

# **The Globalization of Labor Markets and its Policy Implications**

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Frank Oskamp

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## Abbreviations (First Part)

BMBF	Bundesministerium für Bildung und Forschung
CEPR	Centre for Economic Policy Research
CGE	Computable General Equilibrium
ch.	Chapter
CRRA	Coefficient of Relative Risk Aversion
D.C.	District of Columbia
DSGE	Dynamic Stochastic General Equilibrium
DW	Deadweight
ed.	Editor
eds.	Editors
e.g.	exempli gratia (for example)
EITC	Earned Income Tax Credit
eq.	Equation
et al.	et alii (and others)
EU	European Union
EUR	Euro
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
i.e.	id est (that is)



## Abbreviations (Second Part)

ifo	Institut für Wirtschaftsforschung, München
iid	identically and independently distributed
IMF	International Monetary Fund
IZA	Institut zur Zukunft der Arbeit
LWS	Low-Wage Subsidies
MA	Massachusetts
MIT	Massachusetts Institute of Technology
NBER	National Bureau of Economic Research
NJ	New Jersey
No.	Number
NY	(State of) New York
OECD	Organisation for Economic Co-Operation and Development
OFCE	Observatoire Français des Conjonctures Economiques
pp.	Pages
SVR	Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung
U.S.	United States (of America)
Vol.	Volume
WY	Wyoming

# 1 Introduction

Since the 1990s, the integration of labor markets around the world has increased significantly. Political and economic reforms but also new technologies have contributed to open up China, India, and the former communist countries in Eastern Europe to global trade. In particular, the globalized world has experienced a massive rise in the effective global labor supply. The additional effective supply has been absorbed by advanced economies through various channels.<sup>1</sup> The higher effective labor supply has also affected labor demand in advanced economies. With respect to trade – being an important channel according to the IMF (2007a) – and its impact on labor demand, two factors have to be taken into account.<sup>2</sup> First, trade can change the level of demand for certain types of labor. In particular, trade with emerging economies, where low-skilled labor is abundant, weakens the position of low-skilled workers in advanced economies. Hence, low-skilled workers in advanced economies are supposed to face high pressure on wages or – in the case of rigid wages – unemployment. Second, trade can also affect the wage sensitivity of labor demand. Due to a higher wage competition, employers in an open economy may have a higher incentive to dismiss employees when they ask for higher wages than employers in a closed economy. This line of reasoning has an important implication; not only the effective trade but also the mere possibility of trade affects the wage sensitivity of labor demand. If workers – in particular low-skilled workers – in advanced economies can be replaced more easily by workers in emerging economies due to increased trade, the bargaining power of workers in advanced economies declines.<sup>3</sup>

Against this background, the ongoing globalization of the labor markets raises important challenges for policy makers in advanced economies.<sup>4</sup> First, on an aggregate level, there is the question how an increasing effective global labor supply affects wages, inflation and macroeconomic activity. This link is of particular importance for monetary policy. Second, in the field of labor market policy, an important question is what policies can help meet the challenges, which are caused by the ongoing globalization of the labor markets. In particular, policy makers like to know how to

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<sup>1</sup>See IMF (2007a) for a survey on how globalization has affected labor markets.

<sup>2</sup>See Jansen and Lee (2007) for a survey of the literature concerning the relation between trade and employment.

<sup>3</sup>See e.g. Bhagwati (1995) and Rodrik (1997).

