K_t^J(j) \right) - (\text{Fix.+Adj.\,costs})_t^J(j) \right] \]

Dividend maximisation problem

\[
\max_{P_t^J(j), I_t^J(j), U_t^J(j), K_{t+1}^J(j)} E_t \sum_{s=0}^{\infty} \tilde{R}_{t+s} D_{t+s}^J(j)
\]

s.t. Cap. accum. equation, Prod. function, Adj. costs, Type j intermediate good demand
Distributors (I): General features

Two-stage production technology

1st stage
- Produce composite tradable good using domestic tradables and imported goods
- Quadratic import content adjustment costs

2nd stage
- Produce private and government consumption, investment and export goods \( (F \in \{C, I, G, X\}) \) using tradable good produced in 1st stage and non-tradable goods from domestic manufacturers
- Pay tax on profits
- Quadratic price growth adjustment costs
Introducing and calibrating PESSOA Firms Distributors (II): 1st stage

Production function

\[ Y_t^{AF}(f) = \left( \alpha_{AF} \right)^{\frac{1}{\xi_{AF}}} \left( Z_t^{TF}(f) \right)^{\frac{\xi_{AF} - 1}{\xi_{AF}}} + (1 - \alpha_{AF}) \left( \frac{1}{\xi_{AF}} \right) \left( M_t^F(f) \left[ 1 - \Gamma_t^{AF}(f) \right] \right)^{\frac{\xi_{AF} - 1}{\xi_{AF}}} \]

Cost

\[ C_t^F(f) = P_t^T Z_t^{TF}(f) + P_t^* M_t^F(f) \]

Cost minimisation problem

\[ \min_{Z_t^{TF}(f), M_t^F(f)} C_t^F(f) \]

s.t. Prod.function, Adj.costs
Introducing and calibrating PESSOA

Distributors (III): 2nd stage

Production function

\[
Y_t^F(f) = \left( (1 - \alpha_F)^{\frac{1}{\xi_F}} \left( Y_t^{AF}(f) \right)^{\frac{\xi_F-1}{\xi_F}} + (\alpha_F)^{\frac{1}{\xi_F}} \left( Z_t^{NF}(f) \right)^{\frac{\xi_F-1}{\xi_F}} \right)^{\frac{\xi_F}{\xi_F-1}}
\]

Dividend

\[
D_t^F(f) = (1 - \tau_{D,t}) \left[ P_t^F(f)Y_t^F(f) - \Lambda_t^{AF}(f)Y_t^{AF}(f) - P_t^N Z_t^{NF}(f) - (\text{Fix.+Adj.costs})_t^F(f) \right]
\]

Dividend maximisation problem

\[
\max_{P_t^F(f), Y_t^{AF}(f), Z_t^{NF}(f)} \quad E_t \sum_{s=0}^{\infty} \tilde{R}_{t+s} D_{t+s}^F(f)
\]

s.t. Prod. function, Adj. costs, Type f final good demand
General features

- Collects taxes, pay/receives transfers, consumes, issues debt
- Budget constraint
  \[ SG_t = \text{Taxes}_t - P^G_t G_t + \text{NetTransfers}^G_t \]
  \[ B_t = B_{t-1} - SG_t - (i_{t-1} - 1) B_{t-1} \]
- Structural budget balance fiscal rule
  \[ \left( \frac{SG}{GDP} \right)_t = \left( \frac{SG}{GDP} \right)^{tar}_t + d_{tax} \left( \frac{RV_t - RV_{t}^{ss}}{GDP_{t}^{ss}} \right) + d_{debt} \left( \frac{B_t}{GDP_{t}^{ss}} - \left( \frac{B}{GDP} \right)^{tar}_t \right) \]
- Labour income tax rate is set endogenously
Rest of the world and market clearing

Rest of the world = euro area

- Trade linkages: sells goods to distributors, buys export goods from distributors
- Financial linkages: households sell/buy bonds in the RoW

