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Introduction

In this deliverable we discuss the internal logical consistency of the fully integrated EURACE model. This reflects the focus of WP8, i.e., the development, integration and validation of the EURACE model. We placed all scenarios or policy experiments in the "policy oriented" WP9. This way of organizing the results may not, strictly speaking, correspond to the terms of the proposal, but contributes to a better comprehension of our advances without loss of substance.

Chapter 1 describes the construction of a system of national accounts for EURACE, with all the interlinkages between the balance sheets of the agents. We provide the set of accounting rules that is satisfied if and only if the model is stock-flow consistent. We have verified that this is the case for the fully integrated model, thereby validating the internal logical consistency of all monetary and physical flows.

Chapter 2 shows that the model is robust against changes in critical model parameters and against scaling of the population size. It also shows how a switch from synchronous to asynchronous activities of the agents affects the results.

Finally, Chapter 3 presents benchmark results for the Integrated Model used in the more elaborate policy experiments presented in D9.1-D9.3.

Chapter 1

System of National Accounts

1.1 Stock-flow consistent models

An important part of the testing and verification process will be the verification of the internal consistency of the model. For this task we need a stock-flow consistent (SFC) model, that can be defined as:

> "[...] models that identify economic agents with the main social categories/institutional sectors of actual capitalist economies – thoroughly describe these agents' short-period behaviors and consistently model the 'period by period' balance sheet dynamics implied by the latter." (Macedo e Silva and Dos Santos (2008, p. 2))

Using a SFC model we need to check that all monetary flows are accounted for, and that all changes to stock variables are consistent with these flows. This can be accomplished by tracking the time evolution of the balance sheets across the different sectors of the economy. This could be done by constructing a Social Accounting Matrix (SAM) that contains all the monetary flows and changes to the balance sheet between the beginning and end of an accounting period. A SAM consists of a double-entry accounting system in which each flow comes from somewhere and goes to somewhere. It shows how the balance sheets of the different economic sectors (agents) are interlinked, and it also shows how the period-by-period balance sheets change dynamically over time. Such an accounting system at the macro level provides us with a number of accounting identities that should always hold and this can be tested by an external invariant detector such as Daikon.

This provides us with a solid and economically well-founded methodology to test the consistency of the model and it increases the credibility that can be attached to the model's results. Thereby it is not only part of the testing and verification procedure, but is also part of the accreditation process. It will help to raise the acceptability and trust in the model.

1.2 Balance sheets

Below we list for each agent type the items on its balance sheet. The cash flows indicated only relate to the financing activities.

1.2.1 Household

Table 1.1 and 1.2.

Households can have bank deposits (M^h) but they do not receive any interest ($r^m M^h = 0$). They can purchase government bonds (B^h) and private equity shares (E^h). They do not take out bank loans. They receive interest on the government bonds ($+r^g B^h$) and dividends on the shares ($+Div^h$). The equity transactions are denoted in this text as a share purchase by the household ($-SP^h$) or a share repurchase by the firm ($+SR^h$).

1.2.2 Firm - CGP and IGP

Table 1.3,1.4,1.5.

Firms can have bank deposits (M^f) and bank loans (L^f). They do not receive any interest on the deposits ($r^m M^f = 0$), but do have to pay interest on the loans ($r^b L^f$). They can also issue equity shares (E^f) on which they pay dividends ($-Div^f$). They can also do a share repurchase (SR^f). They they do not purchase government bonds, or shares of other firms.

1.2.3 Bank

Table 1.6 and 1.7.

Banks can issue equity shares on which they pay dividends (E^b, $-Div^b$). They have a portfolio of outstanding loans (L^b) on which they receive interest ($+r^b L^b$) and debt instalment payments ($-\Delta L^b$). They do not purchase government bonds, and they do not purchase shares in other firms or banks. The banks have a standing facility with the Central Bank from which they can draw advances freely (A^b), on which they have to pay an interest to the Central Bank ($-r^{cb} A^b$).

1.2.4 Government

Table 1.8 and 1.9.

The government has a bank account at the Central Bank. If there are any changes to the payment account of the government (i.e. withdrawals to pay for unemployment benefits or subsidies) this is recorded as a change in the stock of the asset M^g ($-\Delta M^g$), with a counterpart liability on the balance sheet of the Central Bank ($+\Delta M^g$). The government also has a standing facility at the Central Bank that allows it to have a negative payment account. The government has a liability that is given by the stock of currently outstanding government bonds (B^g) on which it pays the interest rate ($-r^g B^g$).

1.2.5 Central Bank

Table 1.11 and 1.10.

The Central Bank can purchase government bonds (B^{cb}) on which it receives interest ($+r^g B^{cb}$). The Central Bank gives advances to the banks ($-\Delta A^{cb}$), on which the banks have to pay an interest ($+r^{cb} A^{cb}$). Since the Central Bank is not allowed to make a profit, its revenues from government bonds and bank advances ($+r^g B^{cb}$, $+r^{cb} A^{cb}$) are distributed to the government in the form of a dividend ($-Div^{cb}$). In case of multiple governments, the total dividend payment is equally divided among the governments.

Table 1.1: Household balance sheet.

Assets	Liabilities
Cash deposits	(none)
Government bonds	
Firm stocks	

Table 1.2: Household cash flow.

Positive cash flows	Negative cash flows
Cash flow from employment activities:	
Salary	Consumption expenditure
Benefits	Tax payments
Subsidies	
Transfers	
Cash flow from financing activities:	
Interest on gov bonds	Gov bond purchases
Firm share sales	Firm share purchases
Dividend income	
Total income	Total expenses

Table 1.3: Firm income statement (CGP/IGP).

Revenues from sales of goods and services
Operating expenses:
– total payroll
– investment payments (CGP) or energy costs (IGP)
= Operating income (earnings before interest and taxes)
Non-operating expenses:
– interest payments
– debt repayments
= Gross income (earnings before taxes)
– tax payments
= Net income (net profit)

Table 1.4: Firm balance sheet.

Assets	Liabilities
Cash deposits	Total debt
Total value physical capital stock	Shareholder equity
Total value local inventory stocks	

Table 1.5: Firm cash flow (CGP and IGP differ only in the item Investment costs or Energy costs).

Positive cash flows	Negative cash flows
Cash flow from operating activities:	
Sales revenues	Total payroll
	Investment costs (CGP)
	Energy costs (IGP)
	Tax payments
Cash flow from financing activities:	
New loans	Debt installment payments
	Interest payments
New share issues	Dividend payout
Total income	Total expenses

Table 1.6: Bank balance sheet.

Assets	Liabilities
Cash	Total deposits
Loans to firms	ECB debt
	Shareholder equity

Table 1.7: Bank cash flow.

Positive cash flows	Negative cash flows
Loan installments	New loans to firms
Interest payments	Interest on ECB debt
	Dividend payout
	Tax payment
Total income	Total expenses

Table 1.8: Government balance sheet.

Assets	Liabilities
Gov. cash holdings	Outstanding bonds

Table 1.9: Government cash flow.

Positive cash flows	Negative cash flows
Cash flow from public sector activities:	
Tax revenues	Investments
	Consumption
	Total unemployment benefit payments
	Total subsidy payments
	Total transfer payments
Cash flow from financing activities:	
New bond issues	Bond interest payments
Total income	Total expenses

Table 1.10: Central Bank balance sheet.

Assets	Liabilities
Loans to banks	Payment accounts of banks and govs
Gov bond holdings	Fiat money
	ECB equity

Table 1.11: Central Bank cash flow.

Positive cash flows	Negative cash flows
Interest on ECB loans to banks	New ECB loans to banks
Gov bond interest payment	Gov bond purchases
Gov cash deposits	
Bank cash deposits	
Total income	Total expenses

1.3 Social accounting matrix

The social accounting matrix in Table 1.12 is based on the following set of assumptions:

- There are four types of financial assets: cash holdings in the form of bank deposits, bank loans, government bonds, and private equity shares (issued by firms and banks). There is no cash hoarding since all money is held inside the banking sector.
- Every agent has a current account and a capital account. All flows (income and payments) are on the current account while all changes in asset holdings are on the capital account.
- Pure capital gains from holdings of equity must be added separately, since there are no transactions underlying them.
- All rows sum to zero, except current savings, which indicates a net wealth creation by the private sector and the public sector combined.

