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Work Package 9: European economic scenarios: what-if analysis by agent-based simulations

Deliverables D9.1, D9.2, D9.3

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Contents

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Chapter 1

Introduction

This document contains the all deliverables resulting from the EURACE workpackage 9. The reason the different deliverables of this WP were collected in a single document is, that the different deilverables describe different steps of preparation and execution of the policy experiments carried out using the EURACE platform. Hence, they are closely connected to each other and we believe they are best read together in the sequence presented in this document. As described in Annex I, the purpose of WP9 is to carry out policy experiments in different policy domains (innovation policy, stabilization policy, monetary policy) in frameworks that take into account the regional economic differences present in the European Union. To reach this goal we proceed in three basic steps. First, we discuss the type of regional differences in the EU we have captured in the calibration of the model we use as the basis for the policy experiments, this corresponds to deliverable D9.1. Second, we formulate for the three considered policy domains economic policy questions that are relevant for the current policy debate in the EU, this corresponds to deliverable D9.2, where we split the discussion into three parts corresponding to the three policy domains. Third, we present results from our policy experiments and discuss their insights, this corresponds to deliverable D9.3 and again is carried out in three parts corresponding to the three policy domains.

Chapter 2

D9.1: Adaptation of the agent-based software platform to the European Union economy

2.1 A brief recap of the underlying model

In this section we present the key features of the model. For more details we refer to the deliverables D5.2, D6.2 and D7.2. Important building blocks of the model with respect to the dynamics of the real side of the economy are the regional structure (which is switched off for some sets of experiments where appropriate) which allows for different regions with distinct economic characteristics, the differentiated skill structure, the complementarity of specific skills, the quality dynamics of capital goods, the investment behavior of firms influenced by credit potential constraintsand the wage setting.

Different markets are characterized by different degrees of 'locality' thereby producing a system of linked markets with limited regional extension. In particular, the consumption goods market is regional whereas the credit, financial and capital goods markets are global. Labor markets are semi-regional in a sense that workers can in principle work in all regions but costs arise from commuting to other regions. In the case of too high commuting costs the labor markets are considered as being closed. When moderate commuting costs are imposed on commuters labor frictions in terms of mobility of workers between the regions are introduced.

Workers human capital endowments have two dimensions. They embody an exogenously given level of general skills and an endogenously level of specific skills which changes on-the-job with the operation of the currently employed technology. The acquisition of specific skills in the production is faster for higher general skill levels. The specific skills can be interpreted as capabilities and experiences obtained on the job. These skills are associated to the technology being used by the employer. Formally, the workers increase the specific skills over time by a learning process which is modeled in the following way: the speed of learning depends on the general skill level b_w^{gen} of the worker w and the quality of the technology $A_{i,t}$ used by employer i.

$$b_{w,t+1} = b_{w,t} + \chi(b_w^{gen})(A_{i,t} - b_{w,t}) \tag{2.1}$$

Here $b_{w,t}$ are the specific skills of worker w in period t and $\chi(b_w^{gen})$ increases with b_w^{gen}.

The consumption goods producer uses labor and capital as input factors. Both are vertically differentiated. The production quantity $Q_{i,t}$ of firm i in period t is given by

$$Q_{i,t} = \min[B_{i,t}, A_{i,t}] \times L_{i,t}^{\alpha} K_{i,t}^{\beta}, \tag{2.2}$$

where $B_{i,t}$ denotes the average specific skill level in the firms, $L_{i,t}$ is the number of workers and $\alpha + \beta = 1$. Note, that due to the $\min[B_{i,t}, A_{i,t}]$ there is complementarity between the quality of capital goods and the specific skill level of the workers The quality of the capital goods of a single increases with investments of the firm. The technological quality of the for purchase available investment goods increases exogenously following a random process.

The wage has two constituent parts. The first part is the market driven base wage $w_{i,t}^{base}$. The base wage is paid per unit of that specific skill. If the firm can not fill its vacancies it increases the base wage to attract more workers. The second part is related to the specific skills. Since the specific skills represent the productivity of the workers the wage $w_{i,t}$ is higher for higher specific skills. For each of the five general-skill groups the firm i offers different wages $w_{i,t}^{gen}$ in period t. The wage offers are given by

$$w_{i,t}^{gen} = w_{i,t}^{base} \times \bar{b}_{i,t}^{gen} \tag{2.3}$$

where $\bar{b}_{i,t}^{gen}$ are the average specific skills in one skill group in the firm.

For firms, bank credit is the first of external financial sources. For each applicant firm, banks decide how much credit to supply and the correspond- ing interest rate. The amount of supplied credit depends on bank's credit availability (affected by bank's capital, Basel II parameter and already sup- plied credit) and by the Value-at-Risk (VaR) related to the applicant firm. VaR depends on the amount of credit demanded and on the probability of default: the latter is an exponential function of firm's financial soundness computed by the bank. If the sum of the VaRs does not exceed the Basel II threshold, the bank supplies to firms all the credit they required, other- wise firms are credit rationed. If banks experience a shortage of cash due to withdrawals by households, they can take liquid resources from the Central Bank at a minimum interest rate, but they cannot supply additional credit until the debt towards the Central Bank has been repaid. As far as the interest rate is concerned, it is an increasing function of Central Bank's minimum interest rate and of actually supplied credit. The sensitivity of interest rates to the latter is a behavioural parameter which the bank updates adaptively according to past profits.

The financial market ia another possible source of credit for firms. The financial market operates on a daily basis and is characterized by a clearing house mechanism for price formation which is based on the matching of the demand and supply curves. The trading activity regards both stock and government bonds, while market participants are households, firms and the governments. Both firms and governments may occasionally participate to the market as sellers, with the purpose to raise funds by the issue of new shares or governments bonds. Households provide most of the trading activity in the market, to which they participate both for saving and speculation opportunities. The main innovative feature of the EURACE artificial financial market is the modeling of household preferences which takes into account psychological findings emerged in the framework of behavioral finance and in particular of prospect theory . Households portfolio allocation is then modeled according to a preference structure based on a key prospect theory insight, i.e., the myopic loss aversion, which depends on the limited foresight capabilities characterizing humans when forming beliefs about financial returns.

2.2 Adaptation of the Model to EU Scenarios

The basic calibration of the model was discussed in second year deliverable (in particular D7.2) and also in D8.5. It is done in a deliberate way basing parameters on available empirical evidence and considerations of viability and plausibility of simulation outcomes. In order to address the EU policy scenarios in an empirically meaningful way the model has then been specifically calibrated to capture important qualitative and institutional characteristics of different EU members. In order to take account of the different characteristics of the EU economies, we calibrate the model by using two different setups pooling the old EU member states such as France, Germany, the Netherlands etc., and the new members such as Poland, Romania, and Hungary. For each group we select one representative member, Germany and Poland, respectively. Although, obviously there is also substantial heterogeneity within each of the two groups of countries, they share characteristics that are important factors for growth and technological development. Hence, in order to be able to distiguish as clearly as possible the effects of different 'typical' characteristics of old and new member countries we have chosen to study the comparison and the interaction between one representative of each group.

The representation of differences between the old and new member countries focuses on four main components:

- Level of technology embodied in the physical capital stocks of producers
- Size of per capita stock of physical capital in the economy
- Distribution of general skills in the workforce (e.g. education level)
- Familiarity of workers with high level technologies

Note that these aspects induce differences in the two type of countries with respect to important quantities like labor productivity, output and wages, which are also captured in our calibration. Furthermore, country specific information about labor market aspects like social security contributions[1] and job replacement rates have been incorporated but no substantial differences between the countries arise in that respect. Concerning the number of households in both regions, we rely on robustness experiments reported in deliverable D8.5, which showed that no pure size effects arise in the EURACE model with respect to growth rates and other key economic variables. This feature, which is of course quite appealing from an economic perspectice, allows us to work with the same number of households in both regions. Qualitative differences in the economic characteristics of these regions rather than their pure size matters.

To quantify the differences with respect to size and quality of capital stocks and the specific skills of workers that allow them to efficiently use advanced technologies we rely on an empirical analysis provided in Growiec (2008). Based on Data Envelopment Analysis the distance to the World technological frontier is determined for OECD and new EU member countries and the resulting estimates of relative efficiency levels are used to decompose the ratios of per capita output into ratios of several factors including physical capital per

[1]Since in the version of the model employed for these simulations the only government expenses are due to unemployment benefits, only social security contributions but no other aspects of the tax structures have been compared. With respect to social security contributions no significant differences between Germany and Poland arise (see information at http://www.bmas.de for Germany and at http://www.zus.pl/files/english.pdf for Poland).

capita and human capital. Comparing the decomposition values for Germany and Poland one obtains a ratio of per capita physical capital of approximately 1.8 and translating the empirical decomposition to the production function in our setup one obtains an estimation of the total factor productivity ratio of approximately 1.65 between Germany and Poland. We approximate these values by initializing the per capita stock of physical capital in the old member country as twice as high as that in the new member country and both specific skill levels and average capital quality in the old member country at 150% of that in the new member country. Furthermore, it is assumed that the technology used in the old member country corresponds to the technological frontier. The general skill distributions in the old and new member country are chosen to approximate the actual skill distributions in Germany and Poland as reported by the International Adult Literacy Service (see http://litdata.ets.org/ialdata/search.asp). Overall, the key qualitative differences in the calibrations for old and new member countries are summarized in Tables 2.1 and 2.2.

Table 2.1: Experiment design with initial values for different parameters for an old and a new member country.

	Old Member State	New Member State
Technological Frontier	1.5	1.5
Capital Stock	7200	3600
Productivity Capital Stock	1.5	1.0
Specific Skill Level	1.5	1.0
Wage	2.25	1.0
General Skill Distribution	Line 1 in Table 2.2	Line 2 in Table 2.2

Table 2.2: General skill distributions in terms of percentages of workers in each of the 5 skill groups for old and new member countries.

	General Skill Level				
	1	2	3	4	5
New member	0.42	0.33	0.2	0.04	0.01
Old member	0.1	0.3	0.4	0.15	0.05

Chapter 3

D9.2: Adaptation of policy experiments to the European Union economy

3.1 The Lisbon Strategy and Issues in Innovation Policy

In their closing statement of the Lisbon European Summit in 2000, the Heads of States or Governments formulated an ambitious target for the policy of the European Union over the next decade. The EU should "become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion".[1] On the way toward this aim the European Council agreed on an agenda, generally known as the Lisbon Strategy for Growth and Jobs that listed a variety of subject areas in which the individual member states as well as the European Commission had to achieve adequate improvements. A key role was assigned to two policy fields: investments in human capital, and strengthening the innovation activities and R&D.

A further important milestone in the recent history of the EU was the Eastward enlargement in 2004. Ten new countries joined the European Union, 8 of which formally belonged to the former Eastern Bloc (e.g. Poland, the Czech Republic and Hungary). From the fall of the Iron Curtain to present these countries have faced identical structural problems that can be considered as an inheritance of the Communist planned economy: a quantitatively and qualitatively worse endowment of physical capital as well as less skilled human capital compared to established member states like France, Germany or the UK. These disadvantages are the main obstacles for economic growth and avoid a catch up of new member states to old ones.

The two sets of experiments which we will describe and conduct in the following are related to these two broad policy fields. In the first set of experiments we address exactly the policy issues raised in the Lisbon strategy claiming that investments in human capital and innovation activities should be strengthened. The particular question we focus on is to which extent policies may have to differ for strengthening growth as countries differ with respect to how close they are to the technological frontier. This is that we observe that some countries are close to the technological frontier and fully exploit the technological advantages of the available investment goods. Other countries may, however, due to

[1] Lisbon European Council 23rd and 24th of March 2000, Presidency Conclusions, Section 5.

an outdated capital stock or insufficient specific skills, not operate at the technological frontier. Investments in human capital and support of R&D may differ in their effect on fostering growth with respect to whether they are implemented in countries close or far off the technological frontier. Likewise investments in human capital may yield different results depending on the gap between the level of the actually used technology and the technological frontier. We will apply the EURACE model to study whether and if so why these policies applied to countries that differ in their physical and human capital endowments yield distinct results with respect to medium and long-term growth paths.

The strand of literature to which we relate in this set of experiments goes at least back to the catch up-hypothesis proposed by Gerschenkron (1962). According to this hypothesis countries which are backward have some kind of an advantage as they will simply grow by closing the gap to the technological frontier through adopting the technologies that already exist. Building on the catch-up hypothesis Nelson and Phelps (1962) proposed that economic growth has two distinct components. On the one hand it is driven by the growth rate of the technological frontier which reflects the rate and quality with which new discoveries are made. And on the other hand, it is argued, one needs to take into account that total factor productivity increases with the implementation of these technologies whereas the speed at which this occurs would be positively related to the gap between the frontier and the level of the current productivity.

The Nelson-Phelps hypothesis sparked the development of an empirical literature that ascribes human capital a central role for the diffusion of technologies on top of the role as a direct factor of production either through facilitating the use of technology or directly. Among these studies are, e.g., the contributions by Eaton and Kortum (1996), Hall and Jones (1999), Islam (1995) or Temple (1998). In this line of research a somehow puzzling claim was made by Krueger and Lindahl (2001) which also became known as the irrelevance result. These authors found that human capital stocks and growth are no longer positively correlated if one restricts the sample of observations on OECD countries. Clearly this was evidence against the Nelson/Phelps hypothesis questioning the results of previous studies and the relevance of human capital in general and in particular as a factor contributing to the closing of a gap between the technological frontier and the current level of productivity.

Recently Vandenbussche et al. (2006) challenged the irrelevance result by bringing into the picture a distinction with respect to how far countries are away from the technological frontier and the composition of the human capital stock. Generally speaking, it is argued and empirically shown that as countries are far away from the technological frontier a relatively higher endowment with unskilled labor is more beneficial as imitation needed to approach the technological frontier is achieved better by this type of labor. However, as a country is close to the technological frontier the same endowment with unskilled labor is not conducive to growth. What is needed in these situations is a shift in the technological frontier which requires not imitation but innovation processes for which a relatively high endowment with skilled labor is needed. Vandenbussche et al. (2006) test the prediction with cross-country panel data while Aghion et al. (2005) employ cross US-state data. Both contributions find supporting evidence for the distinct channels that have to be considered when evaluation the effect of human capital stocks on the growth performance of countries.

Distinguishing between the different roles that human capital may play in explaining productivity growth clearly has important policy implications as already strongly argued for by Benhabib and Spiegel (1994, 2005). And evidently this is the direction into which we are heading with our analysis: trying to disentangle the different channels and effects various policies either targeting the general skill level of a workforce or the innovative capacity of an economy may have on productivity growth.

We add to the existing literature by looking into the appropriateness of human capital investments versus investments in innovation activity within a framework where we have two types of skills that are associated with different functions. There are general skills which play the role of facilitating the adoption of specific skills. A higher human capital endowment of an economy with general skills will allow the workers in an economy to faster develop the specific skills needed to fully exploit an existing technology. Thus a gap between the technological frontier and the current productivity may exist for two reasons. The current capital stock may not consist of the latest available technology. And secondly, even if the current capital stock is made out of the latest available technology, the specific skills of the worker may not be available to actually fully exploit it at the highest possible productivity. In other words, in the first case, current productivity is constrained by the current capital stock, and in the second case it is constrained by the current specific skill level. It is by no means a straightforward exercise to determine which kind of policy, investments in human capital or strengthening innovation activities is the more effective policy for fostering productivity growth. Policies targeting innovation activities are moving the technological frontier while investments in general skills will facilitate the building up of specific skills which are needed to fully exploit the technological level of the current capital stock. We conduct our analysis for different sizes of gaps between the current level of productivity and the technological frontier further distinguishing along the lines whether the current capital stock, the current specific skill level or the current technological frontier is the constraining factor.

The second set of experiments targets the European enlargement process asking to which extent different policies of opening up labor markets affect output and consumption in regions that start(ed) from different levels of economic development, and how these policies impact on the convergence processes in general. It is related to the first set of experiments in the sense that labor movements from one region to another have an effect on the specific and general skill levels in the regions thus affecting the speed of adoption of the current level of productivity to the technological frontier. In a very recent study Aghion et al. (2009) investigate the spill overs occurring between regions in terms of human capital endowments by letting workers migrate. In that sense our set-up is similar. We, too, look into the effects of different allocations of workers and therefore human capital across the regions by studying distinct scenarios of opening up regions for labor commuting. As in the previous set of experiments, we draw on the same model as a test-bed with the important distinction that we switch on the spatial structure of our agent-based model. Thus, in terms of modeling choices we look into a different role of human capital for the growth mechanics as opposed to Aghion et al. (2009). In particular, they make a distinction between "high brow" and "low brow" educational endowments with the former fostering innovation and the latter imitation of existing technologies. The role which we assign to human capital endowments is different. Our distinction is between general and specific skills, as already outlined before, with general skills driving the speed of specific skill adoption which are necessary to run the current capital stock.

