Supplement of agent-based model "Mak(h)ro_0"

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22nd April 2022

Corresponding document
Title: "A basic macroeconomic agent-based model for analyzing monetary regime shifts"
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Citation: Florian Peters, Doris Neuberger, Oliver Reinhardt, and Adelinde M. Uhrmacher. A basic macroeconomic agent-based model for analyzing monetary regime shifts, 2022. URL `https://arxiv.org/pdf/2205.00752`

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Revision History

Revision	Date	Author(s)	Description
0.0.0	Date	Name	Action

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Contents

1 Introduction

This supplement corresponds to the macroeconomic agent-based model "Mak(h)ro_0" which is implemented in ML3 and SESSL (Reinhardt et al. [2022]) and serves as a guidance document between the model description (Peters et al. [2022]) and simulation environment. The purpose of the model is to provide a baseline simulation model that support studies to compare different monetary systems concerning their macro-financial stability features.

2 Model variables and parameter

2.1 Variables

The model variables with their corresponding initial values are arranged by agent-type and listed in the ML3-file between lines 1 to 125. Table 2 presents the main variables, giving a short description and the symbol used in the model description (Peters et al. [2022]).

2.2 Parameter

The model parameters with their corresponding baseline values are arranged by model entities and listed in the ML3-file between lines 146 to 194 and in the scala-file (SESSL) between lines 26 and 94. Table 3 presents all parameters, giving a short description and the symbol used in the model description (Peters et al. [2022]).

3 ML3 code arrangement

To combine the model description (Peters et al. [2022]) with the model implementation in ML3, the provenance model (Figure 3 in Peters et al. [2022]) serves as a template. Table 4 gives an overview of the entities' code locations. ML3-Rules which are specifically related to accounting can be found in lines 444 - 530 for firms and lines 1,230 - 1,255 for banks. The interbank experiment can be found in lines 1,442 - 1,515.

4 Validation

The validation outcome presented in Section 5 of the model description (Peters et al. [2022]) has been conducted with R. The corresponding R-scripts are provided in the repository and need to be adapted with respect to the working directory and path to the simulation outcome. The R-scripts are named according to the stylized facts (SF) used for the validation. The relative standard deviations, mentioned in Section 5.1 (SF1), are calculated in the R-Script "SF3_cross_macro" (lines 248 ff.). The representative simulation run as stated in SF1, SF2, SF4, SF6, SF9, and SF10, is named "run-0.csv" in the corresponding repository folder (Simulation replications). The other stylized facts have been produced using all 20 simulation replications combined in a data frame that spans 12,000 periods (without the warm-up phase of 200 periods for each simulation replication).

Interbank market experiment (SF13) To replicate the interbank experiment (lines 1,442 - 1,515 in ML3) the variable "nowness" has to be added to the variable list for the Central Bank (lines 94 ff. in ML3) and the open market transaction mechanism (lines 1276 - 1297 in ML3) has to be deactivated. It is recommended to use at least three replications (line 18 in SESSL), since the interbank rate at the start of the experiment phase, around period 50, can be disrupted by

Table 2: Variables Mak(h)ro_0

ML3[a]	Symbol[b]	Description	Initial value[c]
Goods market			
Firm			
price	p_i	price of a good	1
targetProduction	$Y_i^{T\prime}$	target production	-
demand	D_i	total demand of a good per period	1
inventory	N_i	stock of produced goods	50
liquidity	Liq_i	firm cash at bank deposit	100
turnover	-	total sales of produced goods per period	-
equity	E_i	equity at bank deposit	100
debt	L_{ib}[d]	loan liabilities and withdraw facility	-
wage	-	wage costs per employee	2
profitAfterTax	-	earnings after taxes	-
consumptionUnit	q_i^C	real consumption sales (in good units)	-
consumption	-	nominal consumption	-
Household			
wealth	Liq_h	financial wealth or bank deposits	2
Government			
debt	D_g	debt account	-
liquidity	Liq_g	liquidity account	-
Investment market			
investment	inv_i[e]	investment amount in investment strategy	10
investmentConsumeUnit	q_i^I	real investment sales (in good units)	-
investmentConsume	-	nominal investment sales	-
investmentAmount	-	investment amount consumed	10
investmentTurnover	-	investment sales of produced goods	1
investmentCosts	-	investment purchase of produced goods	-

[a] Variable definition in ML3 code.
[b] Variable definition in model description (Peters et al. [2022]).
[c] Variable value in ML3 code.
[d] ML3 code also includes withdraw facility.
[e] The investment target is also captured.

Table 2: Variables Mak(h)ro_0 (continued)

ML3[a]	**Symbol**[b]	**Description**	**Initial value**[c]
		Credit market	
Firm			
depositProfit	-	deposit interest earnings	-
Bank			
equity	E_b	equity level	10
liquidity	R_{bc}	liquidity level at Central Bank account	10
margin	m_b	interest mark-up	0.01
creditDemandLeverage	-	credit demand without firm solvency weighting	-
creditDemandSolvency	-	credit demand with firm solvency weighting	-
riskLevel	υ_b	risk level	1
Central Bank			
keyRate	i_c	main refinancing operation	0.01
priceInflation	-	nominal inflation indicator	-
demandInflation	-	sum of sold goods within the economy	-
inflationBasis	-	inflation identification of previous inflation measurement	2

[a] Variable definition in ML3 code.
[b] Variable definition in model description (Peters et al. [2022]).
[c] Variable value in ML3 code.