Account	Household		Firm I (CGP)		Firm II (IGP)		Bank		Government		CB		Total
	current	capital	current	capital	current	capital	current	capital	current	capital	current	capital	
Real economic activity													
Consumption	$-C$		$+C$										0
Gov. cons			$+G$						$-G$				0
Investment			$-I^{fI}$		$+I^{fI}+I^{g}$				$-I^{g}$				0
Salaries	$+W$		$-W^{fI}$		$-W^{fII}$								0
Taxes	$-T^{h}$		$-T^{fI}$		$-T^{fII}$				$+T$				0
Financing activity													
Share purchase	$-SP^{h}$		$+SP^{fI}$		$+SP^{fII}$		$+SP^{b}$						0
Share repurchase	$+SR^{h}$		$-SR^{fI}$		$-SR^{fII}$		$-SR^{b}$						0
Dividend on stocks	$+Div^{h}$		$-Div^{fI}$		$-Div^{fII}$		$-Div^{b}$		$+Div^{cb}$		$-Div^{cb}$		0
Interest on deposits	$r^{m}M^{h}=0$		$r^{m}M^{fI}=0$		$r^{m}M^{fII}=0$		$r^{m}M=0$						0
Interest on bank loans			$-r^{b}L^{fI}$		$-r^{b}L^{fII}$		$+r^{b}L^{b}-r^{cb}A^{b}$				$+r^{cb}A^{cb}$		0
Interest on gov. bonds	$+r^{g}B^{h}$								$-r^{g}B^{g}$		$+r^{g}B^{cb}$		0
Public sector activity													
Benefits	$+Ben^{h}$								$-Ben$				0
Subsidies	$+Sub^{h}$		$+Sub^{fI}$		$+Sub^{fII}$				$-Sub$				0
Transfers	$+Tr^{h}$		$+Tr^{fI}$		$+Tr^{fII}$				$-Tr$				0
Current savings	Sav^{h}		$Prof^{fI}$		$Prof^{fII}$		$Prof^{b}$		Sav^{g}		0		$+SAV$
Changes in asset stocks													
ΔBank deposits		$-\Delta M^{h}$		$-\Delta M^{fI}$		$-\Delta M^{fII}$		$+\Delta M^{b}$		$-\Delta M^{g}$		$+\Delta M^{g}$	0
ΔBank loans to firms				$+\Delta L^{fI}$		$+\Delta L^{fII}$		$-\Delta L^{b}$					0
ΔCB loans to banks								$+\Delta A^{b}$				$-\Delta A^{cb}$	0
ΔGov. bonds		$-\Delta B^{h}$								$+\Delta B^{g}$		$-\Delta B^{cb}$	0
ΔFirm shares		$-\Delta E^{h}$		$+\Delta E^{fI}$		$+\Delta E^{fII}$		$+\Delta E^{b}$					0
Current savings													
+ net capital transactions	0		0		0		0		0		0		$+SAV$

Table 1.12: Social accounting matrix (SAM) of monetary flows between different sectors of the economy. The variables denote sums over all agents in each sector. The top section of the table indicates the cash flows, the bottom half denotes the changes in asset holdings. A (+) sign denotes a receipt while a (−) sign denotes a payment.

1.4 Validation rules

To validate the internal consistency of the model we list 20 rules that we have successfully tested. On the one hand these rules are balance sheet accounting identities, and on the other they are conservation rules for material quantities and monetary values. Having thus validated the model we are confident that the EURACE model is stock-flow consistent, and can form a solid basis for further extensions in the future.

Balance sheet identities

RULE 1

Firm balance sheet: assets and liabilities.

```
firm_payment_account+firm_total_value_local_inventory+firm_total_value_capital_
stock=firm_total_debt+firm_equity
```

RULE 2

IGFirm balance sheet: assets and liabilities, all net profits are paid in dividends.

```
igfirm_net_profit=igfirm_dividend_per_share*igfirm_shares_outstanding
```

RULE 3

Bank balance sheet: assets and liabilities.

```
bank_cash+bank_credit=bank_equity+bank_ecb_debt+bank_deposits
```

RULE 4

Government total debt is the value of its outstanding bonds.

```
gov_total_debt=gov_value_bonds*govt_outstanding_bonds
```

RULE 5

ECB: The issued fiat money to government(s) equals the total value of bond holdings of the ECB.

```
ecb_bond_holdings_value+ecb_cash=ecb_fiat_money_govs+ecb_fiat_money_banks
```

Aggregates across sectors

RULE 6

Payment accounts: aggregate bank deposits equals the sum of payment accounts in agent memory.

```
bank_deposits=firm_payment_account+igfirm_payment_account+hh_payment_account
```

RULE 7

Credit money: aggregate Bank credit outstand equals total loans to firms.

```
bank_credit=firms_total_loans
```

RULE 8

Definition of GDP.

```
eurostat_monthly_gdp=eurostat_monthly_investment_value+household_expenditure+
govt_monthly_cons_expenditure
```

RULE 9

Total number of shares outstanding equals the total number of shares in household portfolios.

```
household_assets=firm_current_shares_outstanding+igfirm_shares_outstanding+bank_
current_shares_outstanding+govt_outstanding_bonds
```

RULE 10

Debt installment payments by firms to banks and received by banks are equal. `firm_debt_installments=bank_loan_installments`

RULE 11

Interest payments by firms to banks and received by banks are equal.

```
firm_interest_payments_to_banks=bank_interest_payments_from_firms
```

RULE 12

Taxes paid and received are equal.

```
govt_monthly_tax_revenues=firm_tax_payment+igfirm_tax_payment+household_tax_payment+
bank_tax_payment
```

RULE 13

Deposits at ECB.

```
ecb_deposits=bank_payment_account+gov_payment_account
```

RULE 14

Check the number of active firms.

```
eurostat_no_firms=firm_active+eurostat_no_firm_bankruptcies
```

RULE 15

Daily dividend payments send and received are equal.

```
firm_total_dividends+igfirm_total_dividends+bank_total_dividends=household_dividend_daily
```

RULE 16

Material quantity conservation rule: Eurostat total sold quantity compared with firm data on number of goods sold (in volume).

```
eurostat_monthly_sold_quantity=firm_total_sold_quantity_volume
```

RULE 17

Investments in monetary value: Eurostat data (aggregated across the firms' investment costs) equals the IGFirm revenues.

```
eurostat_monthly_investment_value=igfirm_revenues
```

RULE 18

The Banks' aggregate ECB debt is found on the ECB balance sheet (`fiat_money_banks`, LHS), and on the banks' balance sheet (`bank_ecb_debt`, RHS). Similarly, the governments' debts are on the ECB balance sheet (`fiat_money_govs`, LHS), and equals the value of the ECB bond holdings (`bond_holdings_value`, RHS).

```
ecb_fiat_money_banks+ecb_fiat_money_govs=ecb_bond_holdings_value+bank_ecb_debt
```

RULE 19

ECB fiat money is by definition the sum of the fiat money created for governments and for banks.

```
ecb_fiat_money=ecb_fiat_money_govs+ecb_fiat_money_banks
```

RULE 20

Monetary conservation rule All deposits in the banking sector plus bank equity, plus the money in the public sector (government payment account), should equal the credit money created by the banks plus the fiat money created by the central bank.

```
bank_deposits+bank_equity+gov_payment_account+ecb_cash==bank_credit+ecb_fiat_money
```

Chapter 2

Robustness checks

In this chapter we want to give an impression how sensitive the model reacts to changes in the environment of the model. The robustness is demonstrated along three dimensions: First, we investigate the effect of a variation in a single model parameter; then we turn to the question whether there are differences in simulation results if the agents act synchronously or asynchronously; and finally we show the impact of scaling the population size.

For the robustness checks we compare the averaged time series of 10 batch runs over 5000 iterations for two key macroeconomic variables, output per capita and the unemployment rate. The general model set up is the same as has been used in Deliverable 9.1 for the innovation policy experiments (for a further discussion we refer to Deliverable 9.1 and the references listed there).

2.1 Parameter sensitivity

In the academic debate on agent-based modeling the parameterization of agent based models is still vulnerable to criticism due to the high number of degrees of freedom. One way to deal with such criticism is to directly estimate and calibrate the model using empirically based parameter values wherever possible. This has been done in EURACE to a high extent, nonetheless there remain some parameters which have no empirical counterparts or that are chosen in order to stabilize the simulation or yield plausible outcomes.

Which effect the variation of such a parameter potentially has on the simulation outcome is exemplified by varying a parameter used in the firm's production planning decision. Each Consumption goods producer determines once a month the delivery quantities for each mall. This decision is based on past demand quantities at all malls served by a firm and is formulated as a standard production and inventory planning model with stochastic demand that can be found in the standard management literature (see for example Nahmias (2008)). Every period the mall stock of a firm is replenished up to a level such that the probability of stock-out is at a specific level. This level, respectively the underlying quantile of the normal distribution is a model parameter in the EURACE model. This parameter induces production quantities, and therefore hiring and firing, and investments of firms. Hence it is a crucial driver of the qualitative features of the dynamics of the model.