As the previous set of experiments also this contribution studies convergence. There is technology diffusion in the sense that all firms have access to latest technology provided by an investment good producer. However, regions differ in their initial current productivity which is a central distinguishing feature between new and old member states of the EU. In particular there are different endowments with respect to the current technology used, the specific skills necessary to operate the capital stock, and the distribution of general skills. Although the latest technology can be bought by any firm in any region there are restrictions to use this technology because of the constraining factor of specific skills. This brings into the picture a so far not studied channel (see, e.g., Acemoglu, 2009, Ch. 18) for the diffusion of technology and convergence of regions. Labor movement between the regions changes the allocation of specific and general human capital and thus the exploitability of the current technological level and the speed of adjustment to the current technological level. Choices of workers to offer labor in one of the regions is restricted by an exogenous and politically determined level of labor market integration. And thus different policies on labor market integration may have non-trivial repercussions on productivity growth in the regions.

On a more general level the discussion of the policy experiments in this deliverable highlight the fact that the approach followed in the EURACE project, namely to evaluate single or combined policy measures in the framework of a closed macroeconomic model with micro foundations that encompasses the interaction between different sectors, allows insights that go beyond the current economic literature. In particular, in the policy area considered here we extend the literature reviewed above quite fundamentally by incorporating the feedback effects arising from technology and skills development through (regional) demand dynamics on consumption and investment goods markets and by discussing the way frictions on different markets influence policy effects. Furthermore, contrary to new growth literature contributions we can explicitly distinguish between short and long run implications of policies. Within the EURACE framework the focus could also easily be put on feedback effects between the technology and skill dynamics and credit or financial markets, although this is not done in the current deliverable.

In deliverable D7.2 some aspects of skill upgrading policies have been studied in a generically calibrated version of the EURACE model. This deliverable builds on the general insights obtained there but relies on the adaptation of the platform to (stylized) concrete differences observable between EU member countries and focuses on policy issues directly relevant for a major area of the current EU policy agenda.

3.2 Stabilization Policies in Response to Energy Shocks

The variation of energy prices has substantial effects on the economic activity in a region affecting real output, economic growth and employment among other key variables. Rotemberg and Woodford (1996) for example estimate using U.S. data that a 10% increase in oil prices leads to an output decline of 2.5% after five or six quarters. Actual increases in energy prices, however substantially exceed such percentages as demonstrated in Figure 3.1. The figure shows the real energy price behavior during the 2008 energy crisis. The price of Brent crude oil went up by +675% between 2002.1-2008.6 (79 months), which translates to a monthly increase of 2.45%. Then it went sharply down by −70% between 2008.7-2009.1 (7 months), which implies a monthly decrease of −5.8%.

For an economy like the EU, which to a large extend depends on supply of relevant factors like oil from the outside variations of energy prices can be seen as exogeneous shocks affecting the economic dynamics within the EU. An important policy question in this respect is how the implications of such energy shocks can be alleviated by the appropriate choice of policy measures to be introduced in response to a shock.

In our policy experiment we focus on the use of subsidies to mitigate the negative effects of shocks to the macroeconomy due to energy shocks. Specifically, we introduce household subsidies and firm subsidies. These subsidies are used to counteract the effects

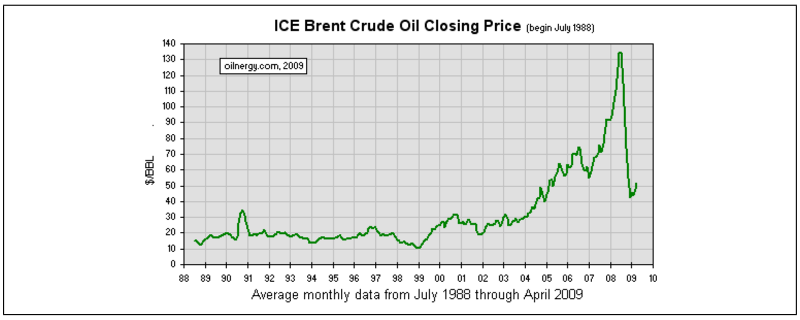

Figure 3.1: Empirical energy prices during the 2008 energy crisis. An increase of 2.45% per month over a period of 79 months (+675%), followed by a sharp decline of −5.8% per month during 7 months (−70%).

of the energy shock on the GDP growth rate, unemployment and inflation by directly stimulating consumption, employment and investment.

The consumer subsidy is meant to compensate for the loss in purchasing power of the households. The objective is to support the demand side of the economy. Each household receives a subsidy as a percentage of its total monthly consumption expenditure. This scheme is somewhat similar to the US tax rebate implemented by G.W. Bush. The percentage is determined at the end of each year, after the government has computed the current GDP growth rate. The Government then announces this percentage, the agents truthfully compute the total subsidy they shall receive and send a message to the Government to claim it. The individual subsidies are computed at the end of each month, after the households knows their total consumption expenditures for the month. This scheme is equivalent to a negative VAT, and amounts to a price discount.

The consumer subsidy is activated as a function of the GDP growth rate X, using two trigger levels a and b, with typically $a < b$. The level a is the 'on' trigger, and b the 'off' trigger: The subsidy becomes active whenever the GDP growth rate *falls* below a ($X < a$), and becomes inactive when the growth rate is again above b ($X > b$).

The first level a can be positive or negative. For example, an aggressive stabilization policy might be to set this level to $a = 0.03$ implying that the subsidy regime becomes active if the GDP growth rate drops below +3%. If instead $a = -0.01$, the subsidy takes effect only after the growth rate has fallen to -1%. In both cases, as already mentioned, the subsidy is awarded until X increases to b. A justification for the asymmetry between the on and off triggers is that the subsidy typically gets activated relatively late during a downturn because of recognition, decision, and implementation lags, but should remain active until strong growth is assured again.

The magnitude S of the subsidy is given by:

$$S = -|X| \tanh(X - b). \tag{3.1}$$

In the case of the firm, the subsidy is meant to compensate the firm for an increase in production costs. These costs consist of labour costs and the costs of acquiring new capital. Therefore we can use the firm's total investments as a basis for the subsidy. Firms

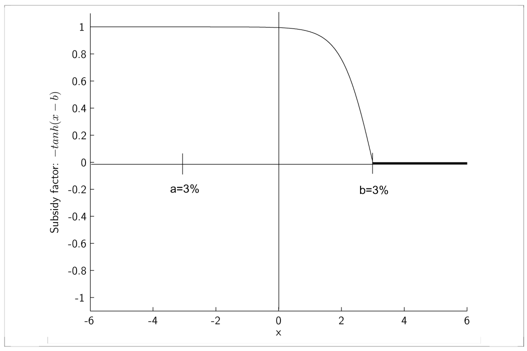

Figure 3.2: Graph of the subsidy multiplication factor s. To obtain the actual subsidy this should be multiplied by $|X|$.

compute the subsidy amount truthfully at the end of their subjective month, after they have computed their capital investments, and send a message to the government informing it of the amount to be paid.

3.3 Quantitative easing monetary policies

The global financial and economic crisis of the years 2007-09 has seen the adoption by leading central banks of an unconventional form of monetary policy called *quantitative easing*. The term quantitative easing describes an extreme form of monetary policy used to stimulate an economy where interest rates are either at, or close to, zero. Normally, a central bank stimulates the economy indirectly by lowering interest rates but when it cannot lower them any further it can attempt to seed the economic system with new money through quantitative easing. In practical terms, the central bank purchases financial assets (mostly short-term), including government paper and corporate bonds, from financial institutions (such as banks) using money, mainly money on electronic accounts, it creates, and so expanding its balance sheets. This process is called open market operations. The creation of this new money is intended to seed the increase in the overall money supply through deposit multiplication by encouraging lending by these institutions and reducing the cost of borrowing, thereby stimulating the economy. Besides, quantitative easing is intended to greatly help the management of government budget deficit, by reducing the cost of debt as well as reducing the risk of debt rolling over. However, there are different risks associated to quantitative easing: there is a risk that banks, being more risk averse in a recession, will still refuse to lend despite the increase in their deposits, or that the policy will be too "effective", leading in a worst case scenario to hyperinflation.

The EURACE simulator has been employed to perform a number of computational experiments to test the performance of the quantitative easing monetary policy together with different fiscal policies.

In particular, the experiments investigates the different economic performance of a quantitative easing monetary policy and of a tight fiscal policy in an economy characterized by a single government. The government may follow two alternative fiscal policies: a tight fiscal policy which pursues a zero government budget deficit objective by increasing tax rates or an accommodating fiscal policy that keeps tax rates fixed at the minimum level even with a budget deficit. In the first case, the budget deficit is funded by both increasing taxes and sales of government bonds to the market. In the second case, where taxes are not increased, the budget deficit is funded by selling governments bonds to households or, it market demand is insufficient to match the supply of new bonds and the present market price, to the central bank, which then applies a quantitative easing monetary policy.

This computational setting may be of help to design policy measures in the Eurozone economic scenario, where monetary authorities have recently started to implement quantitative easing monetary policies, even if limited for the moment to corporate bonds.

Chapter 4

D9.3: European Union economy scenarios

4.1 Effects of Innovation Policies in EU Scenarios

As described in section 3.1 two different types of policy experiments have been carried out to investigate the interaction of different policy measures with respect to technological change as well as local and regional growth in economies with characteristics corresponding to different EU regions.

4.1.1 Fostering growth: Moving the technological frontier versus investments in skills

In this section we describe an experiment addressing the questions whether to use policies targeting general skill levels or policies moving the technological frontier or a combination of the two policies are more conducive for fostering growth differentiating for countries on and off the technological frontier.

Setting up the experiment

We consider a single economy characterized by its quality of the technology stock and the composition of human capital. As generally assumed in EURACE we distinguish here between general and specific skills, where the distribution of general skills among the population represents the education of the people and the specific skills measure the applicability of workers in terms of an efficient use of the technology. The technology is updated by investments in firms' capital stocks where they can only invest in the most up to date technology that is represented by the technological frontier. The boundary evolves according to an exogenous innovation process. Both the specific skills as well as the productivity of the capital stock are measured in the same units as the frontier.

The two policy measures that are described in the Lisbon Strategy as means to gain additional growth can be addressed in the EURACE model in the following way: the policy targeting "investing in human capital" can be represented in our model by a shift of the general skill distribution. The second policy targeting an enhancement of innovation and R&D is captured by a speeding up of the process driving the technological frontier.

We address these issues in a variant of the simulation model with a single region (see Table 4.1). The ratio of the number of households (workers) and firms matches mean firm sizes to be observed in Europe.[1] There is a single investment good producer, one mall, bank, and also one government.

As discussed in the previous subsection old members are characterized by a very close distance to the technological frontier in both specific skills and technology. Furthermore, the general human capital is at a relatively high level. New members exhibit a large distance from the frontier for both technology and specific skills, and they have a low general skill distribution. In the followng experiments we refer to the skill distribution of the new member country as the *low* skill distribution, whereas the skill distribution of the old member hereafter is called the *medium* distribution. For the policy experiments we assume a third distribution, the *high* skill case, where the bulk is concentrated in skill level 5 representing the highest skilled workers. Table 4.2 shows the different distributions that will be applied in the experiments.

Table 4.1: General set up

Description	Value
Regions	1
Households	1600
Consumption goods producers	80
Capital goods producers	1
Malls	1
Banks	1
Governments	1

The experiments are conducted in the following order:

1. We first examine if each individual policy measure contributes to a stronger economic growth.
2. Secondly, we investigate if the combination of measures yields better results compared to the case when only a single policy is implemented.
3. Thirdly we consider whether the policy measures have different impacts depending on whether a gap to the technological frontier exists or not.
4. Since the technology of the capital stock in a new member state has a lower quality, we assume a fourth possibility for policy makers affecting the economic growth in a

[1] See http://epp.eurostat.eu.europa.eu.

Table 4.2: The three general skill distributions in terms of percentages of workers in each of the 5 skill groups

	General Skill Level				
	1	2	3	4	5
Low Skill (New member)	0.42	0.33	0.2	0.04	0.01
Medium Skill (Old member)	0.1	0.3	0.4	0.15	0.05
High Skill (Stylized)	0.05	0.05	0.05	0.05	0.8

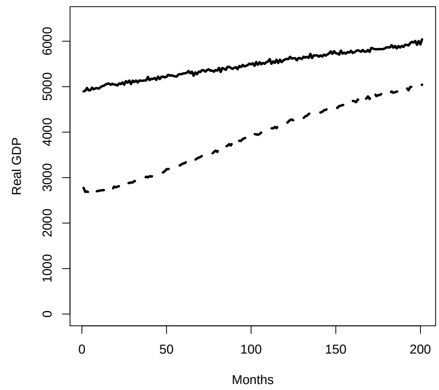

Figure 4.1: Trajectories of real GDP for old (solid line) and new member states (dashed line) over 200 months.

new member state, namely an entire upgrading of the existing capital stock to the current technological frontier.

We ran 20 batch runs with 5000 iterations where we fixed certain variables during the first 1000 iterations in order to allow the system to settle down before changing the environment by carrying out policy measures. The evolution during this transition phase is skipped and is not displayed in the graphs below.

In order to get an idea how the economies evolve without policy intervention we first show in Figure 4.1 the means of the real GDP over 20 batch runs for the base scenarios. Because of the initialization the old member state starts with a GDP that is almost twice the GDP of a new member, but over the 200 months (about 16 years) the new member state can catch up to about 80% of the GDP of the established member. In fact, this convergence is mostly due to a technological catch up with new members decreasing the gap to the technological frontier. In Figure 4.2 the left panel shows the evolution of the technological frontier, and the limiting productivity of the new and old member state.[2] As can be seen there the new member state is able to nearly close the gap in terms of productivity. By the same time the distance between the capital stocks does not change significantly (right panel in Figure 4.2), the same holds for the deployment of the input factor labor (not displayed here).

The growth-enhancing effect of a single policy measure

In the following we focus on the two policy fields that are considered as means for achieving the EU's aims as formulated in the Lisbon Strategy: speeding up the technological progress and a general skill upgrade. To account for the first policy measure we increase the annual growth rate of the technological frontier from 1.4% to 3.5%. The second policy upgrades the general skill level of an old member state from the medium case to the high case. The skill level of new member can be increased from low to medium and in a second step from

[2] As we assume a complementarity between the specific skills of the workforce and the productivity of the capital stock as well as an adjustment process of specific skills towards the technical productivity, the mean specific skills are generally the bounding productivity on the macroeconomic level.

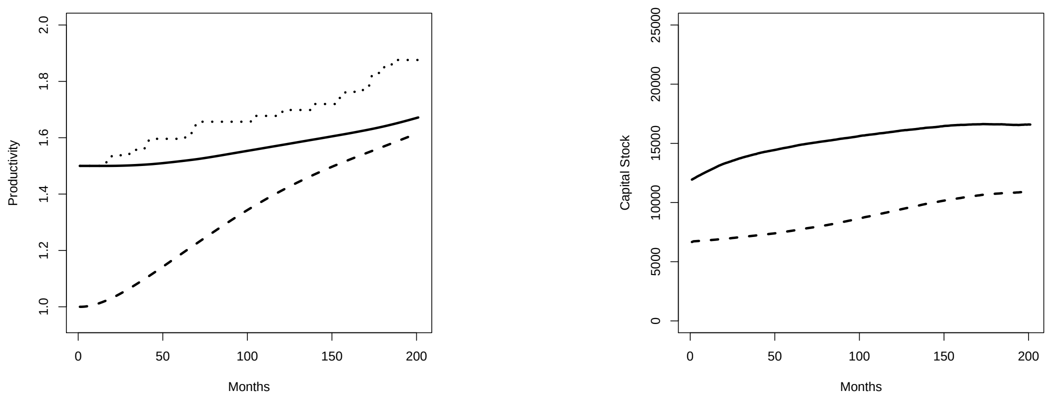

Figure 4.2: Left panel: Technological frontier (dotted line), and limiting productivity for old (solid) and new members (dashed); right panel: economy-wide capital stock for old (solid line) and new member states (dashed line).

medium to the high skill level. In this section we show for both economies how a single policy measure affects the GDP growth compared to its development without any policy. For that purpose, we compute ratios of the real GDP with the policy installed and the base case without policy. This ratio indicates the relative impact of the policy measure.

Figure 4.3 plots the relative advantage of the policy measure affecting the technological progress. It can be seen that this policy measure has a sustainable growth-enhancing effect. The output is higher after the implementation of the policy, where the distance to the no-policy scenario increases over time. A first notable observation is that the higher growth of the technology induces almost the same increase in growth rates for both the old and the new member states. A second observation is that this policy measure has no effect on the short run, but a strong effect on the long run. Table 4.3 gives an overview of the GDP ratios for the short and long term.[3] If the policy is carried out in a new member state the GDP is just about 0.5% higher than in the base case in the short run. But in the long term it exceeds the base GDP by more than 15.4%. A similar observation can be made for an old member, where we actually find a small reduction of output by -0.02% of GDP in the short run, but a strong increase by 14.6% in the long run. Therefore, short term effects are negligible, where long term effects are significant and lasting.

The general skill improving policy measure leads to a different picture. First, as one would expect the upgrade has a positive growth-enhancing effect. Figure 4.4 shows the relative output of the scenario with an upgraded skill distribution, and the output is higher for both the old and the new member. But the policy is less sustainable than the technology improving measure. Although the growth is higher, the distance to the base scenario does not continuously increase over time. Figure 4.4 in combination with Table 4.3 also indicates that there are different short- and long-term effects of the policy measure comparing the impact on growth of an old and new member state. If a new member state upgrades the general skill level, the output ratio increases during the first 80 months, but the distance between the two scenarios settles down after month 80 and

[3]In order to deal with fluctuations, we averaged these ratios from months 40 to 60 for the short term and from 180 to 200 for the long run.