<sup>4</sup>See e.g. Coe (2007), who analyzes the emergence of China and India on the world economy as well as the implications for policy makers.

react to the adverse impact of the increasing global labor supply on compensation and employment of low-skilled workers.<sup>5</sup> Against this background, the chapters of this dissertation focus on three questions:

- What is the impact of an increasing global labor supply on wages, inflation and macroeconomic activity and what are the implications for monetary policy? (Chapter 2)
- What is the impact of a low-wage subsidy, being a popular tool of labor market policy, on skill formation, aggregate employment and welfare? (Chapter 3)
- How do the interactions between employment and training policies look like? (Chapter 4)

The analysis in Chapter 2 is based on a dynamic general equilibrium model. It is concerned with the impact of a labor supply impulse on wages, inflation and macroeconomic activity. To make the analysis as transparent as possible, it is based on global variables, i.e. there is no disaggregation. The analyses of labor market policies in Chapters 3 and 4 are based on a Markov model of the labor market. In particular – given the specific challenges for labor market policy –, a more disaggregated approach is used, i.e. it is distinguished among different types of labor. The analyses are concerned with the decisions of labor market participants in response to policy-induced incentives. Whereas Chapter 3 regards decisions on the labor supply as well as on the labor demand side, and analyzes the impact of one special policy, Chapter 4 focuses on labor demand and analyzes the interaction between two policies. Ignoring possible interactions could distort the evaluation of the policies. Finally, Chapter 5 concludes.

In detail, Chapter 2 analyzes the impact of an increasing effective global labor supply on wages, inflation and macroeconomic activity. The integration of China, India and countries from Eastern Europe has increased the effective global labor supply. This rise has put downward pressure on wages and ultimately inflation.

The analysis shows that it was not simply the wisdom of the central banks, but also the increase in global labor supply that has been responsible for the recent years of low inflation combined with high macroeconomic activity. In particular, the analysis reveals that a main transmission channel was the development of the bargaining power of the employees in combination with the initially lower bargaining power of the employees in the emerging economies. Due to the rising effective global

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<sup>5</sup>The underlying challenge for economic policy has been analyzed comprehensively under the heading "Making work pay" in recent years. See for a survey e.g. OECD (2000a).

labor supply, "employers can increasingly say in a global economy that they will pack up their bags and leave" (Bhagwati, 1995). Hence, if workers in advanced economies can be more easily replaced by workers in emerging economies due to increasing opportunities for trade, the bargaining power of workers in advanced economies declines and thereby also the global bargaining power. Then, also the wage and finally inflation decline. By implication, a slowing of labor supply growth in the future combined with an increasing bargaining power of workers in the emerging economies would reduce the dampening impact on wages and finally on inflation.

Chapter 3 analyzes the implications of a popular tool of labor market policy, low-wage subsidies. In particular, the impacts of low-wage subsidies on skill formation, aggregate employment and welfare are examined. Low-wage subsidies have three important effects. First, they promote the employment of the low-skilled workers. Second, by raising the payoff of low-skilled work relative to skilled work, low-wage subsidies reduce the incentive to become skilled. So, they reduce the skilled labor force, which, however, faces a relatively high employment rate. Third, the government budget constraint is supposed to cause an additional tax burden on the skilled workers; this amplifies the negative effect of low-wage subsidies on the incentive to acquire human capital. Thus, the first effect on the one hand and the second and third effect on the other hand pull in opposite directions in terms of employment.

The labor market and the training system are described by a Markov model. Then, the training decision on the part of the worker and the following effects, in particular the net impact on aggregate employment, can be analyzed. Moreover, labor market institutions are taken into account as they affect the functioning of the labor market. In this context, the model features a variety of common labor market imperfections like wage bargaining as well as hiring and firing costs. The numerical analysis sheds light on the relative strengths of the three effects and thereby assesses the degree to which low-wage subsidies increase or decrease aggregate employment. The simulation shows that low-wage subsidies have a negligible effect on aggregate employment. Although they do stimulate low-skilled employment, they also reduce skilled employment.

Chapter 4 examines the interactions between employment and training policies, more precisely, between hiring and training subsidies. The effectiveness of these policies in stimulating employment and income may be interdependent for various reasons. For example, the more employment policies stimulate the employment rate, the greater the length of time over which workers use the human capital whose acquisition is supported by training policies. Moreover, the greater the government

expenditures on employment and training policies, the higher the taxes required to finance these expenditures. Finally, aggregate income may be reduced. On account of such effects, employment and training policies may be complementary or substitutive. The analysis is based on the model presented in Chapter 3. However, some modifications are necessary to be able to analyze the interactions of the policies, which are regarded in this chapter.