Market clearing

\[
\sum_H L^H_t = \sum_J U^J_t \\
Z^J_t = \sum_F Z^{JF}_t + \text{Fix.} + \text{Adj. costs}_t \\
Y^C_t = \sum_H C^H_t + \text{Fix.} + \text{Adj. costs}_t; \quad Y^I_t = \sum_J I^J_t + \text{Fix.} + \text{Adj. costs}_t \\
Y^G_t = G_t + \text{Fix.} + \text{Adj. costs}_t; \quad Y^X_t = X_t + \text{Fix.} + \text{Adj. costs}_t \\
B^*_t = i_{t-1}B^*_{t-1} + P^X_t X_t - P^*_t M_t + \text{Net Transfers}^*_t
\]
Calibration

- Productivity growth, inflation rate, interest rate: euro area DSGE models
- Structural parameters: DSGE literature
- Nominal and real rigidities: Parameters from the literature as initial guesses
Increasing competition in the domestic markets: motivation

The Portuguese economy: 90’s versus 2000’s

90’s  A case of success in the European integration process
2000’s  Slowdown in economic activity, real divergence vs. euro area

What is behind this ?

Most popular stories are:

- FDI was diverted to Eastern European countries
- Integration of emerging economies with low unit labour costs

It can be disputed:

- FDI: $E(r^K) > \text{cost of capital}$
- Non-competitive Portuguese companies were displaced
Increasing competition in the domestic markets: motivation

How to restore competitiveness in the new international environment?

Increasing competition in domestic markets fosters international competitiveness

- Improves resource allocation
- Reduces non-tradable costs (knock-on effects)
- Crucial for a sound business environment (FDI inflows)
- Faster adjustment to shocks
- Portugal has still margin to improve competition

References: OECD, EC; Aghion; Høj, Conway, Nicoletti; Laxton and Bayoumi; Blanchard and Giavazzi
Increasing competition in the domestic markets: motivation

How to restore competitiveness in the new international environment?

**Figure 2:** Regulation stance in Portugal

![Graph showing Employment Protection Legislation and Product Market Regulation](source: OECD, Employment Protection Legislation Indicators and OECD, Product Market Regulation Indicators)
Simulation design

Features

- Permanent shocks to non-tradables price and wage markups
- Perfect foresight/information

Design

Non-tradable : Decline of 2 pp. in price markup (from 20% to 18%)

  Wage : Decline of 2.5 pp. in wage markup (from 25% to 22.5%)

Pass-through : 80 % of the decline achieved in 2 years
The impact of increasing competition in non-tradables

Table 1: LR impact

<table>
<thead>
<tr>
<th></th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>1.3</td>
</tr>
<tr>
<td>Consumption</td>
<td>1.9</td>
</tr>
<tr>
<td>GFCF</td>
<td>2.1</td>
</tr>
<tr>
<td>Exports</td>
<td>1.5</td>
</tr>
<tr>
<td>Imports</td>
<td>0.3</td>
</tr>
<tr>
<td>Human wealth</td>
<td>1.2</td>
</tr>
<tr>
<td>Real wage (firms)</td>
<td>0.5</td>
</tr>
<tr>
<td>Labour inc. tax (pp.)</td>
<td>-2.0</td>
</tr>
<tr>
<td>NFA ( % GDP)</td>
<td>4.7</td>
</tr>
<tr>
<td>Real exch. rate (+ depr.)</td>
<td>1.5</td>
</tr>
<tr>
<td>Domestic ToT (+ depr.)</td>
<td>1.7</td>
</tr>
<tr>
<td>Price tradables</td>
<td>0.3</td>
</tr>
<tr>
<td>Price non-tradables</td>
<td>-1.4</td>
</tr>
<tr>
<td>Tradables output</td>
<td>2.0</td>
</tr>
<tr>
<td>Non-tradables output</td>
<td>1.4</td>
</tr>
<tr>
<td>Tradables hours</td>
<td>1.7</td>
</tr>
<tr>
<td>Non-tradables hours</td>
<td>1.2</td>
</tr>
</tbody>
</table>