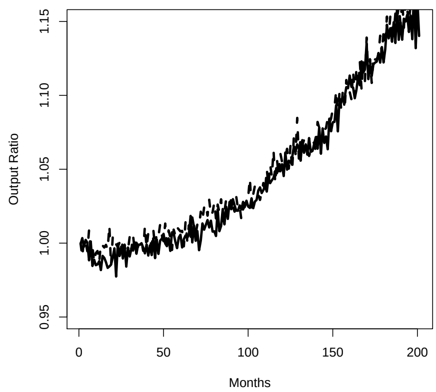

Figure 4.3: Comparing the output effects of a policy measure affecting the technological progress for the two economies new (dashed line) and old (solid line). The effect is the same for old and new member states.

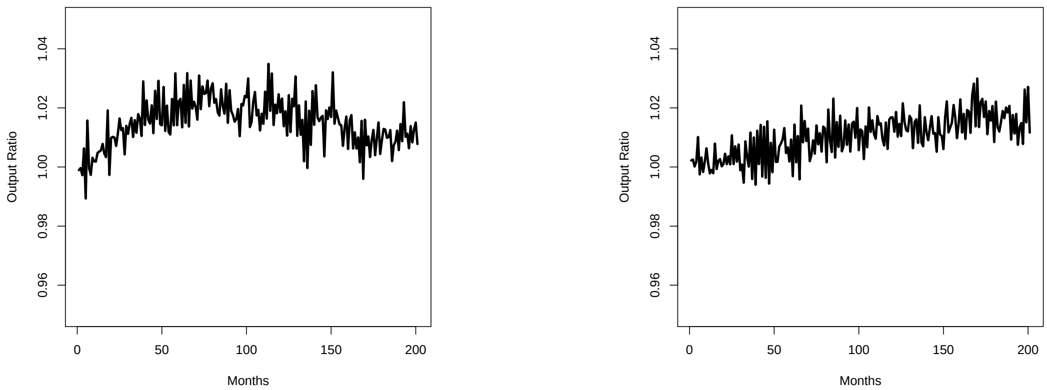

Figure 4.4: The growth-enhancing effect of a skill upgrade for a new member state (left) and old member state (right).

ends up at a constant but positive level. Table 4.3 quantifies the impact of an upgrade leading to a higher output of 1.89% in the short run, but to an additional GDP of 1.07% in the long run. For an old member state the trend deviates from the former cases: here, the growth effect is (0.53% additional GDP) in the short run very weak, but it becomes stronger over the long term (1.6% more GDP).

Given the three possible skill distributions, a new member state also has the opportunity to upgrade its skill level to the highest skill distribution. In order to have a better comparability to old member states we assume that in a first step the skill distribution has already been brought up to the medium level and then policy makers decide to upgrade it again, to the highest level. The advantage of this assumption is that it allows us to compare the quantitative effects of the skill upgrade directly.

Figure 4.5 shows the GDP of a new member with high general skills relative to the GDP with a medium general skill distribution. Here we can, as in Figure 4.4a, also observe

Table 4.3: Short and long term effects of the single policy measures; means of the averaged ratios of output relative to the base scenario from month 40 to 60 (short run) and 180 to 200 (long run).

	Short Run	Long Run
Policy 1: Higher Frontier Growth:		
New Member State	1.0054418	1.1544546
Old Member State	0.9997584	1.1460897
Policy 2: Skill Upgrade:		
New Member State (Upgrade from Low to Medium)	1.018878	1.010697
New Member State (Upgrade from Medium to High)	1.087265	1.047307
Old Member State	1.005275	1.016052

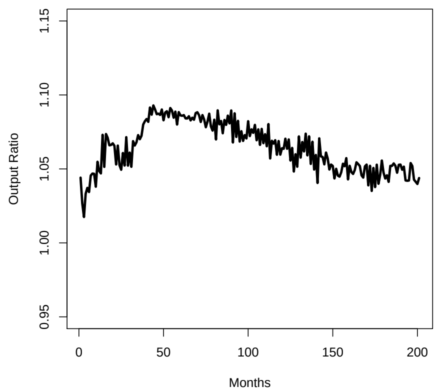

Figure 4.5: The real GDP of a new member state with high general skills relative to the GDP with medium general skills.

the same shape of the evolution of relative GDP, but on a higher level. In the short term the growth-enhancing effect is stronger than in the long run, where the short term gain is about 8.7% but decreases to a level of 4.7% in the long run (see Table 4.3).

If we compare the growth effects of a skill upgrade from a medium to a high level in both economies, we find an interesting observation: the same policy would be more efficient to be carried out in a new member state than in an established member, if first the general skill level in the new member country was upgraded to the current level in the new member country. The output differential is between 8.5% to 0.5% formidable for the short run, and with 4.5% to 1.6% it is still considerable in the long run.

Figure 4.6 provides an explanation for the observed phenomenon. In both economies firms buy the best practice technology when investing in their capital stocks, where the frontier starts at the same level and evolves according to the same random process. While old member states start with a productivity level that is equal to the boundary for both the technology stock and specific skills, the values of a new member state are on a level that corresponds to 66% of the frontier. Consequently, new member states have much more potential to catch up than old member states whose emerging productivity gap is only

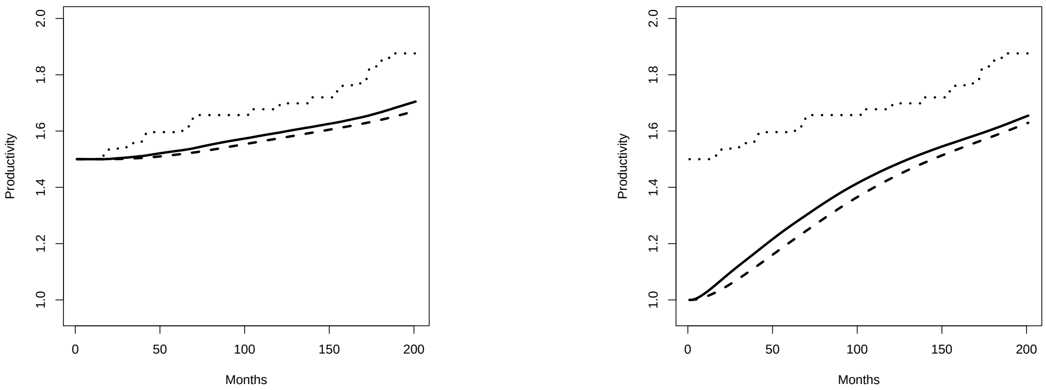

Figure 4.6: Technological frontier and specific skills for an old member state (left panel) and a new member state (right panel); technological frontier dotted lines, specific skills with medium general skill distribution dashed lines, specific skills with high general skill distribution solid lines.

due to the technical progress. Thus, we observe a faster technical productivity increase in new member states, and, since the specific skills are tied to the technology, a faster increase in specific skills as well. Higher general skills lead to a faster adaptation of new technologies in terms of specific skills by the workforce, therefore differences in general skill levels are more crucial for the adaption of specific skills than in the case of an old member with a small productivity gap. This can be seen in Figure 4.6: although there are differences between the specific skill level in the scenarios with medium and high skills for both economies, the difference is more salient for only a new member state. Because this general skill advantages are most effective when the largest technology improvements occur, the general skill difference has its strongest impact in the short run when the new member state catches up most of the gap to the frontier, which explains the higher growth-enhancing effect of a skill upgrade for a new member state in the short run.

The growth enhancing effect of combined policy measures

In the previous section we described the growth effects of two separately carried out policy measures: We obtained different effects for both policy measures, and different results for old and new countries, respectively. We now examine the impact of a combined policy, where both measures are carried out simultaneously. For the sake of compatibility we assume that in a former policy step a first skill improving policy was implemented in a new member state so that the initial skill distribution is for both countries the medium one.

The left panel in Figure 4.7 shows the relative GDP of both countries compared to their base cases. It illustrates the combined effect of a technology improving measure and the skill upgrade (starting from a medium level). The Figure 4.7a should be compared to Figure 4.3 which shows the isolated effect the technological improvement. The result of the combined policy is similar to the single technology improvement, in the sense that GDP growth is affected in a sustainable manner, but in addition the growth level is higher. But there are also differences between the economies. The combined measure leads to stronger improvement of the economic performance in the new member state, where the difference in output gains between the two economies is more pronounced in the short run but becomes smaller in the long run. Table 4.4 quantifies this observation: in the short run the combination of policies yields an additional output of 8.89% for new members while old members gain only 2.02% more output. In the long run these are 23.4% for new members and 19.4% for old members, respectively.

The isolated effect of the skill upgrade is displayed in the right panel of Figure 4.7. It shows the relative GDP of the batch runs for the combined policy versus the scenario where only the technology improving policy is implemented. Thus, it reveals the additional gains that can be achieved when the technology improving policy is combined with the skill upgrade. This should be compared to Figure 4.4, which showed the effect of the skill upgrade policy versus the no-policy case.

Similar to the case where we investigated the effect of a skill upgrade without a faster growing frontier, we have to distinguish short term and long term effects. For the new member state the skill upgrade has a stronger growth-enhancing effect in the short run (Table 4.4 indicates this is 7.13%) than in the long run (3.36%). For the old member states the opposite is true: In the short run the output effect is weaker than in the long run (2.04% vs. 4.22%).

Table 4.4: Output effects of the combined policy measures: Means of the averaged ratios of output relative to the base scenario from month 40 to 60 (short run) and 180 to 200 (long run).

	Short Run	Long Run
Combined Policies:		
New Member State (Upgrade from Medium to High)	1.088808	1.233900
Old Member State	1.020167	1.194420
Isolated effect of the skill upgrade:		
New Member State (Upgrade from Medium to High)	1.071294	1.033576
Old Member State	1.020414	1.042170

The mechanism driving the results is here the same as in the case where we only considered the skill upgrade: higher general skill levels lead to a faster adaptation of new technologies, and consequently to a faster effective productivity growth. This results in higher output. But the effect is more pronounced since now the boundary is also growing on a faster rate and consequently the technical productivity grows faster as well. Thus, general skill differences influence the speed of the specific skill adjustment stronger than in the scenario before. The combined policies are complementary. The technological improvement acts as a catalyst for the positive growth effect of the skill upgrade.

As described in the previous section, the short term advantage of new member states is due to the considerably high gap between the productivity and the frontier (for both specific skills and technology). Investments in the capital stock increase the its quality and hence its productivity where this occurs on a relatively high speed due the gap. The general skill level determines the speed with which the specific skill can follow the capital productivity; the effective productivity grows faster if the labour force has higher general skills. In the long term the productivity growth slows down which diminishes the positive

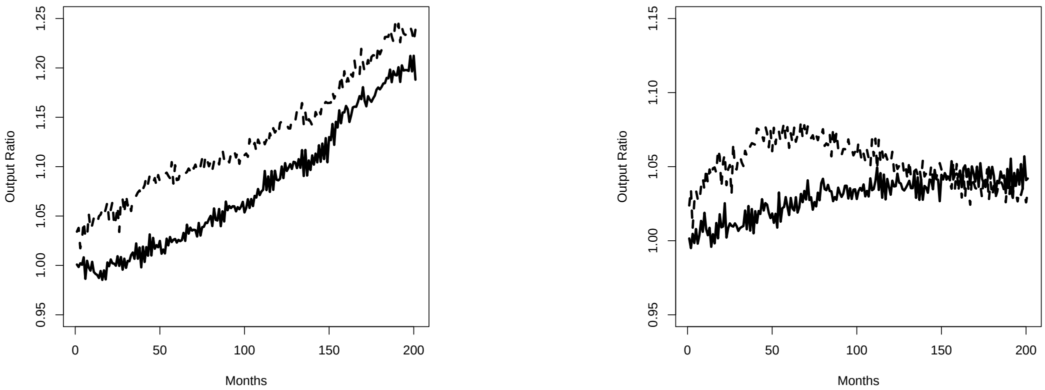

Figure 4.7: Left panel: growth effects of combined policy measures; Right panel: Additional output gain from a skill upgrade if combined with the technology improving policy; old member solid, new member state dashed line.

output effect.

Upgrading the capital stock - another policy option for new member states?

In this section we investigate the effectiveness of the policy measures for new member states if they are combined with a third policy, the modernization of the capital stock. In the new member setting considered so far we assumed that the technical productivity and the mean specific skill are further away from the boundary, and the technology is implicitly modernized by new investments where this modernization lasts quite long until the quality approaches the level of established members.

The question arises what are the growth effects if this modernization is carried out and finished more rapidly. We investigate this question by means of the very extreme case where the quality of the capital stock is immediately brought up to the most recent technology level.

Figure 4.8 summarizes the results for the three policy scenarios described above: the improvement of the technology, the skill upgrade (here investigated medium to high), and the combination of both. For all policies we observe the same shape: At the beginning we have a very strong increase of the relative GDP, which decreases over time and the GDP ratio apparently converges to 1.0.

The very strong increase at the beginning can easily be explained by the fact that in this special case the technological productivity does not increase on a low but moderate rate as it would if induced by physical investments. Rather it is shifted up immediately and since the specific skills converge to the shifted productivity, the effective productivity increases much faster. This causes the very strong growth-enhancing effect in the short time. But this is just an acceleration of catching up the technology, while in the long run the technology and the output end up on the same level as without the capital stock modernization.

The modernization has slightly different effects on the output growth if combined with different policies. The growth effect when upgrading the general skills leads to a higher output increase which also ascends more steeply than the case where the skills are not

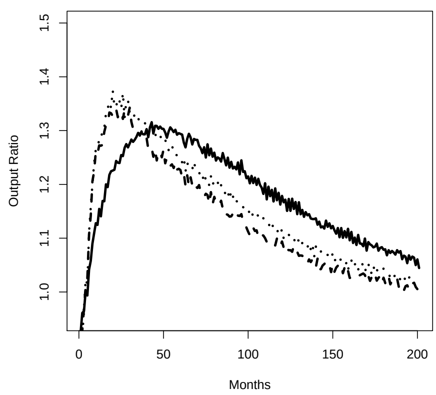

Figure 4.8: Comparing the effects of the policy measures for a new member in case of a modernization of the capital stock before implementing the policy: technological improvement (solid line); skill upgrade (dashed line); combination of both policies (dotted line).

upgraded, in which case it does not matter if the policy is combined with the technology improving policy. But on the other hand when the skills are not upgraded the convergence is slower, thus the positive output effect is more sustainable.

4.1.2 Integration of European Union regions: Policies of opening up labor markets and their impact on convergence

We turn to the second set of experiments now. In this part we will analyze the difference between various scenarios of the integration of two labor markets of two regions which have a high or low technological development, respectively. One region is the technological leader. In this region the consumption goods producers use high quality capital goods for production whereas in the other region firms use low quality goods. We assume that the consumption goods market as well as the capital goods are global. Hence the low developed region gets access to the high quality capital goods. In the presence of the complementarity between the quality of capital goods and the skills to use these capital goods we address the question how the regions will develop regarding key macroeconomic variables like sales, output, and capital stocks.

Setting up the experiment

Table 4.5 summarizes the general setup of the model only stating the specific settings related to the set of experiments to be conducted in this section. All else is equal to the common test-bed already used in the first set of experiments. In particular, the other parameter settings as described in section 2.2 apply.

Most importantly we switch on the spatial feature of the EURACE model allowing for two economically distinct regions. Households and firms are equally distributed across these regions. Note, however, that there is a single capital good producer and a single bank operating globally. Region 1 is characterized by the properties of an old member country, whereas region 2 is a new member country (see Table 2.1 for the corresponding

Table 4.5: General set up

Description	Value
Regions	2
Households	1600
Consumption goods producers	80
Capital goods producers	1
Malls	2
Banks	1
Governments	2

parametrization).

The region specific setup is the same in all four policy scenarios of our experiments which read the following:

1. Closed scenario: Workers can only work in their domestic region.
2. Open scenario: Workers can work in both regions.
3. Open-c: Workers can work in both regions but they have commuting costs.
4. Closed-1000-open-c: Workers can work in both regions after the first 1000 periods (50 months) and have to bear commuting costs.

These experiments are thought to address policy question like which labor market policy can be regarded best with respect to a set of economic indicators. In particular whether there is a case of opening labor markets completely or not, or whether one should consider retarding the opening up of labor market flows between the regions.

For each scenario we ran 50 single runs. Each single run represents 5000 periods (days) or 250 months. As before we execute a transient phase of 1000 periods in order to let the economy develop and to avoid starting effects which may influence the whole run. The transient phase is not part of the economic analysis in the following and consequently not shown in the figures. The results for each scenario that we present below are derived by averaging over the 50 batch runs in every period (corresponding to a total length of 200 months) and for each variable.

Simulation results

We start by showing the sales figures in terms of box-and-whisker plots for each of the four scenarios for month 200. The boxplots give a first impression about the different sales levels between the scenarios and also between the regions.