The simulation shows that there are significant interactions between both policies. However, only in the absence of the government budget constraint, there are complementarities with respect to income. The analysis provides a methodology for examining policy interactions, which may be useful well beyond the bounds of hiring and training subsidies.

## 2 The Increasing Global Labor Supply and its Macroeconomic Implications

### 2.1 Introduction

This chapter argues that changes in the effective global labor supply have played an important role in generating the golden years of low inflation and booming macroeconomic activity for much of the period from the early 1990s till around the beginning of 2008. Our analysis suggests that the expansionary monetary policy over much of this period was compatible with low inflation because the rapid growth of the labor supply put downward pressure on wages and prices. By implication, a slowing of labor supply growth in the future would give monetary policy a more inflationary bias and thereby presumably lead monetary authorities to adopt a more restrictive monetary policy stance. A slowing growth could be caused by bottlenecks in the movement of people from rural to urban areas, bottlenecks in training these people, a global recession leading to under-utilization of labor; moreover, the growth could decline because the big push to integrate the emerging economies was run much of its course and future integration is likely to proceed at a slower pace.

The account can be summarized straightforwardly as follows. Since the 1990s, workers from the emerging economies – e.g. from China, India and from Eastern European countries, in particular Russia, – have joined the global labor market by producing goods and services that are traded on international markets. In this sense, the globalized world has experienced a massive rise in the effective global labor supply.

The increase in labor supply in these countries has put downward pressure, in the first instance, on wages there. Sluggishness in exchange rates – China, for example, has pegged its currency largely to the U.S. dollar – has enabled this downward wage pressure to spread to the developed countries such as the U.S., Western Europe and Japan.<sup>6</sup> This development has dampened inflation worldwide.

While this was happening, many central banks pursued policies closely akin to inflation targeting, often aiming to keep inflation at or below 2 percent. We argue that, the deflationary pressure arising from the growth of the effective global labor supply contributed to the period of low inflation and booming macroeconomic activity extending from the 1990s to recent years, interrupted only briefly by the bursting of the internet bubble at the beginning of this millennium. Our argument suggests that it was not simply the wisdom of the central banks, but the increase

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<sup>6</sup>Naturally this only holds in the absence of complete specialization.

in global labor supply that has been responsible for the recent years of low inflation combined with high macroeconomic activity. Meanwhile, the long boom appears to have come to an abrupt end with the financial crisis of 2008. The effect of this crisis on global macroeconomic activity dwarfs any influence the growing effective global labor supply may have had. But once the dust settles and the financial crisis is over, we will want to know whether we can return to the golden years of booming macroeconomic activity and low inflation again. Our analysis suggests that the answer to this question will depend in part on whether the global labor supply will continue its rapid growth. Should this growth rate slow, then this favorable combination of a high level of macroeconomic activity and a low rate of inflation may no longer be sustainable.

Our analysis incorporates labor market search and matching frictions (along the lines of Mortensen and Pissarides (1994) and Pissarides (2000)) into a New Keynesian macro model. To capture the effect of labor supply growth on inflation, we assume that wages are sticky and that prices are a markup over wages. For this purpose, we suppose that wages are set in a staggered multi-period setting, in the spirit of Gertler and Trigari (2008), except that the latter is concerned with real rigidities, whereas this analysis focuses on nominal rigidities.<sup>7</sup>

The chapter is organized as follows. After the preliminaries in Section 2.2, the model is outlined in Section 2.3. Section 2.4 presents the numerical analysis. Section 2.5 concludes.

## 2.2 Preliminaries

Before presenting the model, we summarize briefly how the analysis in this chapter contributes to the macroeconomic literature on explaining the long boom that started in the 1990s and then we provide some empirical background for our labor supply transmission mechanism.