Table 2: Variables Mak(h)ro_0 (continued)

ML3[a]	Symbol[b]	Description	Initial value[c]
Interbank market			
Bank			
depositMargin	-	deposit interest mark-up	0.0001
interbankMargin	im_b	interbank interest mark-up	0.01
depositDemand	-	deposit demand by households and firms	-
reservesDemand	RD_b	reserve demand by banks with a shortage of reserves	-
basisMoney	R_b	reserves	100
reserveRequirement	-	defines reserves amount in relation to fraction of deposits	105
centralLoan	-	loan liabilities to the Central Bank	-
interbankVolume	-	transaction volume of reserves between banks	-
centralCosts	-	interest costs of Central Bank loans	-
interbankCosts	-	interest costs of interbank loans	-
interbankProfit	-	interest profits of interbank loans	-
Central Bank			
basisMoney	R_{cb}	reserves	-
lendingFacility	-	lending facility	-

[a] Variable definition in ML3 code.
[b] Variable definition in model description (Peters et al. [2022]).
[c] Variable value in ML3 code.

Table 3: Parameter Mak(h)ro_0

ML3[a]	Symbol[b]	Description	Baseline[c]
Goods market			
Firm			
productivityBase	α	productivity factor	2
fullEmployment	u_{nat}	natural unemployment rate	0.05
gamma_y	γ_y	production change sensitivity	0.15
gamma_p	γ_p	price change sensitivity	0.11
inventoryTarget	N_i^T	relative inventory target	2
zeta_h	ζ_h	sensitivity of employee hiring process	0.65
zeta_f	ζ_f	sensitivity of employee firing process	0.50
insolvencyRatio	-	maximum debt ratio	2
minEquityRatio	-	minimum equity ratio	0.40
minEmployees	-	minimum employee size	5
avgPrice	$\overline{p}$	average price path	1.50
Other			
delta	-	global parameter	0.8
tax	-	government tax	0.10
benefit	-	unemployment benefit	1
Investment market			
Firm			
gamma_inv	γ_inv	investment change sensitivity	1
investmentDuration	dur	investment loan duration	18
minInvestCycle	-	maximum investment frequency	3
Credit market			
Bank			
gamma_m	γ_m	loan interest margin sensitivity	0.001
gamma_r	γ_r	risk level sensitivity	0.10
loanDuration	dur	global loan duration	18
ratioSolvency	-	capital requirement	0.07
ratioLeverage	-	leverage requirement	0.03
creditTarget	-	credit creation buffer	0.10
probabilityDefault	pd_{ib}	max default probability	0.50
Central Bank			
inflationTarget_inv	π	inflation target	0.02
naturalInterest	i^*	global interest level	0.10

[a] Parameter definition in ML3 code.
[b] Parameter definition in model description (Peters et al. [2022]).
[c] Parameter value in ML3 code.

Table 3: Parameter Mak(h)ro_0 (continued)

ML3[a]	Symbol[b]	Description	Baseline[c]
Interbank market			
Bank			
gamma_i	γ_i	interbank interest change sensitivity	0.001
interbankFrequency	-	interaction frequency	20
Central Bank			
facilityRange	-	interest rate corridor	0.01
fractionalReserve	-	minimum reserve requirement	0.01
Deposit market			
Bank			
gamma_d	γ_d	deposit interest change sensitivity	0.001
depositBuffer	-	interaction frequency	0.03
Household			
hhAccountChange	-	bank account change frequency	12
accountFluctuationHH	-	minimum reserve requirement	0.10
Firm			
firmAccountChange	-	bank account change frequency	120

[a] Parameter definition in ML3 code.
[b] Parameter definition in model description (Peters et al. [2022]).
[c] Parameter value in ML3 code.

Table 4: Mak(h)ro_0 code line location in ML3 by entities

Note: Link between provenance model (Figure 3 in Peters et al. [2022]) and ML3 code location.

Entity	**Code line location in ML3**
Real economy	195 - 530
Goods market	199 - 342
goods supply	202 - 261
labor market	262 - 280
goods demand	281 - 310
bankruptcy	311 - 342
Investment market	343 - 443
investment cycle	347 - 413
investment demand	414 - 443
fiscal	1,367 - 1,388
Financial sector	531 - 1,366
Credit market	535 - 909
credit demand	538 ff.
credit supply	550 - 883
bank bailout	884 - 909
Monetary system	910 - 1,229
interbank	922 - 1,229
monetary policy	1273 - 1,366

excessive bank lending. This effect occurs because the Central Bank has no control over the interbank rate in the experiment phase. The stop time (line 22 in SESSL) needs to be set to 150.

References

Florian Peters, Doris Neuberger, Oliver Reinhardt, and Adelinde M. Uhrmacher. A basic macroeconomic agent-based model for analyzing monetary regime shifts, 2022. URL `https://arxiv.org/pdf/2205.00752`.

Oliver Reinhardt, Tom Warnke, and Adelinde M. Uhrmacher. A language for agent-based discrete-event modeling and simulation of linked lives. *ACM Transactions on Modeling and Computer Simulation*, 32(1):1–26, 2022. ISSN 1049-3301. doi: 10.1145/3486634.