1. Real exchange rate depreciation
   \[(p^N \downarrow, p^T \uparrow) \Rightarrow \lambda^F \downarrow \Rightarrow (p^X \downarrow, \epsilon \uparrow)\]

2. Higher demand for domestic intermediates and final goods
   \[(p^X \downarrow, \epsilon \uparrow) \Rightarrow X \uparrow \]
   \[\epsilon \uparrow \Rightarrow (Z^T \uparrow, M \uparrow)\]

3. Increase in the capital intensity of output
   \[(p^I/v) \downarrow \Rightarrow (K/L) \uparrow\]

4. Households’ consumption increases
   \[(w \uparrow, \tau_L \downarrow) \Rightarrow hw \uparrow; fw \uparrow \Rightarrow C \uparrow\]

Source: Own calculations
The impact of increasing competition in labour market

**Table 2: LR impact**

<table>
<thead>
<tr>
<th></th>
<th>NT</th>
<th>W</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GDP</strong></td>
<td>1.3</td>
<td>1.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Consumption</td>
<td>1.9</td>
<td>1.7</td>
<td>3.5</td>
</tr>
<tr>
<td>GFCF</td>
<td>2.1</td>
<td>0.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Exports</td>
<td>1.5</td>
<td>1.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Imports</td>
<td>0.3</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Human wealth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real wage (firms)</td>
<td>0.5</td>
<td>-0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Labour inc. tax (pp.)</td>
<td>-2.0</td>
<td>-1.2</td>
<td>-3.2</td>
</tr>
<tr>
<td>NFA (% GDP)</td>
<td>4.7</td>
<td>4.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Real exch. rate (+ depr.)</td>
<td>1.5</td>
<td>0.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Domestic ToT (+ depr.)</td>
<td>1.7</td>
<td>0.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Price tradables</td>
<td>0.3</td>
<td>-0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Price non-tradables</td>
<td>-1.4</td>
<td>-0.3</td>
<td>-1.7</td>
</tr>
<tr>
<td>Tradables output</td>
<td>2.0</td>
<td>1.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Non-tradables output</td>
<td>1.4</td>
<td>0.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Tradables hours</td>
<td>1.7</td>
<td>2.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Non-tradables hours</td>
<td>1.2</td>
<td>1.1</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Source: Own calculations

1. Real exchange rate depreciation
   \[ (p^N, p^T) \downarrow \Rightarrow \lambda^F \downarrow \Rightarrow (p^X \downarrow, \epsilon \uparrow) \]

2. Higher demand for domestic intermediates and final goods
   \[ (p^X \downarrow, \epsilon \uparrow) \Rightarrow X \uparrow \]
   \[ \epsilon \uparrow \Rightarrow (Z^{TF} \uparrow > M^F \uparrow) \]

3. Higher labour intensity
   \[ (v/p^I) \downarrow \Rightarrow (K/L) \downarrow \]

4. Households’ consumption increases
   \[ D^U \downarrow < (w \uparrow, \tau_L \downarrow) \Rightarrow hw \uparrow \]
   \[ ; fw \uparrow \Rightarrow C \uparrow \]

R. Félix (BdP)
Increasing competition in the domestic markets Simulation design and results

Implementation issue: SR negative impact on consumption

Figure 3: SR impact

1. Real interest rate increases temporarily \((\pi \downarrow; \bar{i}) \Rightarrow r \uparrow\)

2. Households' consumption declines \(r \uparrow \Rightarrow hw \downarrow \Rightarrow C \downarrow\)

3. Higher demand, hours increase \(\pi \downarrow \Rightarrow \epsilon \uparrow \Rightarrow Y \uparrow \Rightarrow L \uparrow\)
The impact of increasing competition: main findings

- Increasing competition in domestic markets promotes the real exchange rate adjustment of the Portuguese economy within the EMU
- A cut in non-tradable goods prices and wage markups improves international competitiveness and boost economic activity
- Practical implementation issue: short-run negative impact in consumption and leisure
- Estimated impacts are on the downside: fiercer competition induces productivity gains not considered
The Portuguese economy in the EMU: a story of shocks and frictions (ongoing research!)