In our standard set up this parameter is set to 0.842 corresponding to a stock-out probability of 20%. In addition to the standard value and in order to investigate the sensitivity, we ran simulations with a probability of 90%, 50%, and 2.5%. The stabilizing effect of a low stock-out probability can be seen in Figure 2.1. If the planned mall stock is only sufficient to satisfy the

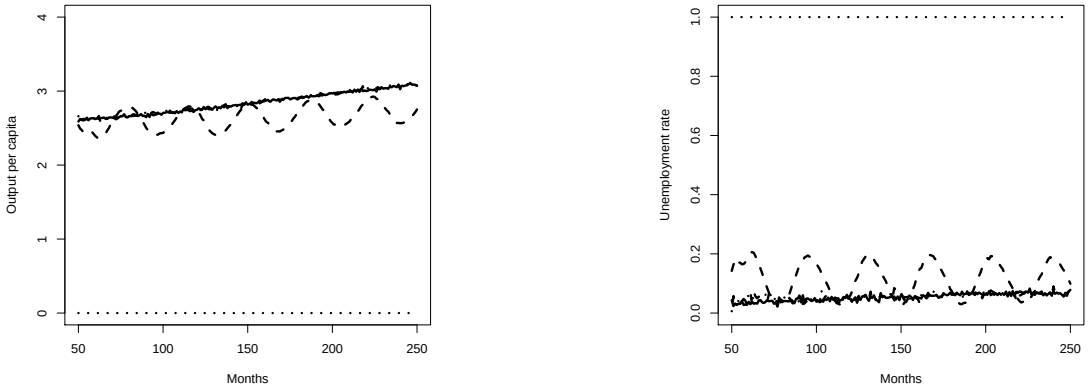

Figure 2.1: Sensitivity of the model to a variation in the stock-out probability on output per capita (left panel) and unemployment rate (right panel); 90 % dotted line, 50% dashed line, 20% solid line, and 2.5% dashed-dotted line.

expected demand with a probability of 10% (i.e. a stock-out probability of 90%) the economy collapses, immediately leading to full unemployment. But a stock-out probability of 50% already yields a completely different picture: The economy does not collapse, but output and unemployment oscillate with a constant cycle duration. With that probability the unemployment rate is already on a economically reasonable level. If the probability is decreased to a level of 20% the oscillation of both variables disappears and leads to a further decrease of the unemployment rate and output increase, respectively. Yet another reduction from 20% to 2.5% does not change the result significantly.

We carried out these robustness checks for several parameters to find plausible regions for them. A general point is that especially for those parameters driving the individual behavioral rules a elaborated robustness check is important as they influence the aggregated outcome of the simulation.

Summarizing, in this experiment we showed that the EURACE model is relatively robust against a change in the parametrization. We demonstrated the sensitivity to changes in model parameters by varying a parameter that is a crucial factor of the production planning of firms. As long as the parameter is set in an economically reasonable range, a variation does not change the performance, but outside of this range the outcome changes dramatically where in a very extreme case the simulation breaks down.

2.2 Time synchronization

In the second experiment we test if the time scale on which the agents make their decisions plays any role for the simulation outcome. In the majority of agent-based models there is a strong time-synchronization of actions because all agents make the same type of decisions simultaneously. In EURACE we have two different kinds of triggers for agent's actions: Event driven decisions are made if certain conditions in the agent's environment have changed and is reflected by a change in agent's memory (e.g. if a household becomes unemployed); however, most of the agent's decisions are calendar-time driven. This means there are fixed days in the month (respectively week or year) on which agents take certain actions. For example firms'

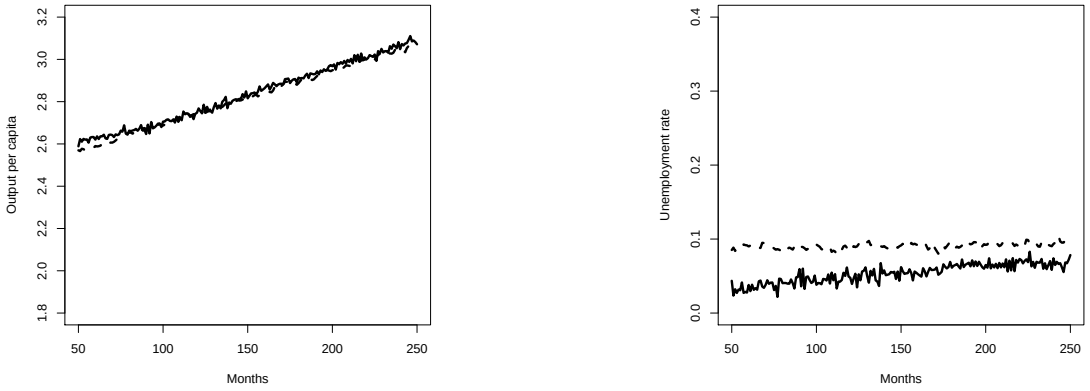

Figure 2.2: Differences in output per capita (left panel) and unemployment (right panel) of a asynchronized (solid line) versus synchronized (dashed line) decision making.

decision about their monthly production quantities are made on fixed days of the month. These days of the month to act can vary between agents such that we have asynchronized production cycles. In the other case these days coincide such that we have synchronized activation days. The timing of production cycles has a high potential to influence the comparative performance since it sets the day when firms enter the labour, credit, financial and consumption goods market; consequently, this determines whether on all these markets the activities of agents are completely synchronized or not. The EURACE framework allows to explicitly study the aggregate effects of time-synchronization of individual behavior by varying these activation days.

Figure 2.2 shows the influence of an asynchronized versus synchronized decision making process of agents on the macroeconomic variables output per capita and unemployment rate. The effect is not that noticeable but especially the impact on the unemployment rate is verifiable. The unemployment is lower when decisions are made asynchroneously.

2.3 Population scaling

The third experiment investigates the effect of scaling the population size thereby leaving the ratio between households and firms constant. Furthermore the initial production plan and the firm's endowment with capital and households' with wealth is not changed.

A priori the impact of the population size is not clear but it should be a very important point of interest when talking about agent-based macroeconomic models. The computational effort to run and analyze large-scale agent-based models is still enormous, and from that perspective the question is still worthwhile if there are additional gains from large-scale simulations in fact. So the question that could be posed is: Is it necessary to run a macro model with an empirically reasonable number of agents or is a small scale model also able to generate the same insights? Note that Axtell (2000) makes the point that in order to reproduce the firm size distribution one needs at least several millions of workers, since empirically the largest firm (Wall Mart) has 1.5 million employees, and there are one million companies with one worker (self employed).

Figure 2.3 indicates that the EURACE model is very robust against a variation of the population size. In terms of output per capita there is just a small difference that establishes after month 150 (iteration 3000), where a scaling effect on the unemployment rate is not detectable.

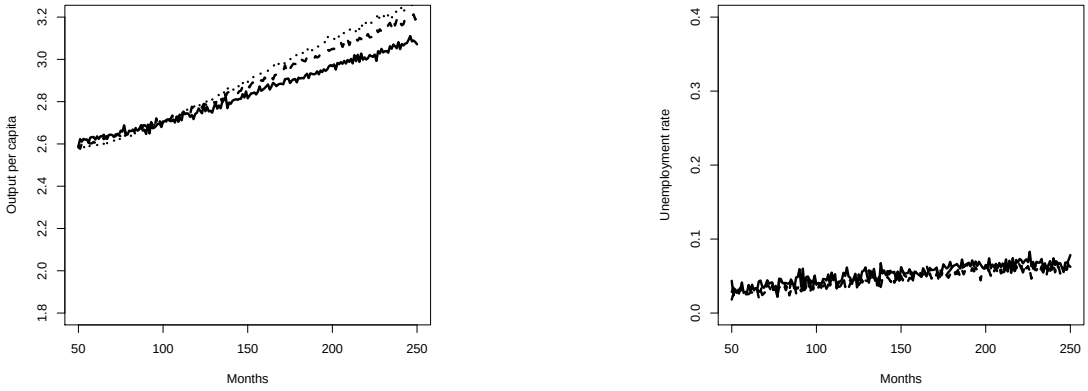

Figure 2.3: Impact of scaling of the agent population on aggregate output and unemployment; solid line 1600 households and 80 firms, dashed line 5000/250, and dotted line 10.000/500.

Thus, this final experiment pointed to the robustness against an increase in the number of agents in absolute terms where their relative number as well as the initial conditions are kept unchanged.

This experiment suggests that the additional advantage seems to be small and a reasonable analysis of an agent-based macro model can be based on small scale models. In any case, this experiment was run with a maximum number of 10.000 households, far away from the empirical number of households in a real economy.

A low sensitivity to a population scaling is true for the given model set up. The model used for these tests has only one region and all agents have the identical initial conditions. If the model is more refined in the sense that it is set up with more than one region and the initial memory of agents is set according to empirical distributions the population size might matter.

Chapter 3

Benchmark simulations with the EURACE Model

3.1 Transient period

Before we show the benchmark results, we show a transient run for the default parameter settings. The numbers of agents are given in Table 3.1.

Figure 3.1 shows a simulation of the model for 20 batch runs of 8000 iterations. After approximately 2400 periods (10 years) the transient phase settles down to a stochastic steady state.

In all time series plots the data is summarized using a box-and-whisker plot in which the dark grey area shows the data between Q1 and Q3 (50% of the data) and the light grey area indicates the outer hinges of the distribution, i.e. 1.5 times the interquartile range (IQR). In Figure 3.2 the box plots show the distribution for each single run.

The main features of the benchmark runs are:

- GDP converges to a level of 1300 and then sets off on a stable growth path.
- The unemployment rate approaches a stable level of 17%.
- Inflation rates are typically between -10% and $+10\%$ annually, although in some periods inflation rates of -20% and $+20\%$ can occur.

Table 3.1: Summary of benchmark settings.

Agent	Totals
Regions	1
Household	1600
Firm	80
IGFirm	1
Mall	1
Bank	2
Clearinghouse	1
Government	1
Central Bank	1
Eurostat	1

- The investment/GDP ratio fluctuates around 17%.

3.2 Benchmark scenario

In this section we show a more detailed overview of the economy that will serve as our benchmark scenario. We show cross sectional data across the various sectors of the economy (Consumption goods, Investment goods, Credit market), and for the different types of agents (Firms, Banks, Households, Government).