The four boxplots in Figure 4.9 correspond to the closed, open, open-c, and closed-1000-open-c scenarios. The total sales in the open-c are higher than in the closed scenario, followed by the open and the closed-1000-open-c scenario. Table 4.6 presents the p-values of the one sided Wilcoxon signed rank test. It becomes obvious that the opening of the labor markets is not per se the dominating alternative if measured against total sales because the closed scenario dominates the open as well as the closed-1000-open-c scenario. The existence of labor market frictions included by the commuting costs seems to have a strong influence on the performance of the scenarios.

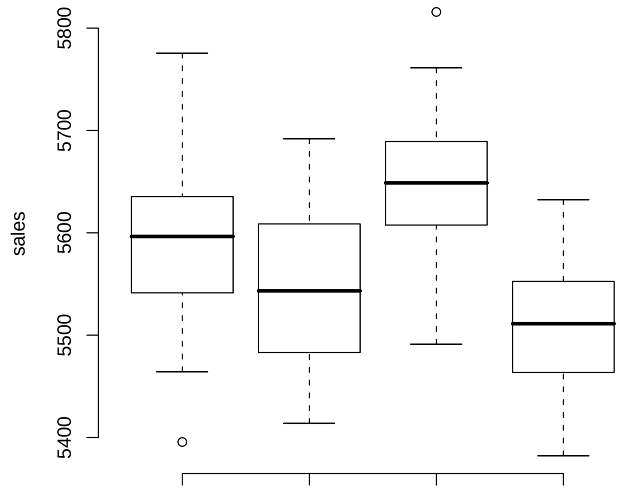

Figure 4.9: Total sales in month 200. Scenarios: Closed, Open, Open-c,Closed-1000-open-c from left to right.

In Figure 4.10 we decomposed the total sales into the regional sales. The first four boxplots represent the sales in region 1 for the four scenarios and the second four represent the sales in region 2. Again the order of the scenarios is closed, open, open-c, and closed-1000-open-c. In region 1 the closed scenario dominates the open-c, followed by the open and the closed-1000-open-c whereas the last two are almost equal. In region 2 the order of the scenarios is different. The open-c scenario dominates the open, followed by the closed-1000-open-c and the closed scenario. Thus, there is heterogeneity with respect to how economically diverse regions are affected by various policy measures targeting labor market integrations. It is not only the ordering of the scenarios within the regions which differs. Additionally the figure illustrates that the largest gap between the sales in the two regions is in the closed scenario. The gaps of the three open scenarios is remarkably smaller whereas the smallest gap can be observed in the open-c scenario.

Figure 4.21 illustrates the regional sales not only looking at the outcomes after 200 months but offering a time perspective. These time series basically reflect the ordering over the four distinct experiments and the two regions with respect to sales already detected in the boxplots.

As another performance measure figure 4.11 presents the regional output. In region 1, the lowest output is obtained in the closed scenario. In the open scenario without commuting costs the output is higher, and in the open-c it is still even higher. The closed-1000-open-c scenario with commuting costs is somewhere in between the open and open-c cases. In region 2 the order is reversed with the closed labor market leading to the highest output. In contrast to the regional sales the smallest gap between the regional output can be observed in the closed scenario and the largest one in the open-c scenario.

Figures 4.9, 4.10, and 4.11 have shown that the ranking of the scenarios changes as

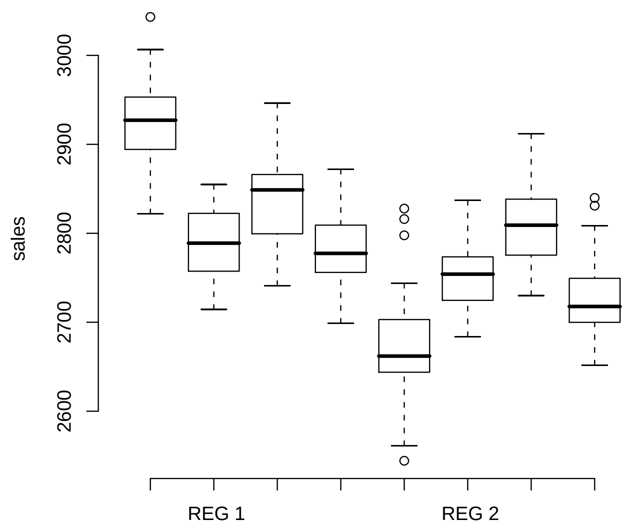

Figure 4.10: Regional sales in month 200. Region 1 (boxes 1-4); Region 2 (boxes 5-8); Scenarios: Closed, Open, Open-c,Closed-1000-open-c from left to right for region 1 and region 2, respectively.

we move from the aggregate to the region specific effects, as well as we turn attention from sales to output as another measure of performance. If the policy objective were to maximize the total sales or the sales in region 2 then the open-c scenario should be chosen. However if the objective were to maximize the sales in region 1 then the closed scenario would be chosen. If the objective is to maximize output, then the open-c is preferred for region 1 but would be the worst for region 2. In order to shed more light and better understand the economic mechanisms behind these results we will turn to other economic variables and their evolution comparing the different scenarios.

Disentangling the economic mechanisms

In the figures below the closed, open, open-c, and closed-1000-open-c scenarios are represented by the solid, dashed, dotted, and dashed-dotted line, respectively.

Figure 4.12 presents the number of commuters from region 1 to region 2 (left panel) and from region 2 to 1 (right panel). Of course there are no commuters in the closed scenario. In the open scenario the number of commuters in both directions is the highest and there is a net flow of commuters from region 2 to 1 (low developed region to developed region). This is due to the absence of commuting costs. Nearly the same net flow can be observed in the open-c scenario but because of the commuting costs it consists of only a very small number of commuters from region 1 to region 2 and only around 100 commuters in the other direction. The net flow in the closed-1000-open-c is slightly smaller. Because labor markets are opened later the wages converged slightly in the meantime and hence region 1 is relatively less attractive in month 50 than in the open and closed-1000-open-c scenario in month 0. The number of commuters from region 1 to region 2 is nearly equal

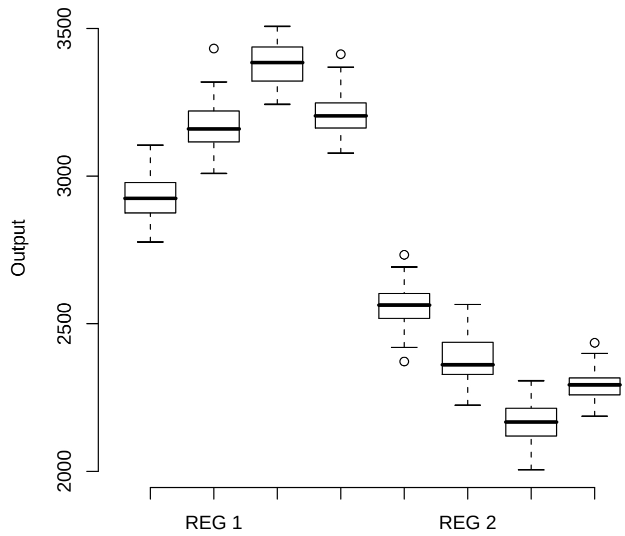

Figure 4.11: Regional output in 200. Region 1 (boxes 1-4); Region 2 (boxes 5-8); Scenarios: Closed, Open, Open-c,Closed-1000-open-c.

the open-c scenario and in the other direction the number is slightly lower. Thus, the net flow is slightly lower.

Due to the commuting a transfer of specific skills from one region to the other takes place which changes the regions capability to appropriate the existing technology at its full potential. And furthermore, since general skills differ on top of the specific skills for workers between the two regions, the prerequisites for the speed of adaption of new technologies via specific skill development are affected. Putting it differently, already at this stage we observe how different labor market integration policies will change technology diffusion by changing the prerequisites of making use of the currently available technology.

Since we can observe different patterns of commuting in the scenarios the average specific skills of employees in the regions and between the scenarios develop in different ways. Figure 4.13 presents the regional average specific skills of employees. In all scenarios except in the closed scenario workers commute from region 2 to region 1 and import their specific skills into region 1. Since in region 2 the workers have lower specific skills than in region 1 the average specific skills of employees in region 1 are the highest in the closed scenario. In the other scenarios the specific skills decrease directly after workers commute into region 1. The specific skills in the open-scenario are the lowest because of the high number of commuters from region 2 into region 1. The specific skills in the open-c and closed-1000-open-c scenarios are nearly the same. Only in the first 50 months the specific skills in the closed-1000-open-c scenario are higher due to absence of commuters. In region 2 this is reversed. Since high specific skills are imported by commuters into region 2 the average specific skills of employees are the highest in the open scenario due to the high number of commuters in that scenario. This is followed by open-c and closed-1000-open-c which are equal after 100 months. The closed scenario has the lowest average specific

Sales total	o-c	>	c	>	o	>	1000
p-values		0.00042		0.00036		0.02502	
Sales reg 1	c	>	o-c	>	o	>	1000
p-values		5.494e-09		7.648e-07		0.1335	
Sales reg 2	o-c	>	o	>	1000	>	c
p-values		8.38e-08		0.00512		1.972e-06	
Output reg 1	o-c	>	1000	>	o	>	c
p-values		1.218e-09		0.002883		3.895e-10	
Output reg 2	c	>	0	>	1000	>	o-c
p-values		6.32e-10		1.336e-07		1.542e-09	

Table 4.6: p-values of the one sided Wilcoxon signed rank test. c (closed); o (open); o-c (open-c); 1000. (closed-1000-open-c)

skills.

Equation 2.3 shows that the wage setting is based on the specific skills of the workforce. Consequently the development of the wages is similar to the development of the specific skills. Figure 4.14 shows the development of the wages that firms are paying. The highest wages in region 1 are paid in the closed scenario because the specific skills are highest. The closed scenario is followed by the open-c, the closed-1000-open-c, and the open scenario. Apart from the specific skills the tightness of the labor market also influences the wage. If the labor supply decreases given a constant labor demand firms have to pay a higher wage per specific skill unit to attract the required workers.

One factor is the commuting of workers because commuters can affect the labor supply in one region. Figure 4.15 illustrates the base wage offers which means the wage paid for one unit of specific skills. The higher the tightness on the labor market the higher is base wage. The highest base wage in region 1 is paid in the closed followed by the open-c, the closed-1000-open-c, and the open scenario. The base wage and the specific skills together explain the different gaps between the wages in the scenarios. Due to the higher base wage in region 1 in the open-c scenario the wage is higher than in the closed-1000-open-c scenario even though the specific skills are equal. In region 2 the highest wages are paid in the open scenario, followed by the open-c, the closed-1000-open-c and the closed scenario. The wages in the open scenario are not much higher than in the open-c scenario although the specific skills are remarkably higher. This is due to the higher base wage in the open-c scenario. The base wage is the highest in open-c scenario followed by the open, the closed-1000-open-c, and the closed scenario.

Beside other factors the base wage influences the price. The prices are presented in Figure 4.16. For region 1 we observe after 100 months that prices are highest in the closed scenario followed by the open-c, the open, and the closed-1000-open-c scenario. The last two are nearly equal. Price developments and and orderings along the different scenarios are mainly driven by the differently evolving base wages as a major part of the price determination of firms that by assumption charge a markup on unit costs.

Given the different wage and price developments it is prima facie not clear that a higher wage in one region in one scenario means that also the purchasing power is higher. In order to give an impression about the purchasing power Figure 4.17 illustrates the regional real wages received by households in both regions. In region 1 the real wages in

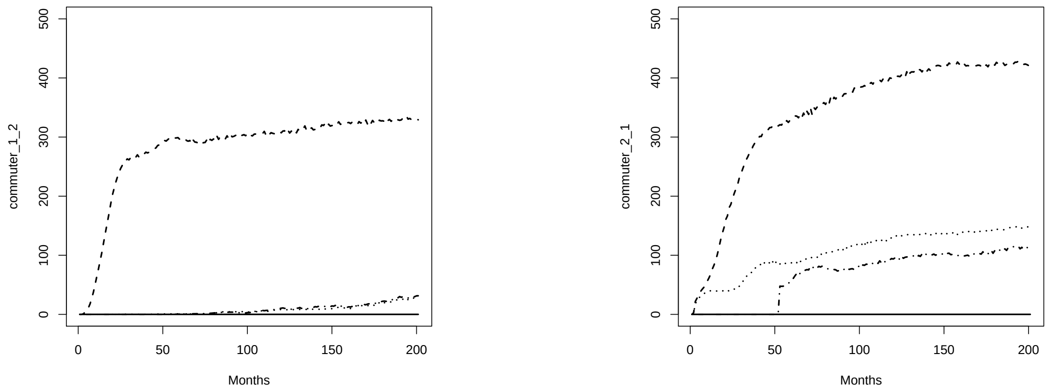

Figure 4.12: Left panel: Commuters from region 1 to region 2 — Right panel: Commuters from region 2 to region 1; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

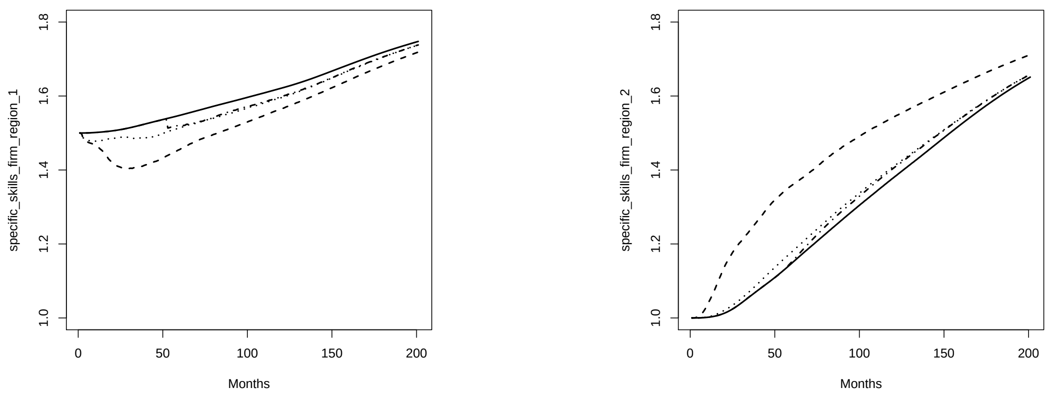

Figure 4.13: Specific-Skills-Firm: Left panel: Region 1 — Right panel: Region 2 ; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

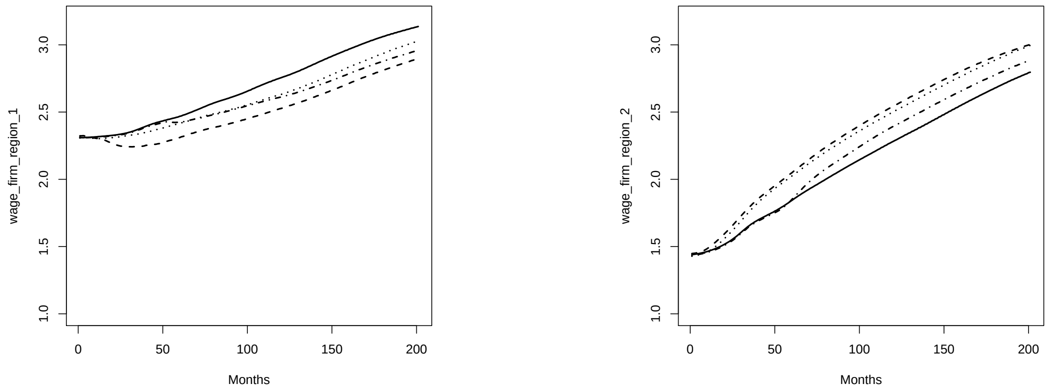

Figure 4.14: Wage-Firm: Left panel: Region 1 — Right panel: Region 2 ; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

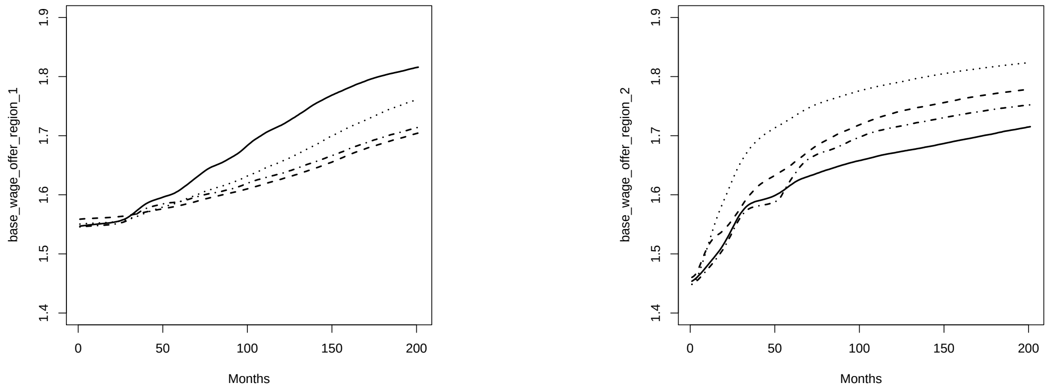

Figure 4.15: Base-wage-offer: Left panel: Region 1 — Right panel: Region 2 ; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

the closed scenario are higher than in the open-c, followed by the open and closed-1000-open-c scenario which are nearly equal. In region 2 the real wages in the open scenario are higher than in the open-c, followed by the closed-1000-open-c and the closed scenario.