### 2.2.1 The Long Boom

There are several standard explanations of the approximately 15-year boom that started in the 1990s.<sup>8</sup> The first is "good luck." Proponents argue that after the two raw material price shocks of the 1970s, economic shocks happened to have been

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<sup>7</sup>See Bodart et al. (2006) as well as Gertler, Sala and Trigari (2008).

<sup>8</sup>This boom has also been referred to as "The Roaring Nineties", see e.g. Stiglitz (2003), Krueger and Solow (2002), and the "The Great Moderation." Although the latter term generally alludes to the fall in the volatility of output and inflation, there is evidence that this reduction in volatility is associated with higher output growth, see e.g. Ramey and Ramey (1995).

weaker and less frequent, paving the way for a long boom.<sup>9</sup> This hypothesis has recently been called into question through the continued strong growth of global Gross Domestic Product (GDP) in 2007 and the first half of 2008, despite the rapid rise of raw material prices.

The second explanation is that financial innovations and improved inventory management techniques have increased economies' capacity to exploit economic opportunities and to match supply and demand, thereby enabling countries to operate at higher levels of economic activity.<sup>10</sup> Yet there is evidence that the contribution of inventory management to the reduction in volatility is limited.<sup>11</sup> The recent financial crisis has called into question the stabilizing effects of various financial innovations.

The third explanation is that the long boom is due to improved macroeconomic policies, including both, a tighter fiscal policy<sup>12</sup> as well as monetary policy focused on price stability,<sup>13</sup> along with improved design of central banks and better central banking communication strategies.<sup>14</sup> However, the empirical evidence on the disinflationary effects of tight fiscal policy is mixed.<sup>15</sup>

To these mainstream explanations we add a further one, namely that the increase in the effective global labor supply has put downward pressure on wage and inflation, thereby permitting lower interest rates than would otherwise have been compatible with central banks' inflation targets.

### 2.2.2 The Global Labor Supply

Since the 1990s large numbers of workers from the emerging economies have joined the effective global labor market, in the sense that they have begun to produce goods and services traded on international markets. As a result, the globalized

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<sup>9</sup>See Ahmed et al. (2004) as well as Stock and Watson (2003) for empirical studies supporting this hypothesis with respect to output.

<sup>10</sup>Concerning the influence of inventory management, see, e.g. Kahn et al. (2002) as well as McCarthy and Zakrajsek (2003). For the effects of financial innovations, see, e.g. Dynan et al. (2006) as well as Jermann and Quadrini (2006).

<sup>11</sup>See IMF (2007b).

<sup>12</sup>See, e.g. Fatás and Mihov (2003).

<sup>13</sup>See, in particular, Bernanke (2004) and IMF (2006). Taylor (1998) and Clarida et al. (2000) show that the U.S. Fed reacted more aggressively to inflation in the 1980s and 1990s than before.

<sup>14</sup>See Rogoff (2003). Ball and Sheridan (2003) analyze the impact of inflation targeting on the economic performance for OECD countries. They show that countries that implemented inflation targeting improved their performance concerning output and inflation compared to the period before the implementation. However, countries without inflation target improved their performance at the same time.

<sup>15</sup>Regarding the theory that persistent fiscal deficits are inflationary, Catao and Terrones (2005) find empirical confirmation only for high-inflation and developing countries, but not for low-inflation, advanced economies. Rogoff (2003) argues that whereas fiscal policy probably has supported the disinflation process particularly in Latin America and Africa, monetary policy played the major role for this process in advanced economies.