Of course there is always a danger of showing too many plots and too much data, but it appears to us essential to do this exercise one time and to show the reader how all the elements of the EURACE system fit together.

In this and all following sections we also show the transient phase of 2400 periods. All plots show distributional data for 20 batch runs. The results reported here are for an income tax rate of 8%.

Macrodata

We have already shown the general trends pertaining to the macroeconomic data in Figure 3.1 above. In Figure 3.3 we show the growth rates of GDP, monthly output, the unemployment rate, and the average wage.

The growth rates of the benchmark runs are:

- The GDP growth rate is about 3% annually, with a minimum of -5% and a maximum of $+10\%$.
- The output growth rate is approx. 2%, with minima of -2% and maxima of 7%.
- The growth rate of the average wage is around 3% per year, with minima of 1.5% and maxima of 3.5%.
- The growth rate of unemployment is centred around 0%, and fluctuates between -16% and $+25\%$ on an annual basis.

Government

For the Government financing we show in Figure 3.4 the monthly tax revenues, total benefit payments, the monthly budget balance, and the total amount of bond financing.

The growth rate of tax revenues and of benefit payments are approximately equal, but since the level of tax revenues is typically lower than that of the unemployment benefit payout there is a monthly budget deficit that needs to be financed by government bonds, as shown in Fig. 3.4d.

Firms

For the firms we show in Figure 3.5 the monthly output, cumulative revenues, earnings, the firm's payment account, the number of employees, and finally the actual capital price paid for machinery. The firm size as measured by the number of employees is 16 on average. In Figure 3.6 we report data pertaining to firms' total capital stock (in units) and monthly investments.

The earnings data and the cumulative revenues show a wide distribution. To show that this is not due to one or two special runs but a generic feature of all runs, we show in Figure 3.7

the complete set of batch run box plots. This plot makes clear that in each run the population distribution of the firms' earnings and cumulative revenues is wide. Whether or not the earnings distribution has power law tails we have not yet investigated.

The firms' financial data are shown in Figure 3.8. We show total assets, debt and equity, as well as the average debt earnings ratio and the average debt equity ratio (first averaged across firms, then averaged across runs).

Total assets increase, while total debt increases slower, so equity is increased. Total earnings stabilize to a level of 100. The average debt earnings ratio is approximately 50%, while the average debt equity ratio is around 5%.

Labour market

From the labour market data we show the average unemployment rate, the unemployment rate for skill level 1 and 5, the average wage and average wage for skill level 1 and 5. Next we show the total number of vacancies and the labour/profit share ratio.

Figure 3.9 shows that the unemployment rate stabilizes to 17%, but due to the heterogeneity in workers' skill level there are stark differences: the unemployment rate for skill level 1 is 30% while for skill level 5 it is 7%.

Figure 3.10 shows that the average labour share/capital share ratio is between 1.5 and 2. This number gives the distribution of total revenues among the owners of the firm and the workers. A figure of 1.5 means that the total wage bill is 1.5 times the share of total revenues that goes to the owners of the firm. So it implies a distribution of 40% for the owners and 60% for the workers. If the ratio is 2, then the distribution is 33% for owners and 67% for workers. The empirical data for Germany for the capital share is: $30 - 40\%$ for owners and the labour share is $60 - 70\%$ for workers. So a ratio between 1.5 and 2.3 corresponds to the empirical data.

Consumption Goods Market

From the consumption goods market we show data pertaining to: monthly output, monthly planned output, quantity sold, total monthly revenues, the firms' average productivity, and the firms' average productivity progress (see Fig. 3.11). This should give a good idea of the production sector. All data are steadily increasing with the firms' average productivity progress of 0.25%.

Credit Market

There are two banks in the system. We show the banks' cash, total deposits, the total credit given to firms, bank equity, ECB debt, and the banks' total dividend payout. On the credit market we see in Figure 3.12 that after the initial transient phase of 2400 periods, banks deposits are increasing, total credits to firms are fluctuating around a positive trend, and banks' equity is constant. Furthermore, banks have no ECB debt, and are able to pay out positive dividends to the households.

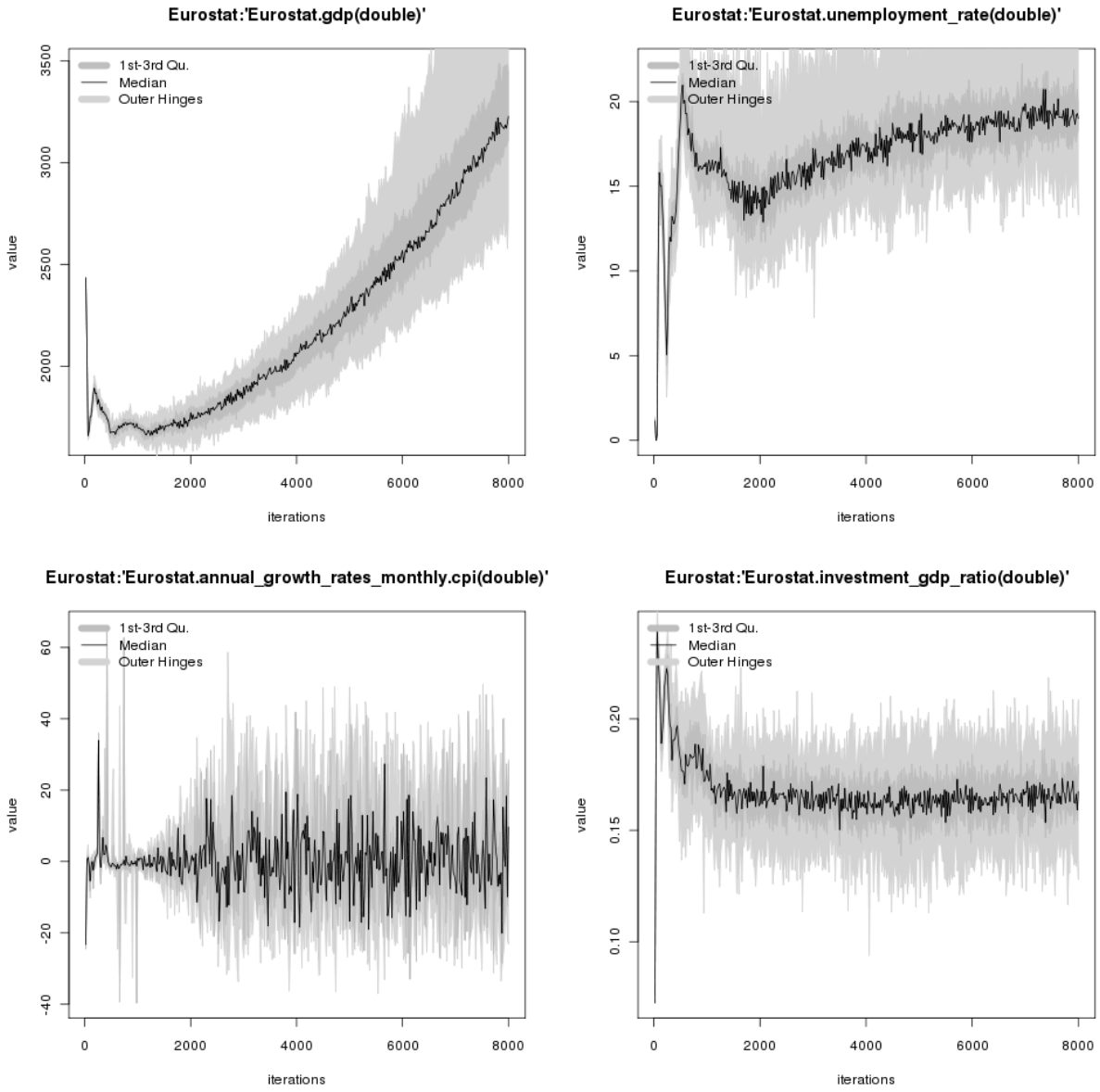

Figure 3.1: Time series plots for 20 batch runs. GDP, unemployment rate, inflation rate and investment/GDP ratio.