All prices are increasing but with different growth rates in the scenarios and also across regions. The prices of the consumption goods of the two regions in one scenario have of course a strong impact on the demand for these consumption goods and hence on the sales, output and base wages. In order to get a clearer picture about the influence of the price development on the demand Figure 4.18 shows the relative prices of consumption goods from region 2 in relation to region 1. The highest relative prices are obtained in the open-c followed by the closed-1000-open-c, the open, and the closed scenario. This means that the relative demand for consumption goods produced in region 1 in relation to region 2 is the highest in the open-c scenario and lowest in the closed scenario.

The different relative demands for consumption goods and labor supply in each region drive the different base wage offers. In Figure 4.15 the base wage in scenario open-c is remarkably higher than in the open scenario although the labor supply is nearly the same. But the demand for consumption goods is higher in the open-c scenario and consequently the base wage offer is higher. But Figure 4.15 shows that also in region 2 the base wage in the open-c scenario is the highest.

That means that the demand for consumption goods from region 2 in the open-c scenario is higher than in the open scenario although the goods are relatively more expensive. The additional demand in the open-c scenario can be traced back to the different developments of the capital stocks. Figure 4.19 presents the total capital stocks of the scenarios. The total capital stock is the highest in the open-c followed by the open which is nearly equal to the closed, and the closed-1000-open-c scenario. Since the households are to the same extent shareholder of every firm they receive more capital income in the open-c scenario than in the others. This additional consumption budget leads to a higher demand for consumption goods from region 2 in the open-c scenario than in the open scenario and explains the highest base wage.

The size of the capital stock of one firm is driven by the demand for its consumption goods and by the relative price of capital and labor. Figure 4.20 illustrates the capital stocks per region. The highest capital stock in region 1 is in the open-c scenario followed by the closed-1000-open-c, the open and the closed scenario. In region 2 it is vice versa. We also observe that the gaps between the capital stocks in the scenarios are different in region 1 than in region 2. The relative capital stock in region 1 in the open-c scenario compared to the other scenarios is higher than the relative capital stock in region 2 in these scenarios compared to the open-c scenario. Hence the total capital stock is the highest in the open-c scenario.

Putting the bits and pieces together ordering of sales levels over the four experiments and along the two regions can be explained as combined effects arising from real wage levels and capital income which households receive as dividends from the firms. As figure 4.17 showed real wages are highest in the closed scenario. Additionally, although households in region 1 receive lower dividends than in the open-c scenario (because in the open-c scenario the total capital stock is higher) the sales are higher in the closed scenario. Obviously, the additional capital income in the open-c scenario is not high enough to compensate for the lower real wages. The sales in the open-c scenario are higher than in the other two scenarios because of slightly higher real wages and higher capital income. The sales in the last two scenarios are nearly equal with a tendency favoring the open scenario. Since the

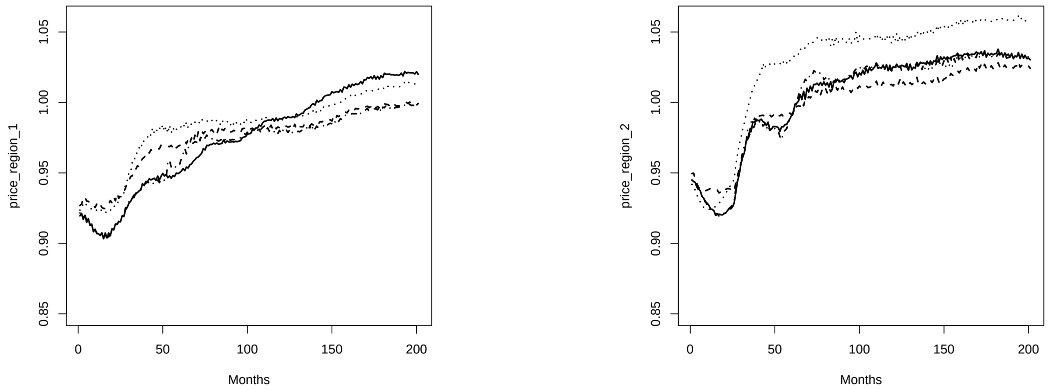

Figure 4.16: Price: Left panel: Region 1 — Right panel: Region 2 ; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

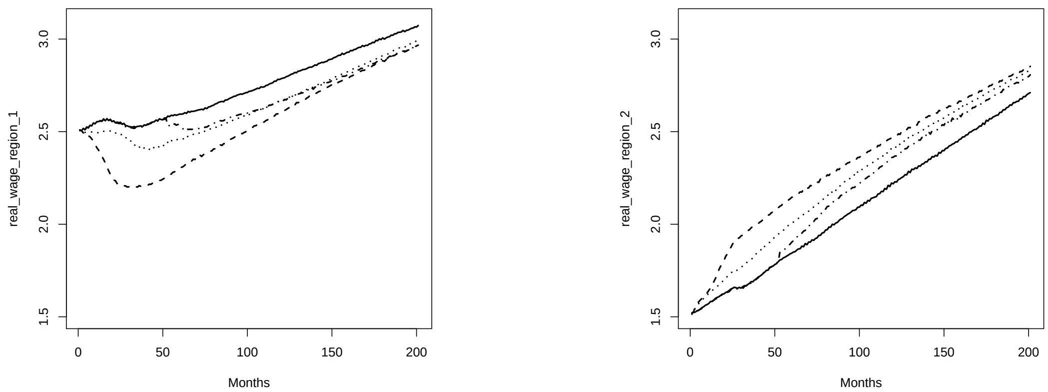

Figure 4.17: Real wage: Left panel: Region 1 — Right panel: Region 2 ; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

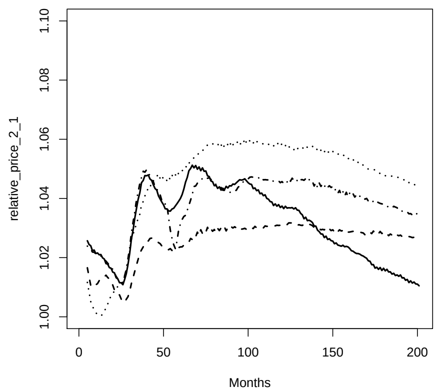

Figure 4.18: Relative Price 2/1: Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

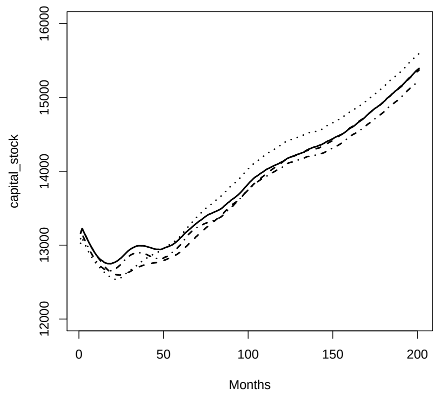

Figure 4.19: Capital-stock total: Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

real wages are almost equal this tendency can be traced back to the higher capital stock in the open scenario.

In region 2 the sales in the open-c scenario are higher than in the open scenario, followed by the closed-1000-open-c and the closed scenario. The real wages (Figure 4.17) are higher in the open than in the open-c scenario. Nevertheless because of the remarkably higher capital stock (Figure 4.19) and consequently higher dividends the sales in the open-c are higher than in the open scenario. The sales in the closed-1000-open-c scenario are lower than the sales in the open scenario because the real wages as well as the capital income is lower. Although the capital income in the closed scenario is higher than in the closed-1000-open-c scenario the sales are lower because of the lower real wages.

Demand side arguments as developed to explain sales patterns and the lack of specific skills that results in a lack of wage transfer in the closed scenario lead to the slowest convergence process in the closed scenario as can be seen in the upper left graph in Figure 4.22. Comparing the panels we can also see that higher specific skill transfer leads to faster convergence process which illustrates the role of labor market integration policies for the diffusion of technologies and consequently convergence. In the open scenario in the upper graph the gap between the regional sales is closed faster than in the open-c followed by the closed-1000-open-c scenario in the lower right corner.

Finally, let us turn to the other performance measure introduced at the beginning. Figure 4.23 shows on the left panel the output in the four scenarios in region 1 and on the right panel for region 2. Since in the closed scenario no workers commute to region 1 the output is lower than in the other scenarios in region 1. Although the net import of workers in the other three scenarios is nearly equal the output in the open-c scenario is the highest because the consumption goods in region 1 are relatively cheaper (see Figure 4.18). Hence the demand for these goods is higher. The same argument holds for the comparison between closed-1000-open-c and open where the output is higher in the closed-1000-open-c scenario. For region 2 the argumentation can be turned around. The labor supply in region 2 in the closed scenario is higher and the consumption goods are relatively cheaper than in the other scenarios. Hence the output is the highest. Since the consumption goods in the open scenario are relatively cheaper than in the closed-1000-open-c where the goods are also cheaper than in the open-c scenario the output is the highest in the open scenario followed by the closed-1000-open-c and the open-c scenario.

In contrast to the sales only in the closed scenario does the regional output converge slowly as can be seen in the upper left corner of Figure 4.24. This development is mainly driven by the absence of commuters. In the other three scenarios in which more workers commute from region 2 to region 1 than the other way round the gap between the regional output remains nearly constant with higher output in region 1.

4.1.3 Summary and Implications of the Innovation Policy Experiments

Two major policy initiatives were undertaken by EU member states in the current decade. First and among other proposals that came with the the Lisbon Strategy, it was strongly argued that investments into human capital and R&D activities should be increased to foster productivity growth in Europe. Secondly, new members states from Eastern Europe joined the European Union, a process which was accompanied with a highly debated gradual opening of the labor markets. The issue of labor market integration raised a lively debate in the public, among politicians and in academia where mostly arguments were exchanged on whether labor migration would undermine provisions of the social welfare

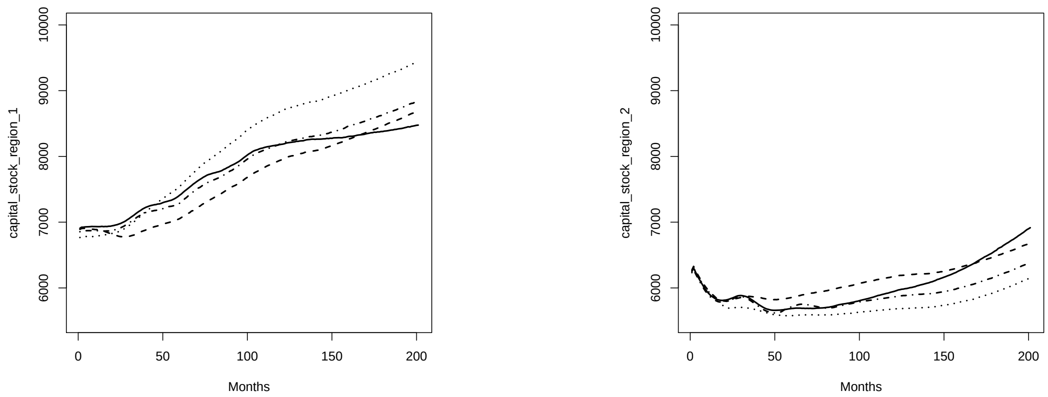

Figure 4.20: Capital-stock per region: Left panel: Region 1 — Right panel: Region 2 ; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

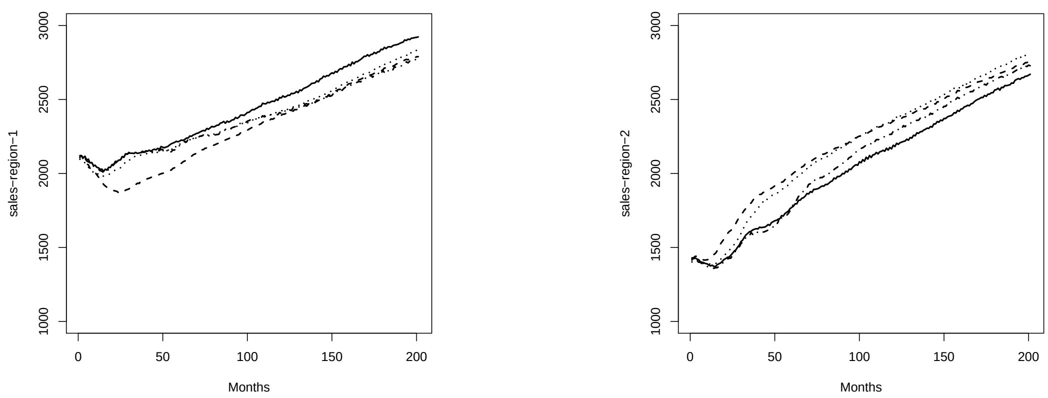

Figure 4.21: Sales per region: Left panel: Region 1 — Right panel: Region 2 ; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

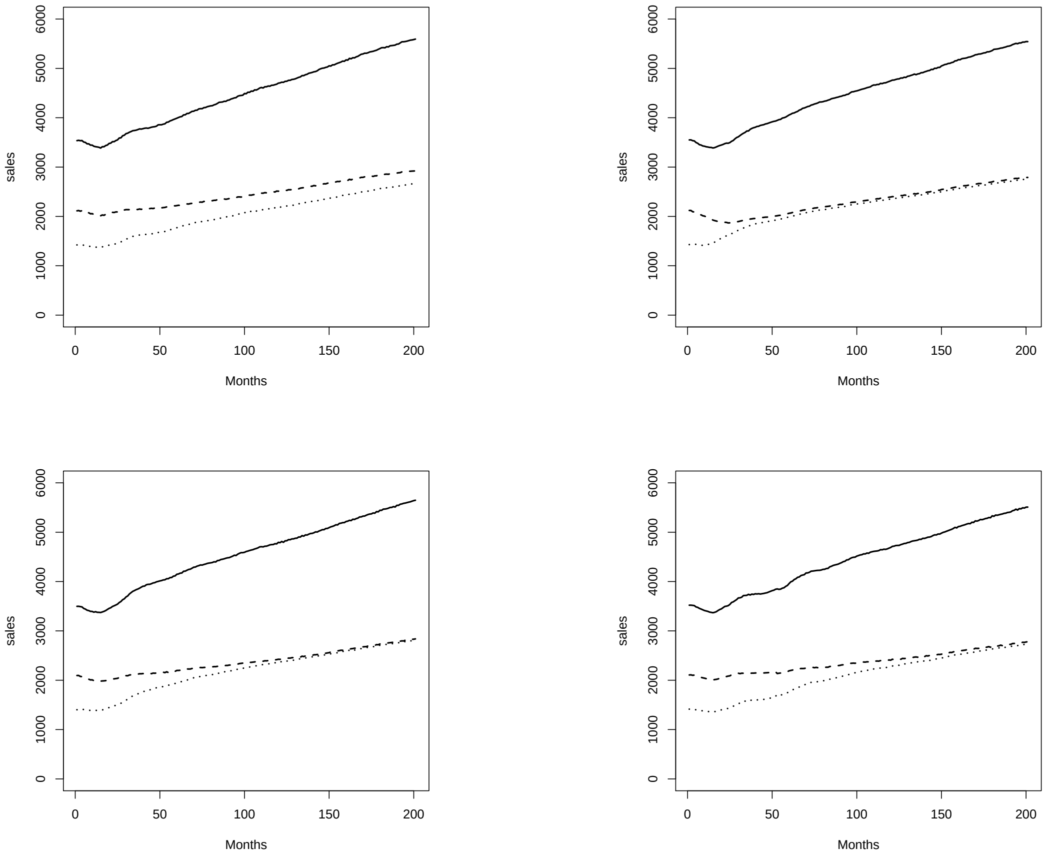

Figure 4.22: Sales: Upper left: Closed; Upper right: Open; Lower left: Open-c; Lower right: Closed-1000-open-c — Total (solid), Region 1 (dashed), Region 2 (dotted).

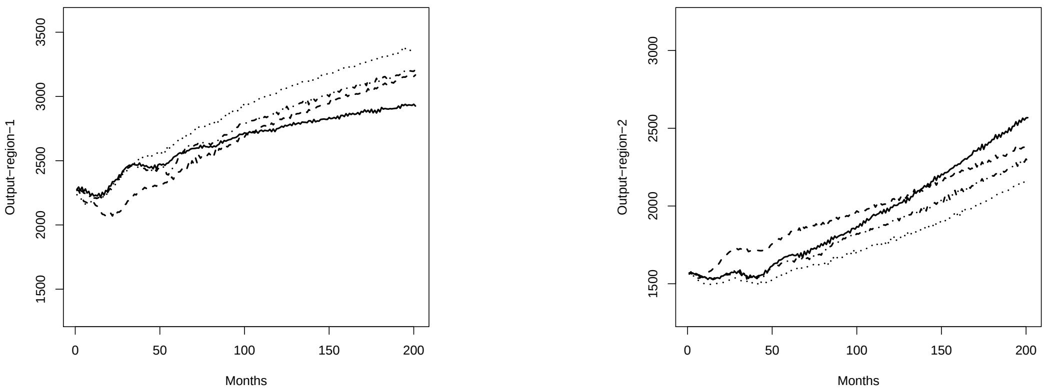

Figure 4.23: Output per region: Left panel: Region 1 — Right panel: Region 2; Closed (solid), Open (dashed), Open-c (dotted), Closed-1000-open-c (dashed-dotted).