world has experienced a rise in the effective labor supply of 81% between 1990 and 2005. Whereas Eastern Europe and Central Asia have contributed 7.6 percentage points, India has contributed 14.2 percentage points. The biggest contribution came from China (36.2 percentage points).<sup>16</sup> China's contribution is a consequence of its economic policy. This included liberalizing the legal framework<sup>17</sup> and raising labor productivity through foreign direct investment (FDI). Whereas FDI at the beginning of the 1980s did not exist, it increased to more than 6% of GDP in the mid-1990s, which corresponds to more than 10% of the total global FDI at that time.<sup>18</sup>

The economic literature indicates that the high economic growth in recent years in China has been driven significantly by an increasing labor supply<sup>19</sup> and its more efficient integration in the production process, along the lines described in the Lewis dual sector development model.<sup>20</sup> Chinese economic growth in the reform area has been associated with the transfer of large amounts of labor from agriculture to the more productive non-agricultural sectors in urban areas. The elastic supply of unskilled labor from the countryside allows rapid modern sector growth to proceed for a long period without putting upward pressure on wages.

The integration of countries like China into the world economy also affects wages of employees in the Western industrialized countries.<sup>21</sup> Bhagwati (1995) noted that "the bargaining power of employers has increased vis-à-vis that of employees because employers can increasingly say in a global economy that they will pack up their bags and leave".<sup>22</sup> However, it is questionable that such downward wage pressure will continue, for the following reasons. First, there is evidence that migration to urban areas is likely to slow down.<sup>23</sup> Second, China's aggregate labor force is due to contract for demographic reasons.<sup>24</sup> The reduction in the labor supply will erode the

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<sup>16</sup>See Appendix 7.1.7 for a survey of the underlying data.

<sup>17</sup>See e.g. Liang and Lauderdale (2006) for a survey on China's process of integration into the world economy. Moreover, to facilitate labor market adjustment processes within China, the government has also reduced restrictions on internal migration and given more discretion to firms. See e.g. Knight and Song (2005) as well as Reutersward (2005).

<sup>18</sup>The calculations are based on data provided by the World Bank (2008).

<sup>19</sup>See e.g. Golley and Tyers (2006).

<sup>20</sup>See Lewis (1954). For an application to China, see Knight and Song (2005) and Knight (2007). The Lewis model assumes that developing countries have dual economies with both a traditional agricultural sector and a modern industrial sector. Initially, in the agricultural sector, there is a huge labor surplus available at a subsistence wage. The industrial sector develops by drawing labor from the agricultural sector. The existence of surplus labor in the agricultural sector ensures that during an extended period of rapid modern sector growth, wages remain steady because the supply of labor to the modern sectors exceeds demand at this wage. The surplus of output over wages is captured by the owners of businesses as profit.

<sup>21</sup>See Freeman (1995) for a survey of the underlying debate at that time.

<sup>22</sup>See also Rodrik (1997). For a theoretical analysis of this effect, see e.g. Zhao (1998); for empirical confirmation see e.g. Abraham et al. (2007) with respect to Belgium.

<sup>23</sup>See e.g. Garnaut (2006).

<sup>24</sup>See e.g. Nielsen and Fang (2007). According to the baseline projection by Golley and Tyers

comparative advantage of China's labor intensive production<sup>25</sup> and have a negative impact on its growth.

Figure 2.1 illustrates the medium variant projection of the development of the working age population in China, India and Russia from 1965 to 2050.<sup>26</sup> The black line depicts the growth rate of the aggregate working age population in these countries. The bars in the graph show the regional composition of the growth rate. Two aspects are noteworthy: first, the growth rate of the aggregate working age population will decrease significantly in the following decades compared to the growth rates in the 1990s and, second, the development in China is the main driving force.