Aim of the study

Assess the performance of the Portuguese economy in the EMU through the lens of a DSGE model and draw some policy implications (if there are some!)

Structure of the article

- Empirical evidence and identification of some stylised facts
- Main shocks and the role of frictions
  - S1 Total factor productivity slowdown
  - S2 The fiscal policy imbalance and the fiscal consolidation
  - S3 The aftermath of the sharp interest rate decline
  - S4 Fiercer competition in international goods markets
  - S5 Still low competition in domestic markets
- Policy implications (hopefully some will arise!)
Directions for further research

- Extend the calibrated version of the model to include
  - Macro-financial linkages
  - The role of commodities, in particular oil
  - Search and matching frictions in the labour market
- Estimate a stripped down version of the model using Bayesian techniques
- Phase-in the model in regular projection and simulation activities
DSGE modelling at the Banco de Portugal

Ricardo Mourinho Félix

Economics and Research Department, Banco de Portugal

IMF Macro Modelling Workshop

Washington, DC

January 6-9, 2009
The regulatory stance in Portugal (A1)

Figure 4: PMR indicators
The regulatory stance in Portugal (A2)

Figure 5: EPL indicators

Employment protection legislation

Collective dismissals

Regular employment: difficulty of dismissal

Regular employment: notice and severance pay for no-fault individual dismissals
The regulatory stance in Portugal (A3)

Figure 6: Weight of administered prices in HICP
Introducing *PESSOA*

**Figure 7: Model flowchart**

- **Households**
  - Labour unions
    - Tradable goods manufacturers
      - Consumer goods retailers
        - Foreign suppliers
      - Export goods retailers
    - Non-tradable goods manufacturers
      - Investment goods retailers
        - Foreign customers
      - Government

Figure 8: The households’ flowchart
Appendix

Firms

Figure 9: The firms’ flowchart

[Flowchart image]

Retailers

Manufacturers

Domestic primary inputs

Rest of the world inputs

M = MC + MI + MX + MG

R. Félix (BdP)
OLG households

Optimal aggregate conditions

\[
\frac{C_t^{OLG}}{n(1 - \psi) - L_t^{OLG}} = \left( \frac{\eta^{OLG}}{1 - \eta^{OLG}} \right) (1 - \tau_{L,t}) w_t
\]

\[i_t = i_t^*\]

\[C_t^{OLG} = mpc_t \left( hw_t^L + hw_t^K + fw_t \right)\]

\[hw_t^L = n(1 - \psi)w_t(1 - \tau_{L,t}) + \frac{\theta_X}{r_t} hw_{t+1}^L\]

\[hw_t^K = (1 - \iota) \left( d_t^N + d_t^T + d_t^C + d_t^G + d_t^I + d_t^X \right) + (1 - \psi) \left( d_t^U + trg_t + trx_t \right) + \frac{\theta}{r_t} hw_{t+1}^K\]

\[fw_t = r_{t-1} \left[ b_{t-1} + b_{t-1}^* \cdot \epsilon_{t-1} \right] \]
Labour unions