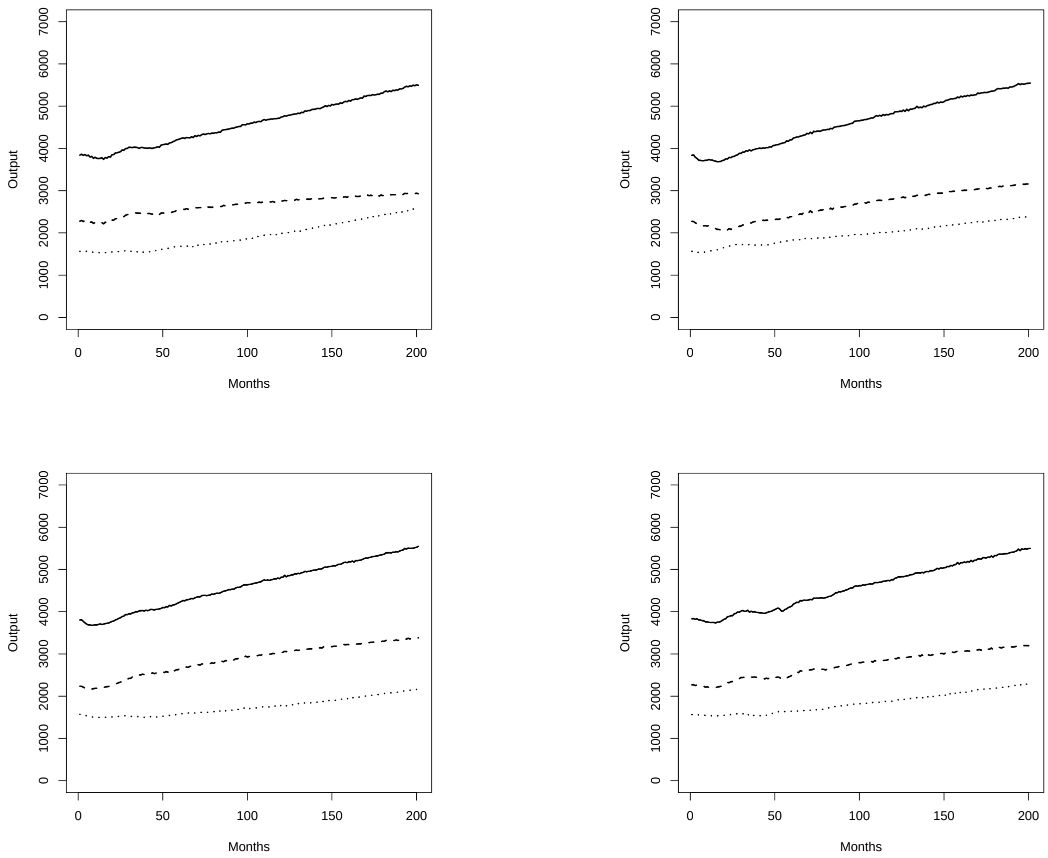

Figure 4.24: Output: Upper left: Closed; Upper right: Open; Lower left: Open-c; Lower right: Closed-1000-open-c — Total (solid), Region 1 (dashed), Region 2 (dotted).

state.

We addressed both policy topics in an effort to demonstrate the applicability of the EURACE model to study likely consequences of alternative policies in a meaningful way. We put our focus on economic mechanisms driving the outcomes of the policy measures at hand that were so far to a lesser extent investigated and where we believe that an agent-based model can improve on previously conducted policy evaluations. In both sets of experiments our focus was on technology diffusion and the likely impact various policies may have on the closing of a technology gap through intermitting variables most importantly the general and specific skill levels of the workforce.

The first set of experiments was conducted within a version of the EURACE model where we set up the framework as a single country and we defined two base scenarios, one representing an old member state and another representing a new member state. We applied the two policy measures plus a third policy only applicable for new members and we found that a policy targeting the technological improvement leads to higher growth in the long term, while a skill upgrade leads to a short term burst, but this burst is too short-lived to be sustainable. For sustainable economic growth it is required to have an environment of technological progress underlying the skill upgrade. Technological growth acts as a catalyst for the positive growth-enhancing effect of a skill upgrade. Without the presence of the technological progress the skill upgrade has a positive effect, but not nearly as large as when there is technological improvement.

Comparing the growth effects of the policy measures in new and old member states, we found that the policies have not necessarily the same effects in both countries. Especially for the skill upgrade we found remarkable differences in the strength of the effects as well as in their short and long term impacts.

As figured out the combination of a skill upgrade and technological improvements leads to a clearly positive growth-enhancing effects in both countries, where the effect is stronger for new member state. Thus, we can summarize that these instruments of the Lisbon Strategy are appropriate for reaching the aims of the Lisbon Strategy, especially because they lead to a faster convergence of new and old member states.

In the second set of experiments targeting the issue of labor market integration and its impact on technology diffusion and convergence, we carried out simulations for four different scenarios concerning the opening of the labor market of two technological differently developed regions. In one scenario we did not allow workers to commute whereas in the other workers could commute with and without bearing commuting cost. We assumed that that consumption goods market as well as capital goods market are already open and that the low developed region gets access to the high quality capital goods.

Due to this access firms in the low developed region improve their technology and hence their employees learn faster and consequently wages are increased. Overall due to the access to high quality capital the regions converged regarding the technology being used, wages, and specific skills.

But the results show that it is ex ante not clear that the opening up of labor markets per se is better than to keep them closed as we consider different indicators as total sales, output or capital stocks. Whether or not the performance is better in open labor markets depends on the frictions of the open labor markets and the point of view taken. Since the output as an indicator for the performance in the different scenarios is mainly influenced by the commuter flows (quantitative effect) and might be blurred by the stocks, and does not give an impression of the development and quality of capital stocks, it seems to be adequate to put more weight on the sales and the capital stocks when answering the question which scenario is the best. From the total and the regional point of view regarding and with respect to sales the open-c scenario is better than the other scenarios where labor markets are opened.

Regarding the capital stock the open-c scenario is to be preferred for the high developed region as well as overall but in the low developed region it is the worst. Since it generates the highest total capital stock and also the highest total sales and therefore the highest total output it is comprehensible to prefer the open-c scenario over the other open scenarios.

Controlling the flows of commuters by imposing commuting costs and allowing commuting as early as possible is the best alternative among the opening scenarios for both regions and overall.

Compared to the open-c scenario the closed scenario performs better in the high developed region regarding the sales (in units) and in the low developed region regarding the output and the capital stock. This is mainly driven by the commuters leaving the low developed region in the open-c scenario. Hence the labor supply and therefore the capital stock and output is higher in the low developed region when labor markets keep closed. Also the absence of commuters protects the wages in the high developed region and leads to higher sales having closed labor markets. But the consequences of preventing commuting and skill transfer are lower total sales, lower total capital stock and therefore lower total output.

In the very long run the open-c scenario - an open labor market with moderate commuting costs - leads also to higher sales in the high developed region due to the better allocation of workers and the higher total capital stock. In addition one should not ignore the fact that the open-c scenario leads to a faster converging process regarding sales in both region and contributed to a more equal wealth distribution between the regions. These arguments lead to the conclusion that the opening of the labor markets, imposing commuting costs to control the subsequent flows of workers, is the best alternative.

4.2 Analysis of Energy Shock Responses

4.2.1 Effects of Energy Shocks without Countermeasures

As a benchmark, we first consider a situation in which there are no active policy measures to counter the negative effects of an energy shock. This is the benchmark scenario. We quantify the correlation between the level of the energy shock and the change in GDP growth rate in this scenario.

Capturing an energy shock in the EURACE model

We typically assume that an energy shock consists of a succession of consecutive, identical (in length and intensity) energy price increases. Thus, an energy shock is captured by three parameters: the intensity of the single price increases (π), their periodicity Π (the number of days between two consecutive price increases), and the number of price increases (n). The total duration of the energy crisis (d) is then $d = \Pi n$. The price increase π is assumed to instantaneously disappear at the end of the total duration. The time profile of a typical energy shock is illustrated in Figure 4.25 below. We analyze the model response to variations to the three parameters duration d, intensity π, and periodicity Π.

In the basic EURACE version, the investment goods producers update the price of the investment good based on the increase in productivity of the machinery. This reflects innovation and technological progress, which occurs probabilistically. We now enrich the model by including the impact of the energy costs on the investment goods.

The energy costs of the investment goods producers are incorporated into the price of the capital good by an energy price mark-up equal to the intensity of the price shock (π):

$$p_{t+1} = (p_t + p_{t,c})(1 + \pi), \tag{4.1}$$

where(p_t) is the price in period t and ($p_{t,c}$) is the price update due to the productivity increase.

The additional revenues stemming from the technologically motivated price increase ($p_{t,c}$) are partly paid out as taxes and partly paid out as dividends to households.

The revenues that accrue due to the energy costs mark-up are not paid out in taxes or dividends. Instead, the money is stored in a variable called `cum_energy_costs` that represents the total cumulative income of the owners of the energy source (the Sheik of Qatar, Dubai, etc.), which does not play any role in the EURACE dynamics. In other words, it leaves the economic system described by EURACE.

Experimental design

In this subsection we describe how we set up the computational experiments.

We consider an energy shock over a pre-determined time interval $[T_a, T_b]$. The first, pre-shock 1000 iterations are ignored in the analysis of the experiment. Following these 1000 initial iterations, we run the model for 240 further iterations before starting the energy shock ($T_a = 240$). After the energy shock period, at $t = T_b$, we run the model for another 240 iterations in order to analyze the legacy of the shock. Thus, the total number of iterations for a single run (without the transient period) is $240 + (T_b - T_a) + 240$. To obtain statistically significant results we perform 20 batch runs per case (parameter combination). See Table 4.8 for details.

Figure 4.25 shows the time profile of such an experiment. The choice of the profile is motivated by empirical evidence as shown in figure 3.1.

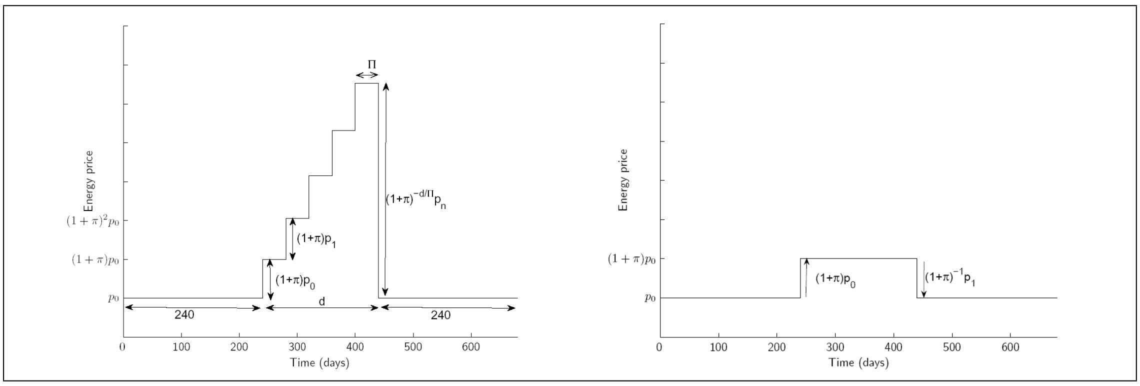

Figure 4.25: The time profile of an energy shock experiment. Left panel: periodicity $0 < \Pi < +\infty$, right panel: periodicity $\Pi = +\infty$.

We consider the following values of d:

Table 4.7: Parameter values

Name	Symbol	Values	Description
duration	d	240	Duration of the energy crisis in days
intensity	π	$\{0.01, 0.05\}$	Percentage price change for a single shock
periodicity	Π	$\{20, +\infty\}$	Periodicity of the shock in days

Table 4.8: Overview of the computational setting.

Name	Value
Cases	4
Batch runs per case	20
Iterations per run	3000
Pre-iterations	1000

- Short energy crisis scenario: $d = 40$ days,
- Long energy crisis scenario: $d = 240$ days,

and for each of these two values the following cases:

- Case 1: periodicity $\Pi = 0$

There is a single instantaneous energy price increase π at T_a, and an instantaneous decrease of the same intensity at T_b. However, in the meantime the capital goods price is updated as usual with the productivity progress, so the price of the investment goods at T_b will nonetheless differ from their price level at T_a.

- Case 2: periodicity $\Pi > 0$
- There are n consecutive instantaneous price increases between T_a and T_b, at equidistant time intervals, and an instantaneous decrease of intensity $(1 + \pi)^{-n}$ in T_b. This brings the price back to its pre-shock level, if no other influences affected the price in the meantime.

Table 4.7 gives the parameter values used in the computational experiments, and Table 4.8 summarizes the computational setting.

Simulations of the Benchmark Case

We focus our analysis on the four cases in Table 4.7. The duration of the energy crisis is always 240 days (1 year), and we have either a periodicity of 20 days or a single shock at the beginning and a single shock downward at the end.

We recall the benchmark results in Fig. 4.26: GDP settles down to a stable growth path, the unemployment rate is stable as well, and the capital goods price shows a characteristic staircase.

In Figure 4.27 we introduce a mild energy shock of 1% at iteration 1240. After 240 days there is a downward shock of 1%. As can be seen from the figure there is a small blip in the capital goods price (Fig. 4.27b), but this has hardly any effect on the economy.

Figure 4.28 shows a single shock of 5%, and a symmetric downward shock at the end. For one year the capital goods price is significantly increased, but still this does not have any significant effect on key macroeconomic variables such as GDP and the unemployment rate.

A more prolonged energy crisis is shown in Figure 4.29, where there are multiple shocks of 1%, one every 20 days. This results in a more pronounced energy spike, as can be seen in Fig. 4.29b. But the effect on GDP and the unemployment rate remains relatively minor. We also show the daily energy costs that are accumulated during the energy crisis (Fig. 4.29c).

The final case is the one shown in Figure 4.30 where we have multiple shocks of 5%, one every 20 days. Here finally we have the signature of a true energy crisis, where at its peak capital goods cost twice as much as it did at the start of the crisis (3.0 vs. 1.5). The downward effect on GDP is pronounced during periods 1240 to 1500.

This case will now be used in the next subsection, where we introduce a macroeconomic stabilization policy to mitigate the effects of such a negative shock to the economy.

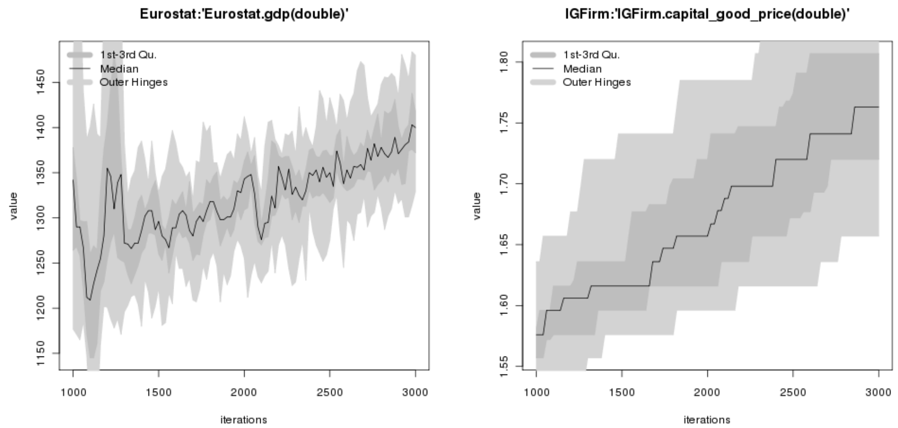

Figure 4.26: Benchmark scenario for the energy shock experiment. GDP and the capital goods price.

$$d = 240, \pi = 0.01, \Pi = 0$$

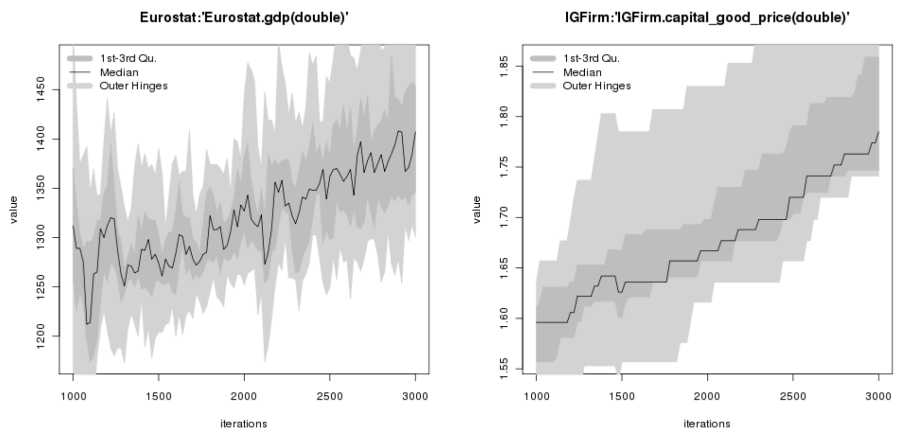

Figure 4.27: Energy shock parameters: duration $d = 240$, intensity $\pi = 0.01$, periodicity $\Pi = 0$.