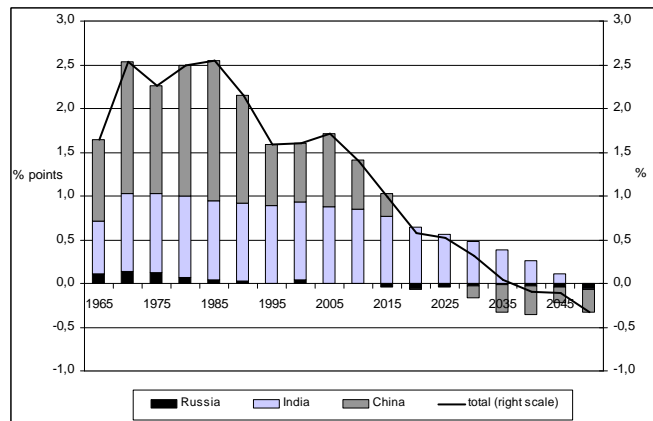


Figure 2.1: Growth of the Working Age Population and Contributions by States

Moreover, labor costs in China have increased significantly. In the recent ten years, the real wage has increased on average by more than 13% per year.<sup>27</sup> In addition to the economic development, labor market policy has also contributed to the increase (e.g. via the minimum wage legislation).<sup>28</sup>

(2006), the labor supply will begin to decline in 2015. According to Peng and Fausten (2006), labor supply contraction will accelerate from 2020 onwards in response to population aging and the prospective reduction of the labor force participation rate of the young population. See also Garnaut and Huang (2006).

<sup>25</sup>Nielsen and Fang (2007).

<sup>26</sup>United Nations (2009). The projection of the population until 2050 is based on assumptions regarding future trends in fertility, mortality and international migration. Because of the uncertainty with respect to these trends, a number of projection variants are produced. Here, "medium" refers to the assumption concerning the future path of fertility.

<sup>27</sup>Between 1987 and 1997, the average wage increased by only 4.2% per year on average – own calculations based on data provided by the World Bank (2008).

<sup>28</sup>See Jiabao (2008).

## 2.3 The Model

To keep the analysis as transparent as possible, we use a global model that describes relations among global variables, such as the global labor supply and the global inflation rate. This extreme simplification allows us to depict the influence of labor supply growth on inflation and macroeconomic activity in a very simple way. Therefore, this model only gives us a broad picture. Detailed predictions would require disaggregation with respect to countries and sectors but such extensions lie beyond the scope of this chapter.

As noted, the process of globalization over the past two decades has involved an increase in the effective global labor supply. As the global economy becomes more integrated, also the division of labor among countries and regions becomes increasingly global. Goods and services that were non-tradable become tradable and trade itself increases as production activities are relocated in accordance with comparative advantage. In this process, increasing amounts of labor are integrated in the global economy. This is the sense in which globalization leads to growth of the effective global labor supply.

We present a simple dynamic general equilibrium model, which is based on Gertler and Trigari (2008).<sup>29</sup> It features three types of agents: firms, households and a government. First, a government issues bonds and imposes taxes and makes transfers to the households. Second, a large number of identical firms produces a homogeneous consumption good through labor. Third, there is a continuum of households supplying labor, consuming goods and holding bonds. Wages are determined by Nash bargaining. As in Gertler and Trigari (2008), we assume that in each period only a fraction of firms and workers reset their wages, but in this model the labor supply grows.

### 2.3.1 Labor Market Dynamics

There is a continuum of workers and a continuum of firms, each of measure one. Firms are indexed by  $i$ . Each firm  $i$  employs  $N_t(i)$  workers at time  $t$ . The number of vacancies, posted by a firm to attract new workers in the next period, is denoted by  $V_t(i)$ . Along standard lines, we assume that the total number of matches,  $M$ , is a Cobb-Douglas function of the total number of unemployed,  $U$ , and the total number of vacancies,  $V$ :

$$M_t = \sigma_M U_t^\sigma V_t^{1-\sigma} \quad (2.1)$$

---

<sup>29</sup>The underlying working paper version is Gertler and Trigari (2006), which is the base of the calculations that are illustrated in this chapter.

where  $\sigma_M$  is the efficiency of matching,  $\sigma$  is a positive constant ( $0 < \sigma < 1$ ). The probability of a firm to fill a vacancy is:

$$q_t = \frac{M_t}{V_t} = \sigma_M \left( \frac{U_t}{V_t} \right)^\sigma \quad (2.2)$$