The equilibrium condition: a wage Phillips curve

\[
\frac{\sigma_{U,t}}{\sigma_{U,t} - 1} w_t - v_t = \\
= \frac{\phi U T_t}{\sigma_{U,t} - 1} \left( \frac{\pi V_t}{\pi V_{t-1}} - 1 \right) \frac{\pi V_t}{\pi V_{t-1}} - \left( \frac{1 - \tau_{L,t+1}}{1 - \tau_{L,t}} \right) \theta \frac{U_{t+1} T_{t+1}}{U_t} \frac{\phi U}{\sigma_{U,t} - 1} \left( \frac{\pi V_{t+1}}{\pi V_t} - 1 \right) \frac{\pi V_{t+1}}{\pi V_t}
\]

in steady-state:

\[
v = \frac{\sigma_U}{\sigma_U - 1} w
\]
Appendix

Manufacturers

The equilibrium conditions: a Phillips curve

\[
\frac{\sigma_{J,t}}{\sigma_{J,t} - 1} \frac{\lambda_t^J}{p_t^J} - 1 = \\
\frac{\phi_{P,J}}{\sigma_{J,t} - 1} \left( \frac{\pi_t^J}{\pi_{t-1}^J} - 1 \right) \frac{\pi_t^J}{\pi_{t-1}^J} - \left( \frac{1 - \tau_{K,t+1}}{1 - \tau_{K,t}} \right) \frac{\theta}{r_t} \frac{\phi_{P,J}}{\sigma_{J,t} - 1} \frac{p^J}{p_t^J} \frac{Z_t^J}{Z_t^J} \left( \frac{\pi_{t+1}^J}{\pi_t^J} - 1 \right) \frac{\pi_{t+1}^J}{\pi_t^J}
\]

in steady-state:

\[
p^J = \frac{\sigma_J}{\sigma_J - 1} \lambda^J
\]
Manufacturers

The equilibrium conditions: desired capital stock level

\[ q_t^J = \frac{\theta}{r_t} \frac{\pi_{t+1}}{\pi_t} \left[ q_{t+1}^J \left( 1 - \delta^J \right) + \frac{r_{K,t+1}^J}{p_{t+1}^I} - \tau_{K,t+1} \left( \frac{r_{K,t+1}^J}{p_{t+1}^I} - q_{t+1}^J \delta^J \right) \right] \]

\[ + \left( 1 - \tau_{K,t+1} \right) \frac{\theta}{r_t} \frac{\pi_{t+1}}{\pi_t} I_{t+1}^J \left[ \phi_K^J \left( \frac{I_{t+1}^J}{K_{t+1}^J} - \frac{I_J^J}{K_J^J} \right) + \phi_I^J \left( \frac{I_{t+1}^J}{K_{t+1}^J} - \frac{I_J^J}{K_J^J} \right) \right] \]

\[ - \left( 1 - \tau_{K,t+1} \right) \frac{\theta}{r_t} \frac{\pi_{t+1}}{\pi_t} \left[ \frac{\phi_K^J}{2} \left( \frac{I_{t+1}^J}{K_{t+1}^J} - \frac{I_J^J}{K_J^J} \right)^2 + \frac{\phi_I^J}{2} \left( \frac{I_{t+1}^J}{K_{t+1}^J} - \frac{I_J^J}{K_J^J} \right)^2 \right] \]

In steady-state, after-tax real return on capital equals the certain equivalent real return of government bonds.

\[ \frac{r}{\theta} = 1 + (1 - \tau_k) \left( \frac{r_{K}^J}{p_{t+1}^I} - \delta^J \right) \]
Appendix

Manufacturers

The equilibrium conditions: optimal investment path

Investment path condition depends on investment adjustment cost parameters.

\[ q_t^J = 1 + (1 - \tau_{K,t}) \left[ \phi_k^J \left( \frac{I_t^J}{K_t^J} - \frac{I_t^J}{K^J} \right) + \phi_I^J \left( \frac{I_t^J}{K_t^J} - \frac{I_{t-1}^J}{K_{t-1}^J} \right) \right] \]

In steady-state, Tobin’s-Q equals unity, market value of installed capital equals replacement cost.