$d = 240, \pi = 0.05, \Pi = 0$

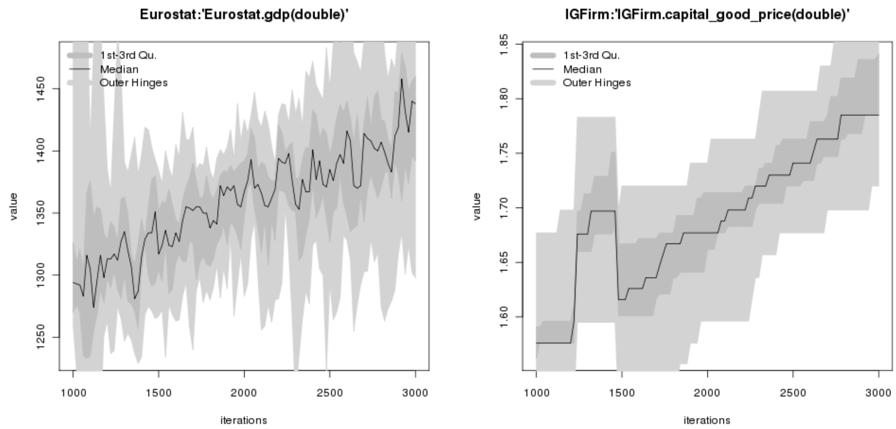

Figure 4.28: Energy shock parameters: duration $d = 240$, intensity $\pi = 0.05$, periodicity $\Pi = 0$.

$d = 240, \pi = 0.01, \Pi = 20$

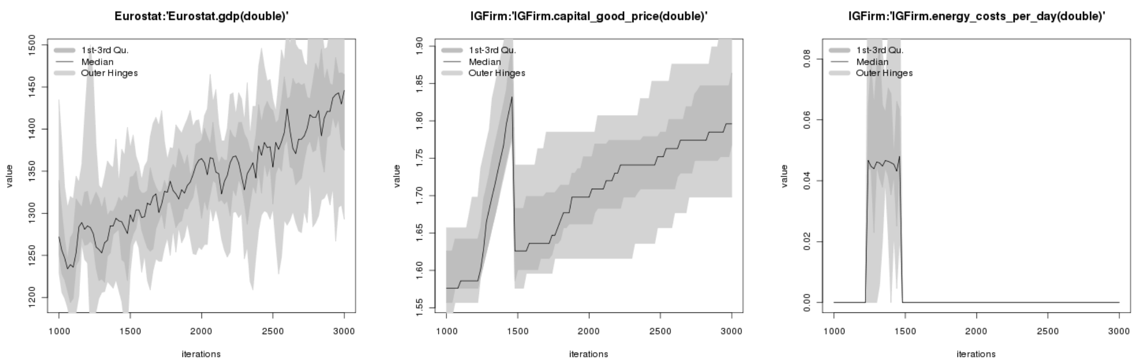

Figure 4.29: Energy shock parameters: duration $d = 240$, intensity $\pi = 0.01$, periodicity $\Pi = 20$.

$d = 240, \pi = 0.05, \Pi = 20$

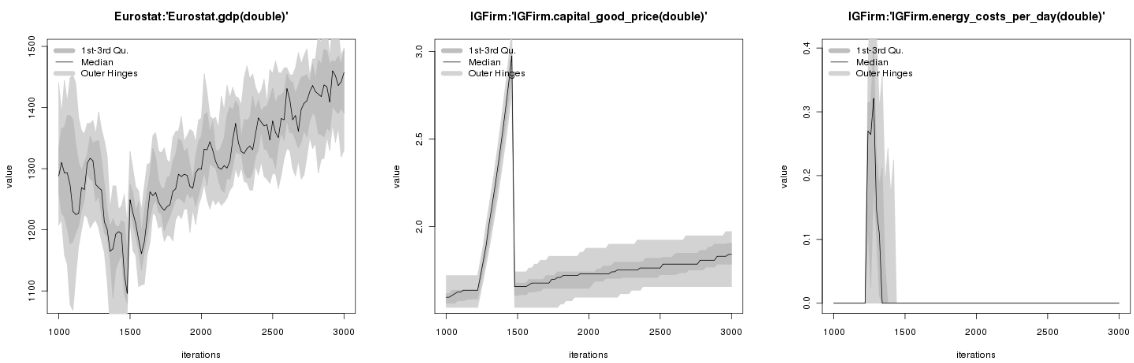

Figure 4.30: Energy shock parameters: duration $d = 240$, intensity $\pi = 0.05$, periodicity $\Pi = 20$.

4.2.2 Effects of Stabilization Policies

We now analyze how the effects of energy price shocks can be influenced by policy measures as described in Section 3.2. We consider the worst case scenario of a prolonged energy crisis with 12 cumulative shocks of 5% ($d = 240$, $\pi = 0.05$, $\Pi = 20$). Figure 4.31 shows the GDP growth rate during the energy crisis of the previous section.

As discussed in Section 3.2, we need to set the trigger for the policy. The first trigger we set to -5%, which means that the subsidy will not take effect until the annualized growth rate of GDP falls below -5%. Note that the government in our model only detects this trigger once a year, so it really has to be a sustained economic downturn before the policy takes effect. In the example the subsidy would be activated around iteration 1200, when the economy first reaches below -5% growth.

The second trigger is set the $+5\%$ which in our example means that the subsidy would only be turned off at iteration 1600, when the economy starts to grow by more than $+5\%$ on a yearly basis. After that it never reaches below -5% again so the subsidy will remain inactive.

Figure 4.32 shows the effect of the stabilizing subsidy. There is still the sharp downturn of -15% at period 1500 following the energy crisis – which lasts from periods $1240 - 1480$ – but after the subsidy regime the growth rate is back to positive levels of 10% to 30%, which is financed by the government subsidy. The subsidy is actually already activated before the energy crisis hits at period 1240, but it grows in intensity as the crisis worsens, and gets switched of as soon as the growth rate reaches $+5\%$ again. Note however that the government does not register this until the end of the calendar year at period 1680, so it has a lagged response in switching off the subsidy. On the longer term the GDP growth is between 0 and 20% instead of the previous levels of 0 and 5%. The right panel in the figure shows that the subsidy gets re-activated three times more, whenever the growth drops below the trigger of 5%.

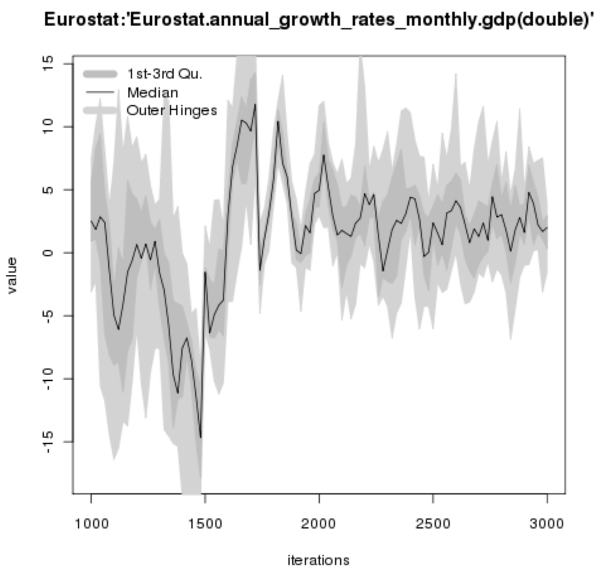

Figure 4.31: Growth rate of GDP during the energy crisis.

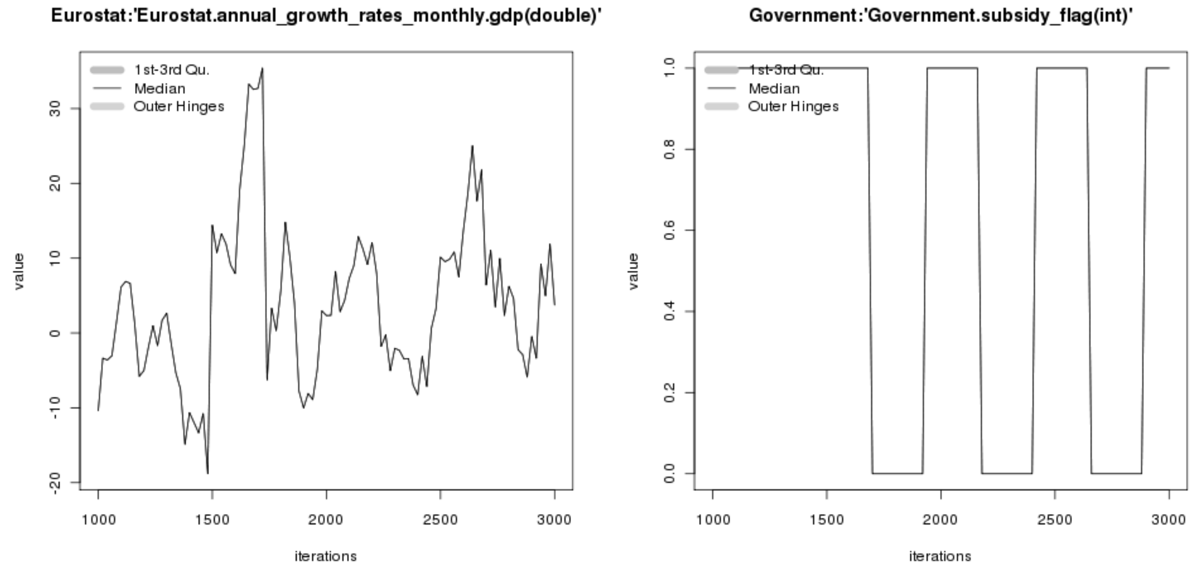

Figure 4.32: Effect of the stabilization policy in the energy shock experiment. Left panel: annual growth rate of GDP; right panel: activation of the subsidy regime by the government, which is lagged following the calendar year of 240 days.

4.3 Analysis of quantitative easing monetary policy experiments

4.3.1 Introduction

This section introduces the findings for a number of computational experiments intended to investigate the different outcomes for the overall performance of the economy, with respect to two different and alternative fiscal and monetary policies, named as *tight fiscal policy* and *quantitative easing policy*, respectively, and described in section 3.3.

The experiments are characterized by the same initial random seed and are then characterized by the same random behavior. The experiments investigates the different economic performance for the two policies considered in an economy characterized by a single government. The government may follow two alternative fiscal policies: a tight fiscal policy which pursues a zero government budget deficit objective by increasing tax rates or an accommodating fiscal policy that keeps tax rates fixed at the minimum level even with a budget deficit. In the first case, the budget deficit is funded by both increasing taxes and sales of government bonds to the market. In the second case, where taxes are not increased, the budget deficit is funded by selling governments bonds to households or, it market demand is insufficient to match the supply of new bonds and the present market price, to the central bank, which then applies a quantitative easing monetary policy.

This computational setting may be of help to design policy measures in the Eurozone economic scenario, where monetary authorities have recently started to implement quantitative easing monetary policies, even if limited for the moment to corporate bonds.

An economy characterized by 1000 households, 10 consumption goods firms, 1 investment goods firms and 2 banks has been considered.

4.3.2 Computational results

Figures and 4.35 show the difference between the two policies in terms of policy variables, i.e., tax rates and fiat money, and in terms of the outcome for government finances and the bond market, respectively. In the case of tight fiscal policy, the government budget deficit is funded by the increase of taxes, both on labor income and corporate earnings, and the issue of new bonds. In the case of quantitative easing policy, the deficit is just funded by the issue of new bond, which if eventually are unsold in the market, are purchased by the central bank, thus increasing the monetary mass in the economy.

Figures 4.33 and 4.34 show the aggregate data related to the banking sector for the tight fiscal policy and the quantitative easing policy, respectively. Figure 4.37 exhibits the behavior of the main monetary aggregates in the EURACE economy and helps in interpreting Figures 4.33 and 4.34. A quantitative easing policy increases the monetary endowments available to economic agents by means of the injection of new fiat money in the economy through the channel of government bond purchasing, see the lower panel of Figure 4.41. Accordingly, agents in the private sector, i.e., households, consumption goods firms, the investment good firm, and banks, are characterized by higher monetary endowments in the quantitative easing case, see the private sectors deposits as well as banks' liquidity, as emerge from the comparison of Figures 4.33 and 4.34. In fact. with a tight fiscal policy, government intervention produces just a movement of liquid resources from the payment accounts of the private sector to the public treasury. Instead, with a quantitative easing policy, we have a growth of money mass. As it is clear from a logical point of view and from simulations, aggregate private deposits (households plus firms) are then lower in the case of a tight fiscal policy.

It is worth noting, however, that the amount of credit money created by the banking system is higher in the tight fiscal policy case, so it emerges that the banking system partially substitute the role of the central bank in creating money for the economy. This is an interesting outcome that can be described as follows: being propensity to consume and to invest more or less constant in the two policies considered, firms positive cash flows are inferior in the tight fiscal policy case. This does not necessary imply lower firms profits, but it simply implies that firms are less liquid, being their capital more immobilized in the form of stocks and physical capital. Consequently, firms are forced to heavily resort to external funding in order to finance stocks and production plans. This means that cash flows and credit operate as (imperfect) substitutes. Therefore firms need to ask more funds from banks to fund their activity. Given the reasonable level of firms leverage, they are not rationed on the credit market and the final outcome is a higher amount of credit money in the economy in the case of a tight fiscal policy.

The higher level of credit money in the economy, even if partially works as a substitute for the lack of creation of new fiat money, determines more financially fragile firms and is unable to provide a macroeconomic performance similar to the one obtained by means of the quantitative easing policy. In fact, Figures 4.39 and 4.40 clearly shows a generally higher levels of output and a lower levels of unemployment in the quantitative easing case. Besides, in the tight fiscal policy case firms are generally characterized by a lower endowment of capital stock, thus indicating the benefit of a quantitative easing policy even for the long-term growth of the economy. On the other hand, Figure 4.36 shows that the stock market is more volatile in the quantitative easing policy case. This is probably due to the higher level of private deposits in this scenario and the consequent higher amount of money invested in the market that amplifies fluctuations.

Furthermore, it is worth noting that the price and the wage indexes do not exhibit remarkable differences in the two policy cases. Indeed, even if the monetary mass is generally lower in the tight fiscal policy case, this scenario exhibits slightly higher levels of price and wages in particular at the end of the simulation. This finding is quite surprising and is deeply under study for a clear understanding.

Finally, the experiments show that generally a quantitative easing monetary policy leads to higher production and lower unemployment, without causing higher inflation in prices and wages. It is worth noting, however, that the quantitative easing policy reaches these objectives not by means of a higher level of credit money in the system, but just by reducing the crowding effect on the demand side of the economy which is caused by the financing of public debt.

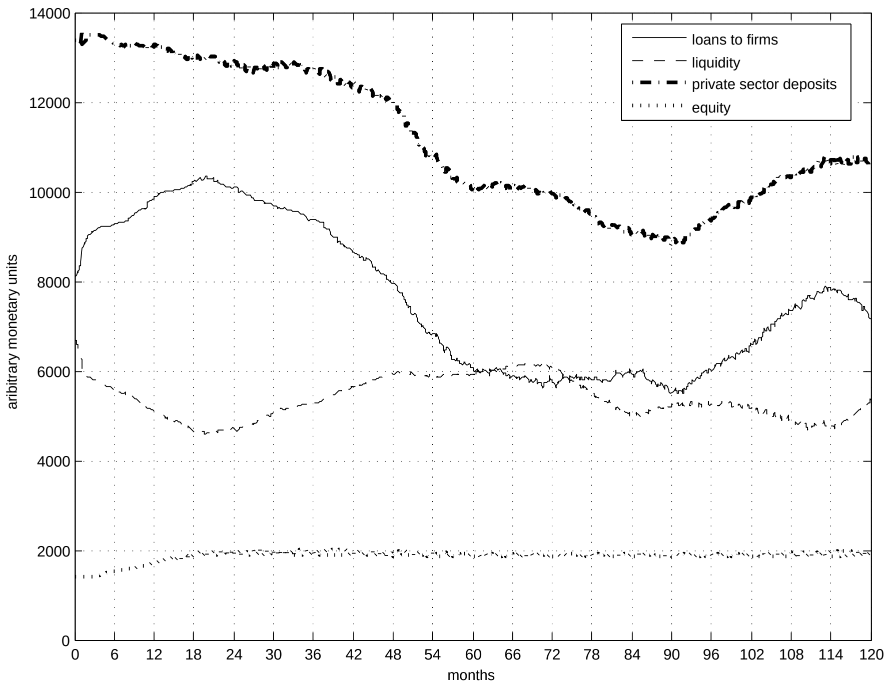

Figure 4.33: Aggregate data of the banking sector for the tight fiscal policy case.