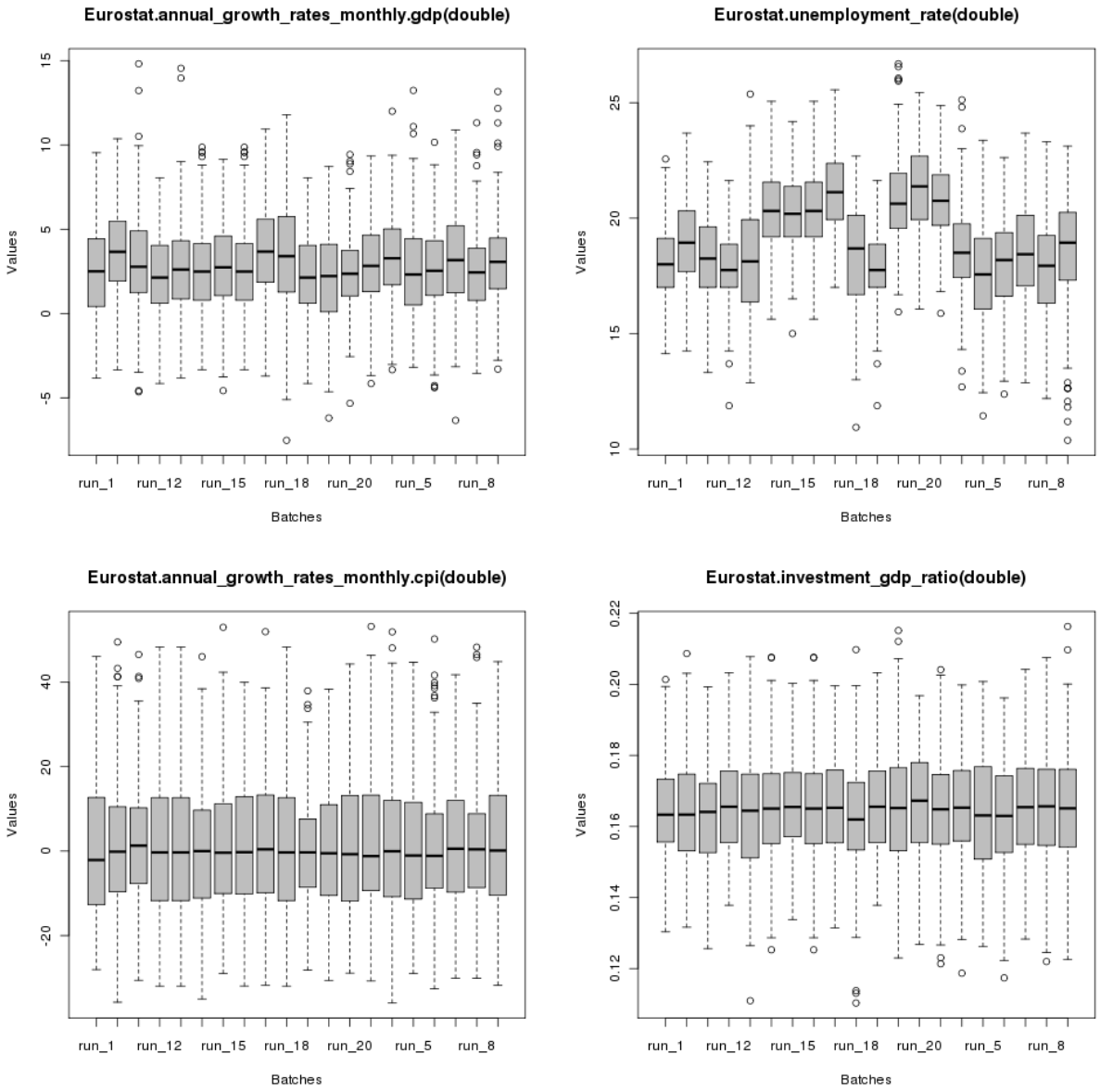

Figure 3.2: Box plots for separate runs of GDP, unemployment rate, inflation rate and investment/GDP ratio.

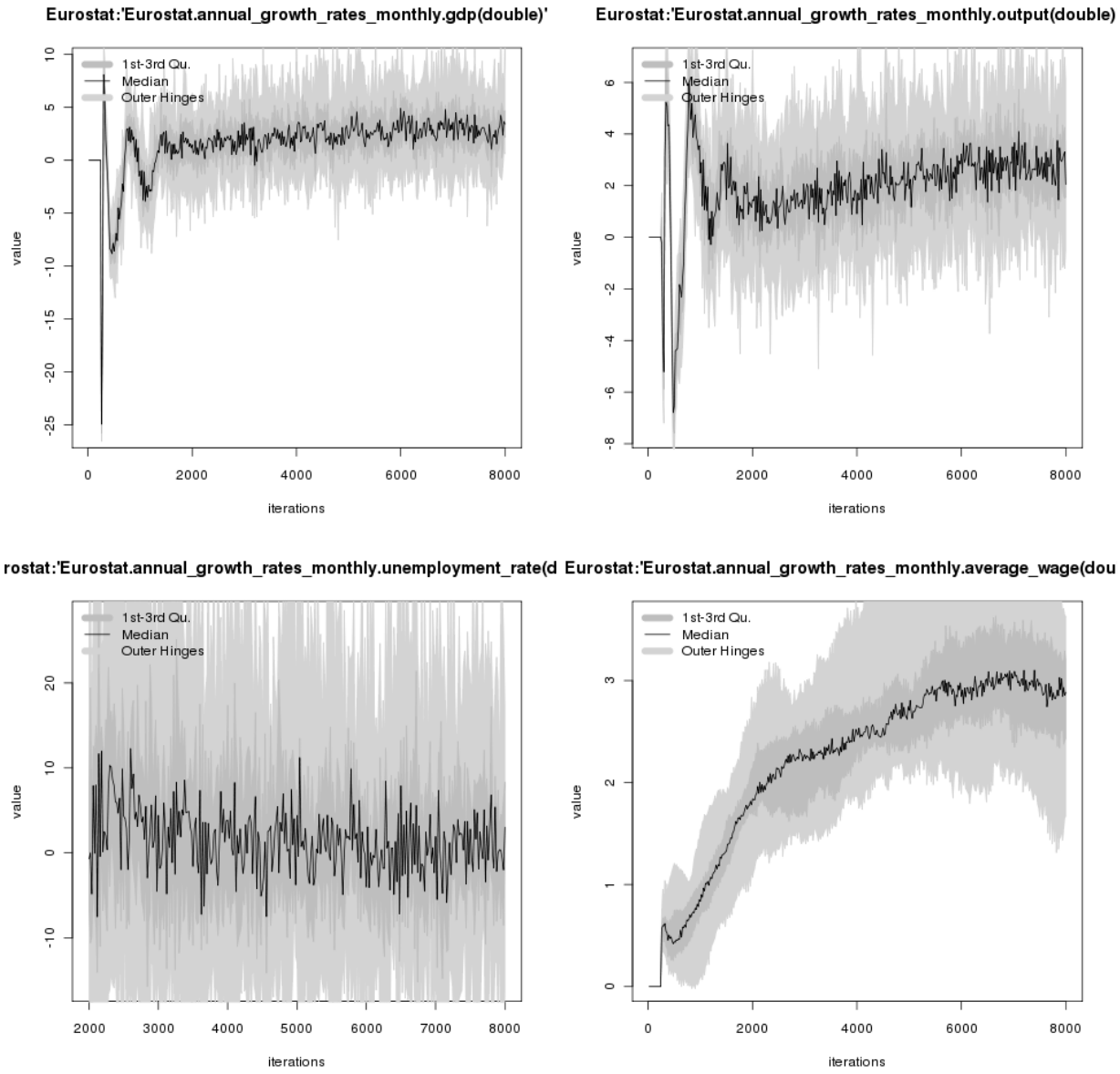

Figure 3.3: Annual growth rates (with respect to the same month the previous year) of GDP, total output, unemployment rate and average wage.

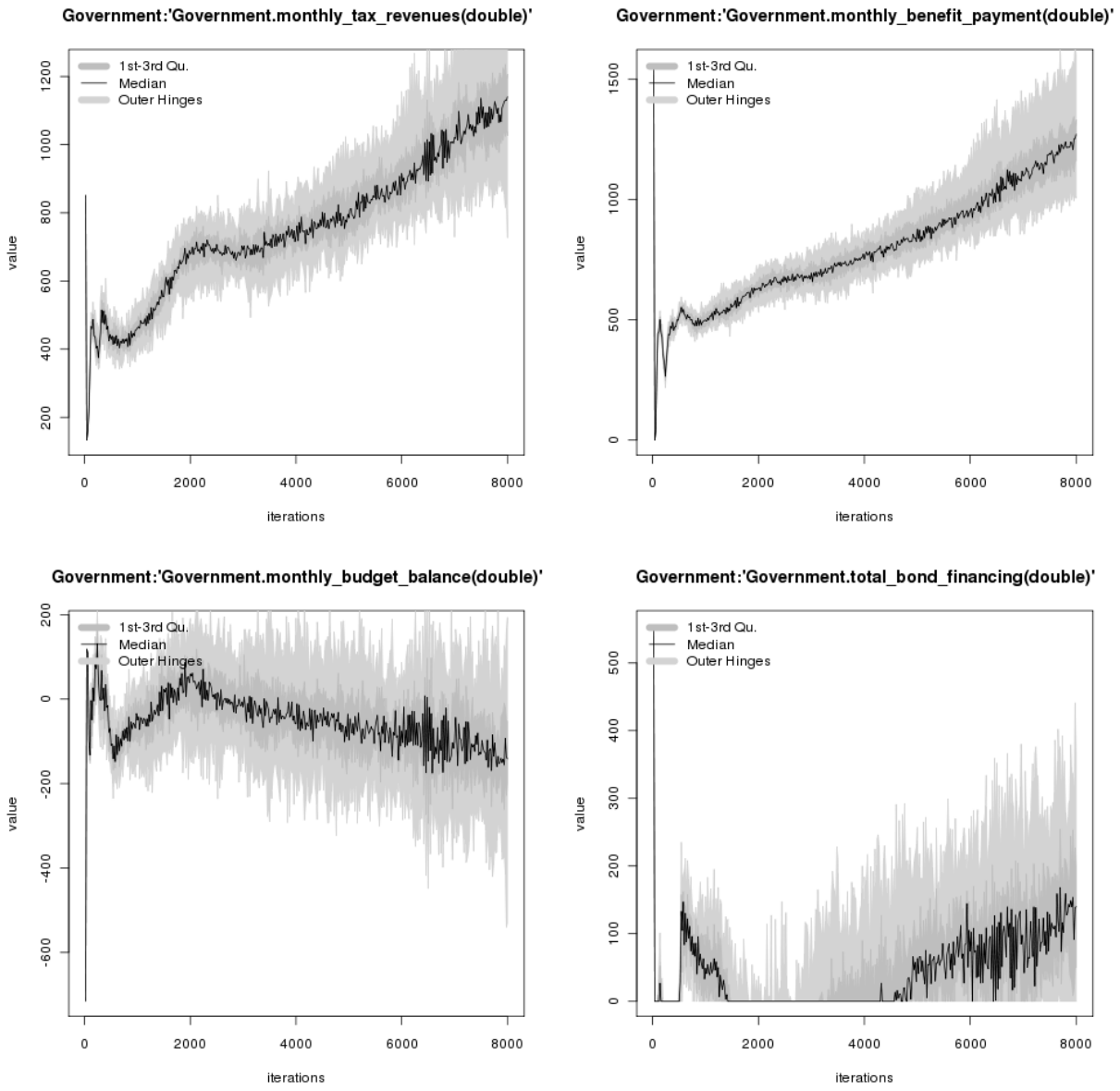

Figure 3.4: Government finances.