The equilibrium conditions: optimal labour demand

\[ (1 + \tau_{SP,t}) v_t = \lambda_t^J \left( \frac{Z_t^J \alpha_{U}^J}{T_t A_t^J U_t^J} \right)^{\frac{1}{\xi Z_t^J}} T_t A_t^J \]
# Calibration: steady-state key ratios

## Table 3: Steady-state key ratios

<table>
<thead>
<tr>
<th>Expenditure (as a % of GDP)</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private consumption</td>
<td>0.64</td>
<td>0.61</td>
</tr>
<tr>
<td>Government consumption and GFCF</td>
<td>0.22</td>
<td>0.21</td>
</tr>
<tr>
<td>Private investment</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>Exports</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>Imports</td>
<td>0.37</td>
<td>0.33</td>
</tr>
<tr>
<td><strong>Labour income share (as a % of overall income)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tradable goods</td>
<td>0.57</td>
<td>0.56</td>
</tr>
<tr>
<td>Non-tradable goods</td>
<td>0.54</td>
<td>0.54</td>
</tr>
<tr>
<td>0.58</td>
<td></td>
<td>0.58</td>
</tr>
<tr>
<td><strong>Capital-output ratio (as a % of output)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tradable goods</td>
<td>NA</td>
<td>2.34</td>
</tr>
<tr>
<td>Non-tradable goods</td>
<td>NA</td>
<td>2.53</td>
</tr>
<tr>
<td>2.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Government (as a % of GDP)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt stock</td>
<td>0.57</td>
<td>0.53</td>
</tr>
<tr>
<td>Fiscal balance</td>
<td>-0.07</td>
<td>-0.02</td>
</tr>
<tr>
<td>Overall revenues</td>
<td>0.38</td>
<td>0.39</td>
</tr>
<tr>
<td>Overall expenditure</td>
<td>0.45</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>External account (as a % of GDP)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net foreign assets</td>
<td>-0.60</td>
<td>-0.60</td>
</tr>
<tr>
<td>Current account</td>
<td>-0.06</td>
<td>-0.02</td>
</tr>
<tr>
<td>Trade balance</td>
<td>-0.08</td>
<td>-0.04</td>
</tr>
</tbody>
</table>
## Calibration: households and labour union parameters

### Table 4: Households parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households discount rate (annualised)</td>
<td>$\beta$</td>
</tr>
<tr>
<td>Intertemporal elasticity of substitution</td>
<td>$\frac{1}{\gamma}$</td>
</tr>
<tr>
<td>OLG households instant probability of death (annualised)</td>
<td>$1 - \theta$</td>
</tr>
<tr>
<td>OLG households habit persistence</td>
<td>$\nu$</td>
</tr>
<tr>
<td>Consumption share - OLG households</td>
<td>$\eta_{OLG}$</td>
</tr>
<tr>
<td>Consumption share - LIQ households</td>
<td>$\eta_{LIQ}$</td>
</tr>
<tr>
<td>Lifetime productivity decline rate (annualised)</td>
<td>$1 - \chi$</td>
</tr>
<tr>
<td>Share of LIQ households</td>
<td>$\psi$</td>
</tr>
<tr>
<td>Share of dividend transfers from OLG to LIQ households</td>
<td>$\iota$</td>
</tr>
</tbody>
</table>

**Memo items:**
- Marginal propensity to consume wealth: 0.05
- Average planning horizon (years): 25
- Average worklife (years): 25

### Table 5: Labour union parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage mark-up</td>
<td>$\frac{\sigma_U}{\sigma_U - 1}$</td>
</tr>
<tr>
<td>Wage rigidity - Adjustment cost</td>
<td>$\frac{\phi_U}{1 - \sigma_U}$</td>
</tr>
</tbody>
</table>