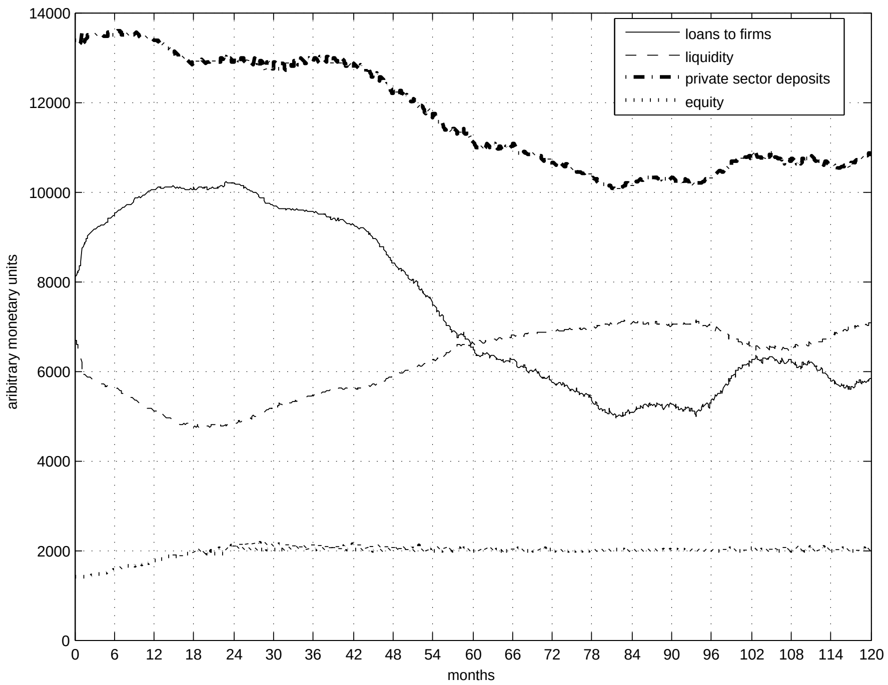

Figure 4.34: Aggregate data of the banking sector for quantitative easing policy case.

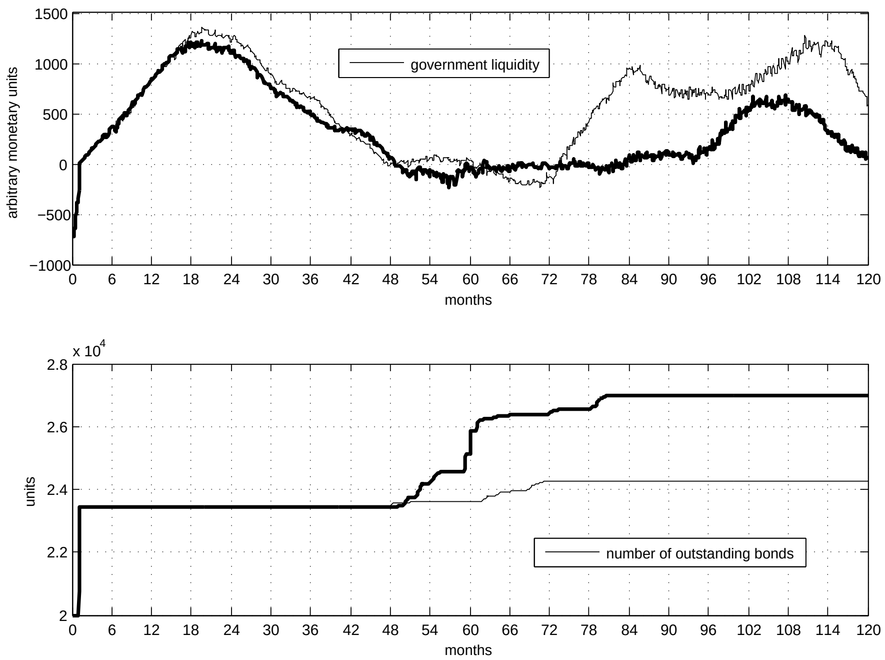

Figure 4.35: Government liquidity and bonds. The thin and the thick lines represent the tight fiscal policy and the quantitative easing policy cases, respectively.

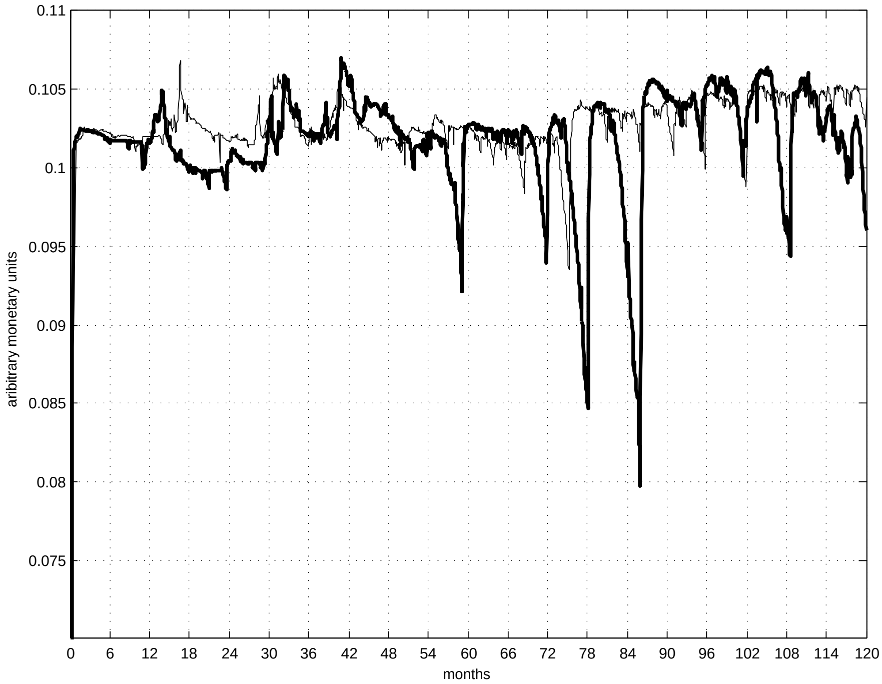

Figure 4.36: Stock price index. The thin and the thick lines represent the tight fiscal policy and the quantitative easing policy cases, respectively.

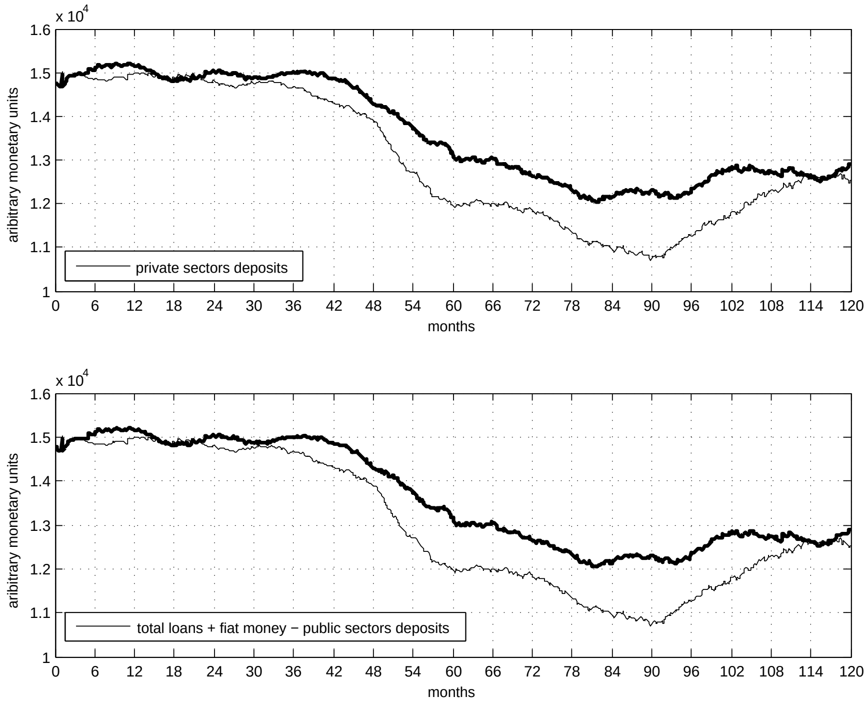

Figure 4.37: Private sector deposits including banks equity(up) and its counterpart (down). The thin and the thick lines represent the tight fiscal policy and the quantitative easing policy cases, respectively.

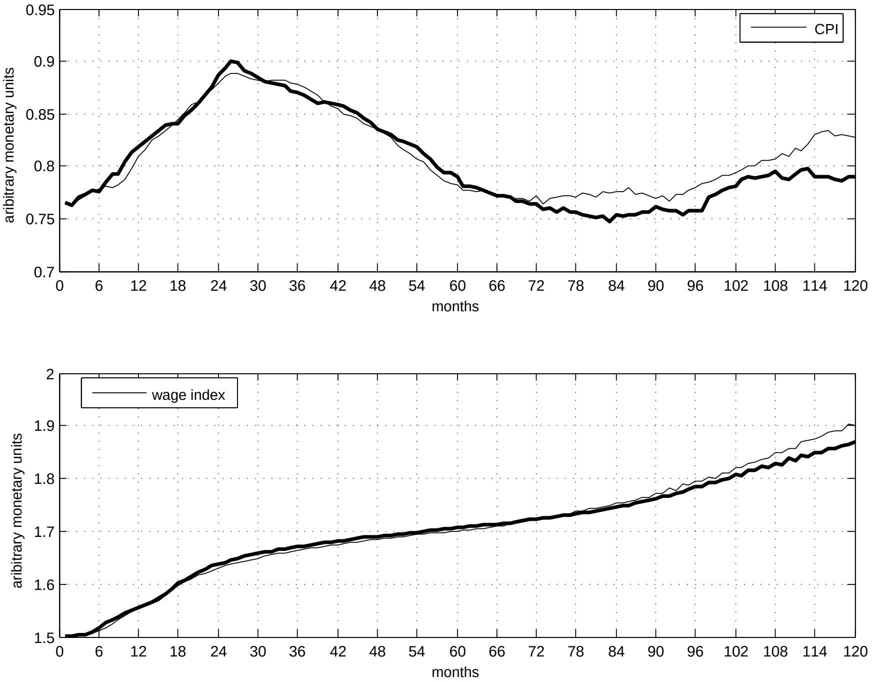

Figure 4.38: Consumer price index (up) and wage index (down). The thin and the thick lines represent the tight fiscal policy and the quantitative easing policy cases, respectively.

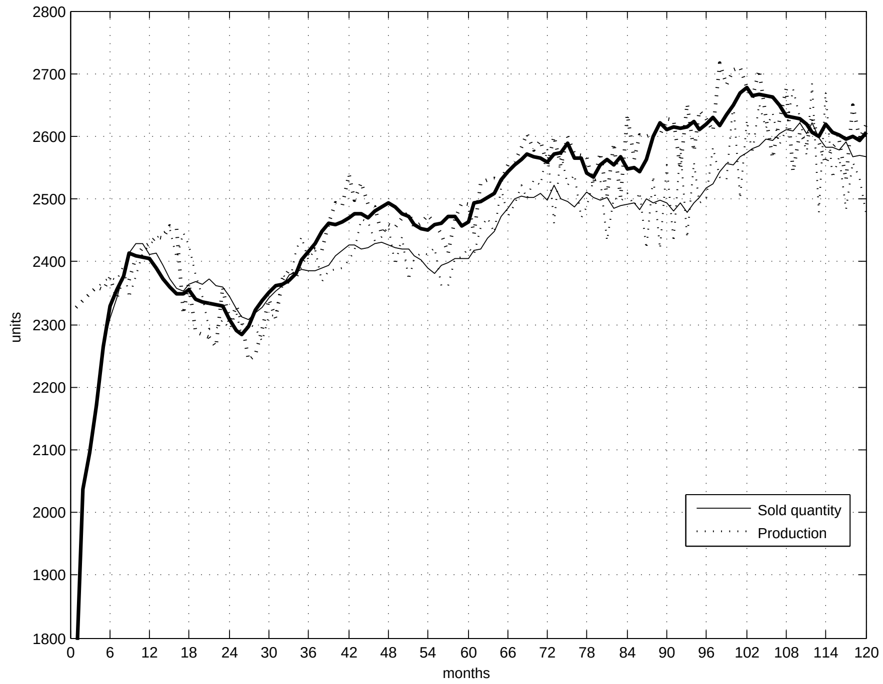

Figure 4.39: Sales (continuous line) and production (dotted line). The thin and the thick lines represent the tight fiscal policy and the quantitative easing policy cases, respectively.

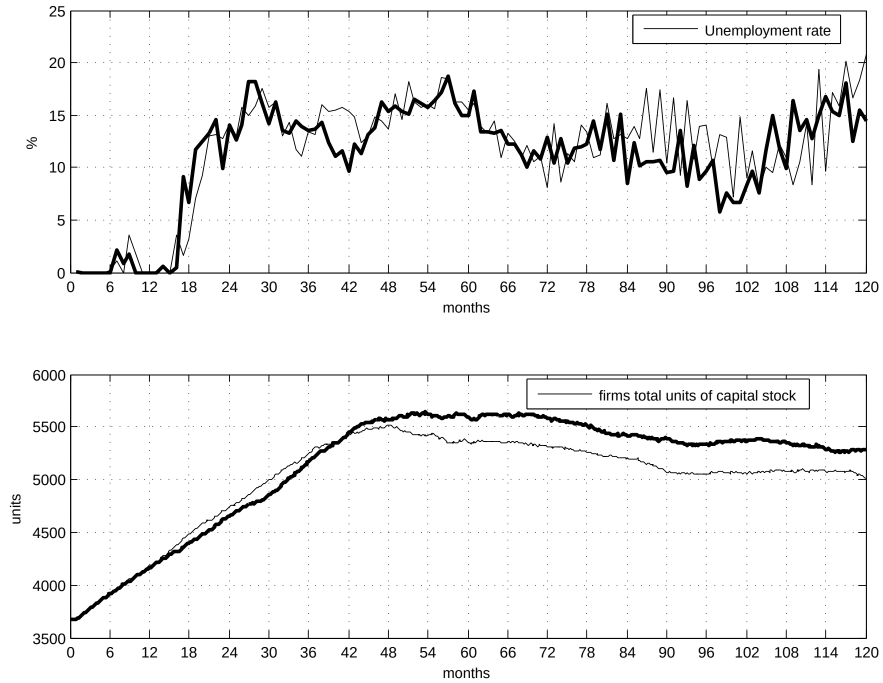

Figure 4.40: Total units of capital stock (up) and unemployment rate (down). The thin and the thick lines represent the tight fiscal policy and the quantitative easing policy cases, respectively.

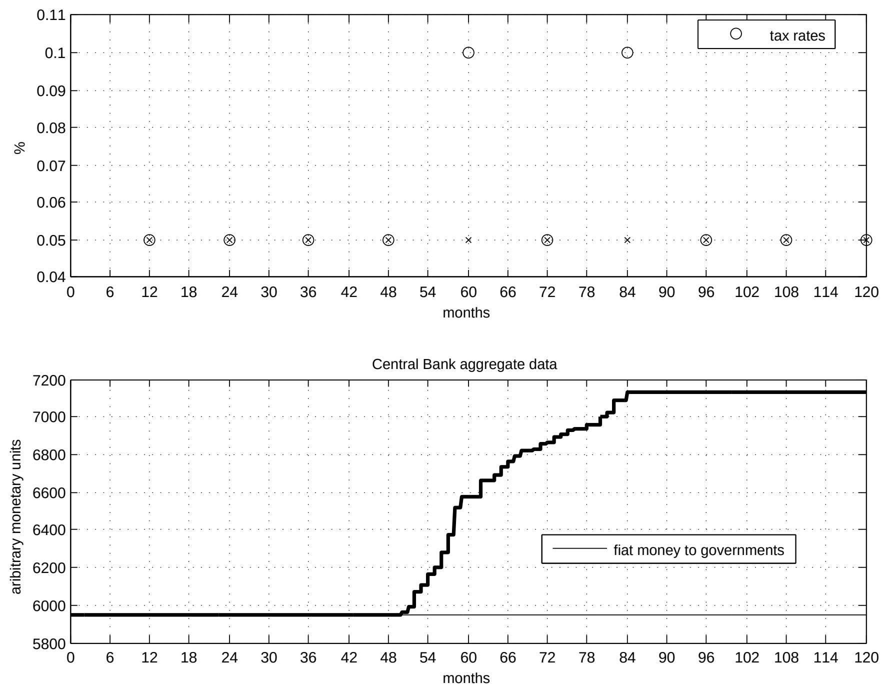

Figure 4.41: Tax rates (up) and central bank fiat money (down). The thin and the thick lines, as well as the circles and the stars, represent the tight fiscal policy and the quantitative easing policy cases.

Chapter 5

Conclusions

In this document several simulation experiments exploring the effects of economic policy measrues in different highly relevant areas of European policy making have been discussed. The experiments were carried out in calibrated versions of the EURACE platform that capture regional differences in key economic characteristics within the EU. It has been demomstrated that the EURACE model allows to shed light on important issues standard analytical models can hardly deal with. Examples are the explicit distinction between short, medium and long run effects of policies, the interaction of different policy types and the detailed consideration of reasons for productivity differences between regions. Overall, these experiments show that the EURACE platform indeed is a general tool that can be flexibly applied for policy evaluation.

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