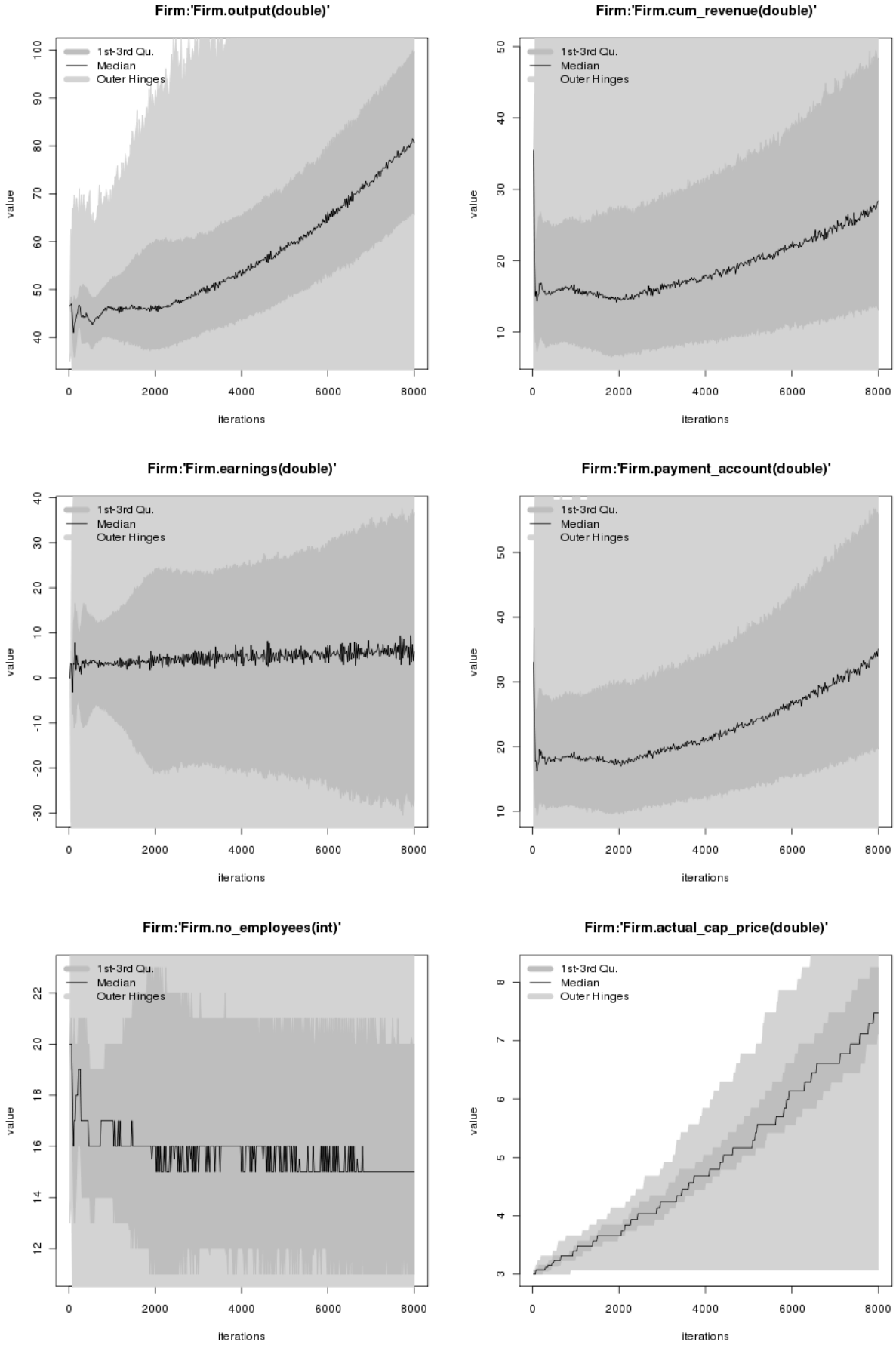

Figure 3.5: Firm production data.

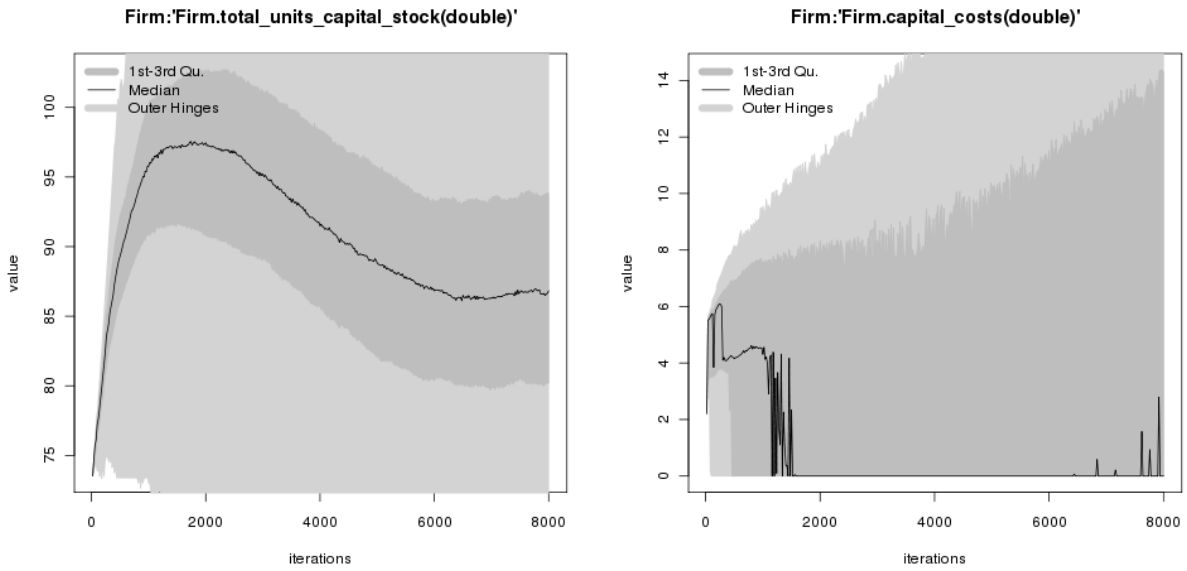

Figure 3.6: Firm capital stock. Left: units of capital stock, right: investments.

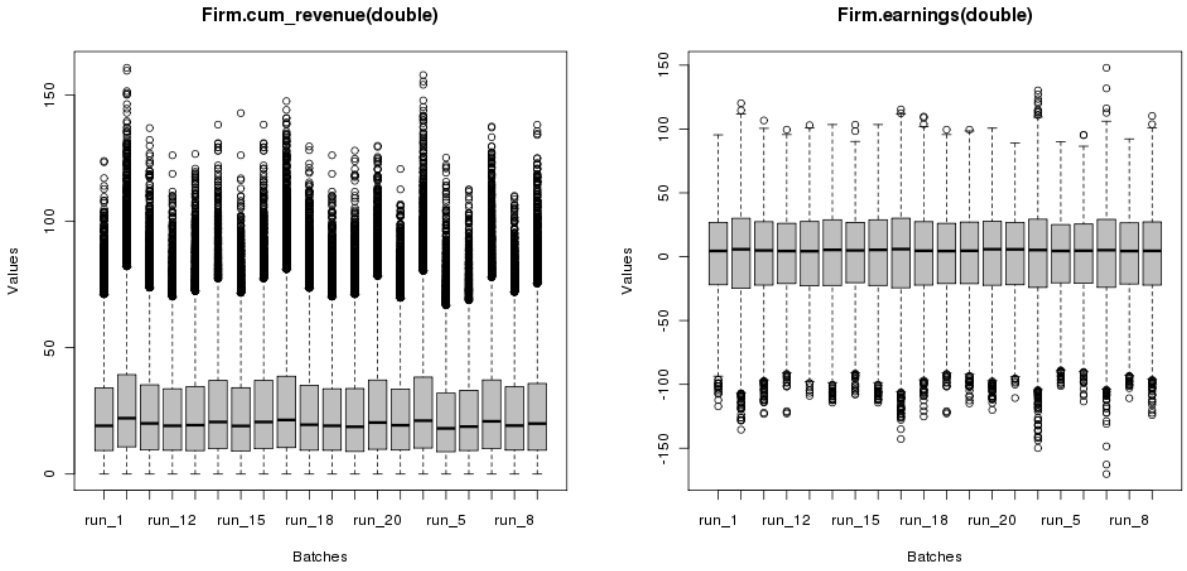

Figure 3.7: Firm production data, all batch runs.