**Memo items:**
- Duration wage contracts (quarters): 6.4
## Calibration: manufacturers parameters

### Table 6: Manufacturers parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tradable</th>
<th>Non-tradable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation rate (annualised)</td>
<td>$\delta$ 0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Labour augmenting prod. growth (annualised)</td>
<td>$g$ 1.02</td>
<td>1.02</td>
</tr>
<tr>
<td>EoS between capital and labour</td>
<td>$\xi_J$ 0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>Quasi labour income share</td>
<td>$\alpha_J$ 0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>Price markup</td>
<td>$\frac{\sigma_J}{\sigma_J - 1}$ 1.10</td>
<td>1.20</td>
</tr>
<tr>
<td>Capital adjustment cost</td>
<td>$\phi_{KJ}$ 50</td>
<td>50</td>
</tr>
<tr>
<td>Investment adjustment cost</td>
<td>$\phi_{IJ}$ 100</td>
<td>100</td>
</tr>
<tr>
<td>Price adjustment cost</td>
<td>$\phi_{PJ}$ 200</td>
<td>200</td>
</tr>
<tr>
<td>Memo items:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration price contracts (quarters)</td>
<td>3.9</td>
<td>5.7</td>
</tr>
</tbody>
</table>

R. Félix (BdP)
Appendix

Calibration: markups

Figure 10: Markups and PMR indicator

Tradables

Non-tradables

y = 0.0114x + 0.1058

y = 0.0996x + 0.0593

PMR indicator

R. Félix (BdP)
## Calibration: distributors parameters

### Table 7: Distributors parameters

<table>
<thead>
<tr>
<th></th>
<th>Consumer $F = C$</th>
<th>Govt. $F = G$</th>
<th>Invest. $F = I$</th>
<th>Export $F = X$</th>
</tr>
</thead>
<tbody>
<tr>
<td>EoS domestic tradable/imported good</td>
<td>$\xi_{AF}$ 1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Assembled good quasi domestic content</td>
<td>$\alpha_{AF}$ 0.12</td>
<td>0.02</td>
<td>0.02</td>
<td>0.19</td>
</tr>
<tr>
<td>EoS assembled/non-tradable good</td>
<td>$\xi_F$ 0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Non-tradable good (quasi) factor share</td>
<td>$\alpha_F$ 0.71</td>
<td>0.98</td>
<td>0.88</td>
<td>0.15</td>
</tr>
<tr>
<td>Price markup</td>
<td>$\sigma_{F} \frac{\sigma_F-1}{\sigma_F}$ 1.05</td>
<td>1.05</td>
<td>1.05</td>
<td>1.03</td>
</tr>
<tr>
<td>Import content adjustment cost</td>
<td>$\phi_{AF}$ 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Price adjustment cost</td>
<td>$\phi_{PF}$ 200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Memo items:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implied import content</td>
<td>0.29</td>
<td>0.10</td>
<td>0.40</td>
<td>0.30</td>
</tr>
<tr>
<td>Implied non-tradable content</td>
<td>0.38</td>
<td>0.88</td>
<td>0.53</td>
<td>0.05</td>
</tr>
<tr>
<td>Duration price contracts (quarters)</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Calibration: government and foreign economy parameters

Table 8: Government parameters

<table>
<thead>
<tr>
<th>Government parameter</th>
<th>( \tau_L )</th>
<th>( \tau_C )</th>
<th>( \tau_K )</th>
<th>( \tau_{SP} )</th>
<th>( \frac{b}{gdp} )</th>
<th>( d_{debt} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour income tax rate</td>
<td>0.29</td>
<td>0.30</td>
<td>0.17</td>
<td>0.19</td>
<td>0.53</td>
<td>0.10</td>
</tr>
<tr>
<td>Consumption tax rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital income tax rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employers social security contribution rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt to GDP ratio (annualised)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed adjustment towards the target debt ratio parameter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Foreign economy parameters

<table>
<thead>
<tr>
<th>Foreign economy parameter</th>
<th>( i^* )</th>
<th>( \pi^* )</th>
<th>( \xi^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign interest rate (annualised)</td>
<td>1.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign inflation (annualised)</td>
<td></td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>EoS between domestic and imported goods</td>
<td></td>
<td></td>
<td>1.50</td>
</tr>
</tbody>
</table>