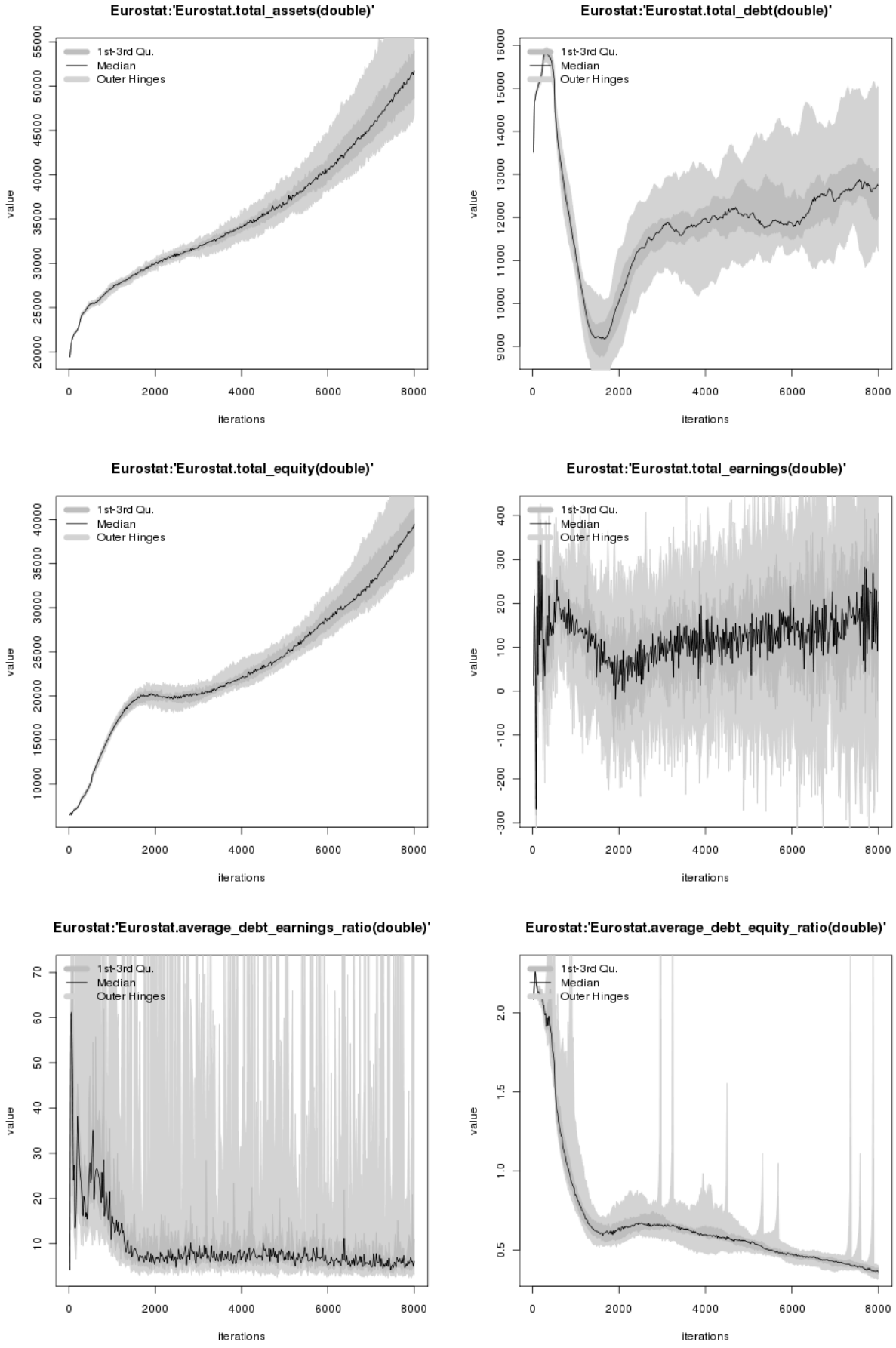

Figure 3.8: Firm financial data.

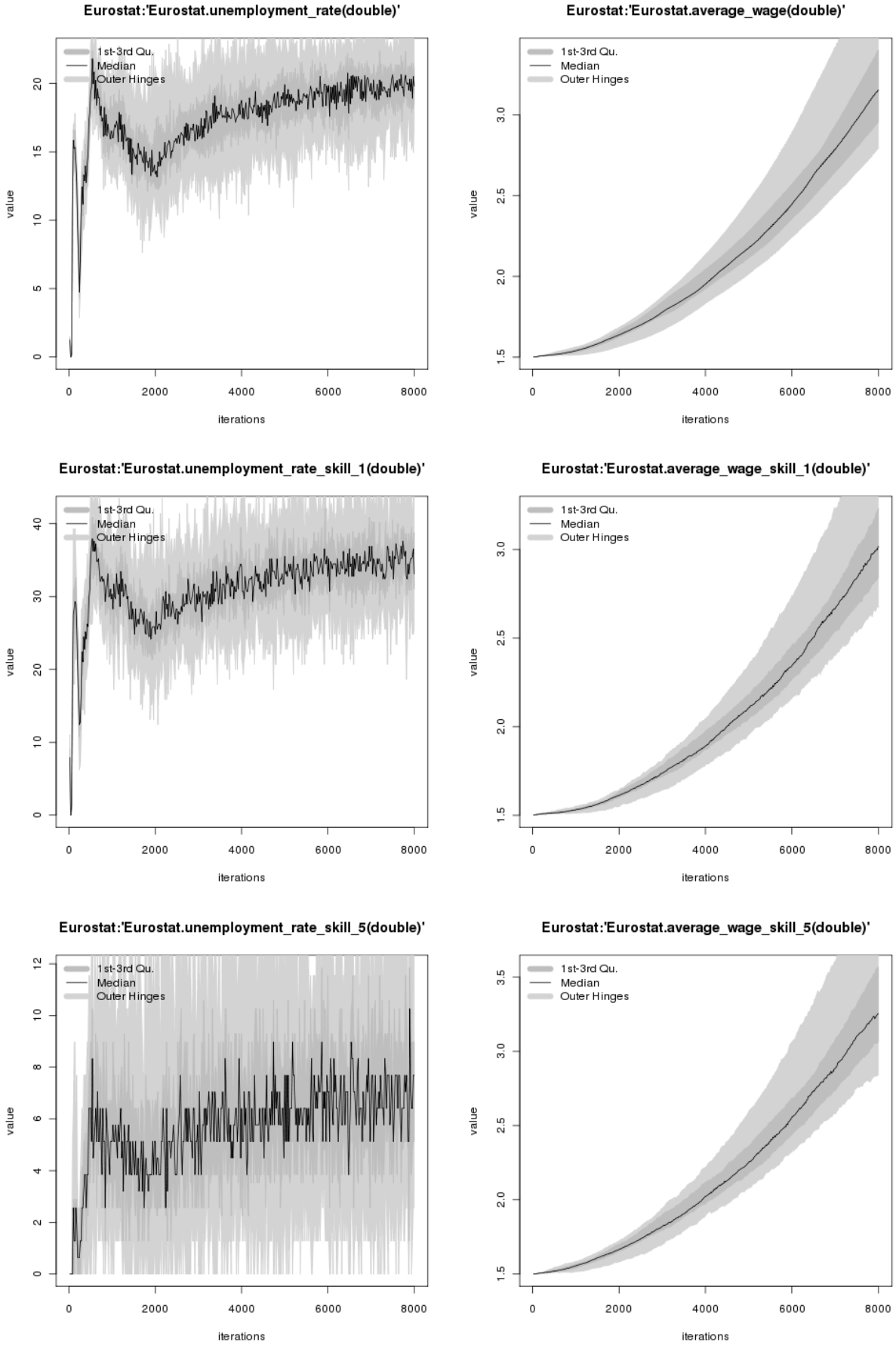

Figure 3.9: Labour market data.

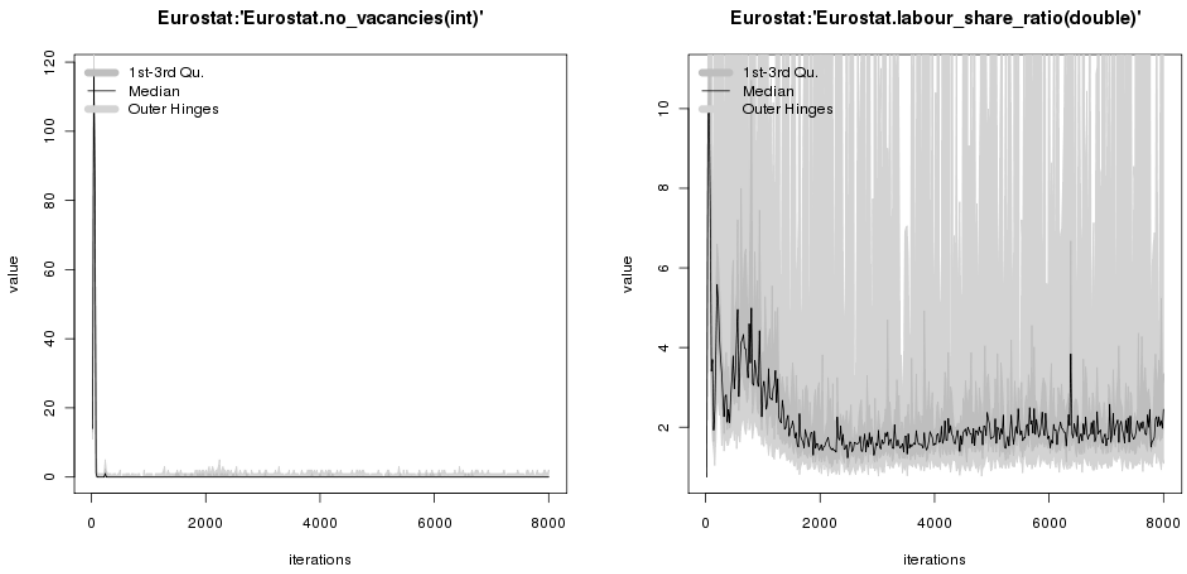

Figure 3.10: Labour market data (cont).

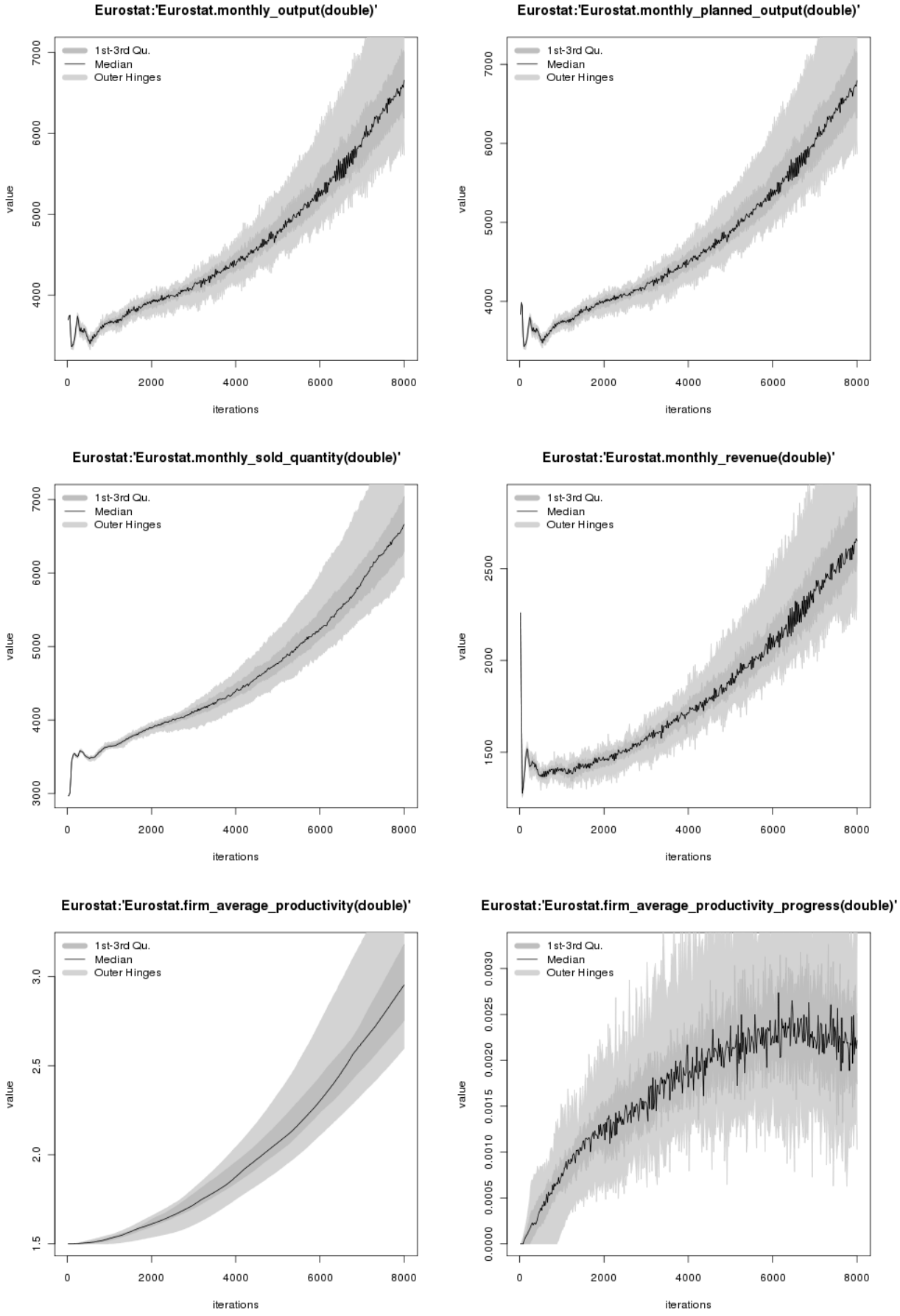

Figure 3.11: Consumption goods market.

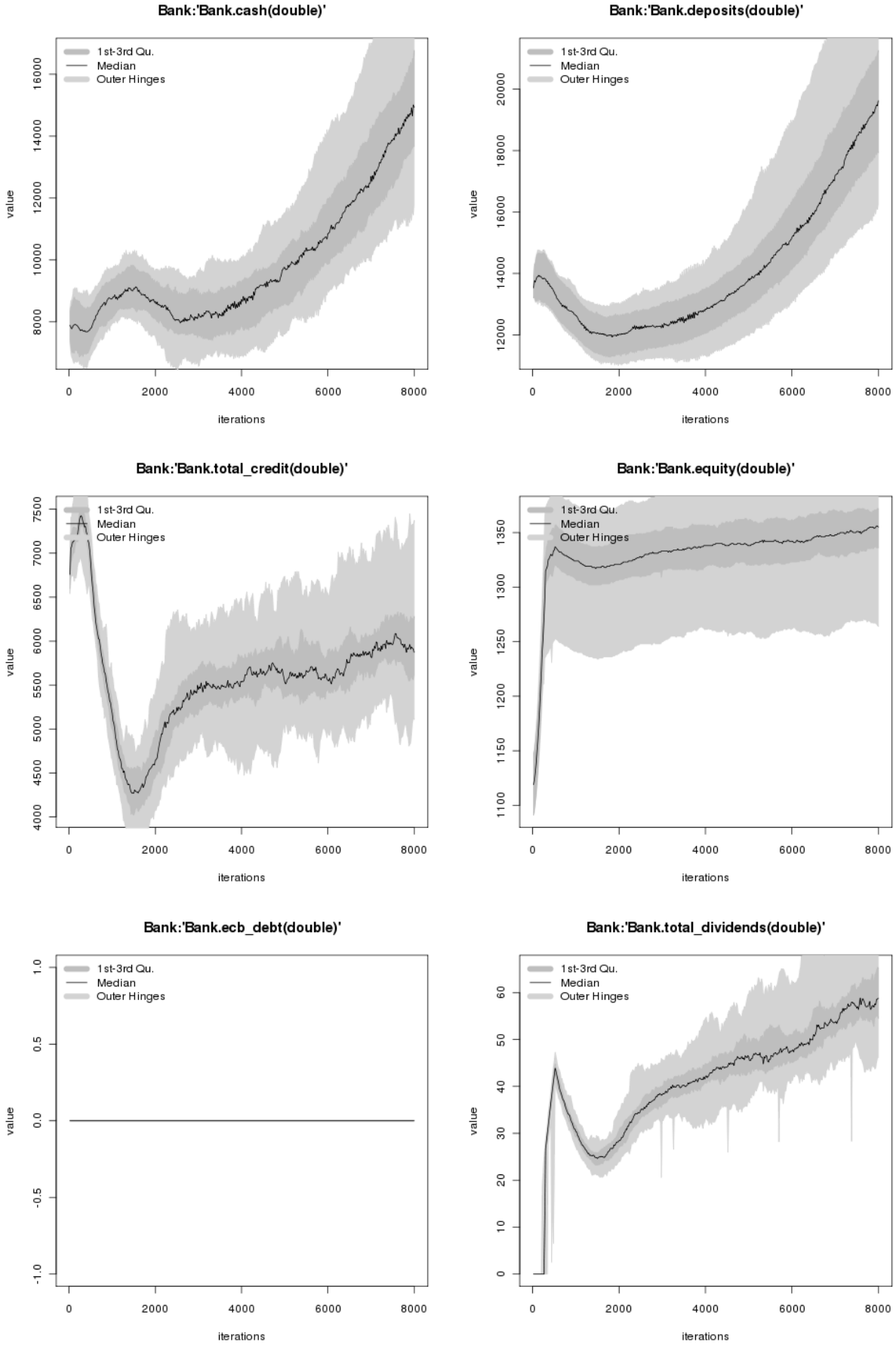

Figure 3.12: Credit market data.

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