The probability of an unemployed person to find a job is:

$$s_t = \frac{M_t}{U_t} = \sigma_M \left( \frac{V_t}{U_t} \right)^{1-\sigma} \quad (2.3)$$

Both, the firms and the workers take  $q_t$  and  $s_t$ , respectively, as given. In any period, each firm exogenously separates from a fraction  $\varphi$  of its workers. The dynamics of total employment are:<sup>30</sup>

$$N_{t+1} = (1 - \varphi) N_t + q_t V_t \quad (2.4)$$

The labor supply  $L_t$  grows at a constant rate,  $g^L$ :

$$g^L = \frac{L_{t+1}}{L_t} - 1 \quad (2.5)$$

The unemployment level is given by:

$$U_t = L_t - N_t \quad (2.6)$$

By combining eq. (2.1), (2.2), (2.4) and (2.5), the dynamics of the employment rate are given by:<sup>31</sup>

$$n_{t+1} = \frac{1}{1 + g^L} [(1 - \varphi) n_t + \sigma_M u_t^\sigma v_t^{1-\sigma}] \quad (2.7)$$

The unemployment rate is:

$$u_t = 1 - n_t \quad (2.8)$$

### 2.3.2 Representative Firm

Firms use labor as the only input. In each period, they produce the output,  $Y_t(i)$ , according to the following production function:

$$Y_t(i) = A N_t(i) \quad (2.9)$$

---

<sup>30</sup>This model ignores employment adjustment along the intensive margin and focuses on the adjustment along the extensive margin.

<sup>31</sup>Note that  $n_{t+1} = \frac{N_{t+1}}{L_{t+1}} = (1 - \varphi) \frac{N_t}{L_t} \frac{L_t}{L_{t+1}} + \sigma_m \left( \frac{U_t}{L_t} \right)^\sigma \left( \frac{V_t}{L_t} \right)^{1-\sigma} \frac{L_t}{L_{t+1}}$ .

where  $A$  is the productivity, identical for all firms. The hiring rate,  $x_t(i)$  is defined as the ratio of newly hired people,  $q_t V_t(i) = M_t(i)$ , to the existing number of employees,  $N_t(i)$ :

$$x_t(i) = \frac{M_t(i)}{N_t(i)} \quad (2.10)$$

As in Gertler and Trigari (2008), we assume that labor adjustment costs are quadratic:  $\frac{\kappa}{2} x_t^2(i) N_t(i)$ . Let  $W_t(i)$  be the wage,  $\delta$  be the discount factor of the representative household and  $\delta \Lambda_{t,t+1}$  be the discount factor of the representative firm, where  $\Lambda_{t,t+1} = \frac{u'(c_{t+1})}{u'(c_t)}$ . Then the real profit of firm  $i$ ,  $\Pi_t(i)$ , is:<sup>32</sup>

$$\Pi_t(i) = Y_t(i) - W_t(i) N_t(i) - \frac{\kappa}{2} x_t^2(i) N_t(i) + \delta E_t \Lambda_{t,t+1} \Pi_{t+1}(i) \quad (2.11)$$

At any time, the firm maximizes its profit by posting vacancies and hence by choosing its hiring rate. In this context, first, the value of adding an additional employee at time  $t$  is calculated:<sup>33</sup>

$$\frac{\partial \Pi_t(i)}{\partial N_t(i)} = A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + (1 - \varphi) \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \stackrel{!}{=} 0 \quad (2.12)$$

Second, the first-order condition for profit maximization with respect to the number of vacancies is calculated:

$$\kappa x_t(i) = \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \quad (2.13)$$

By combining eq. (2.12) and eq. (2.13), we get the forward-looking difference equation for the hiring rate:

$$\kappa x_t(i) = \delta E_t \Lambda_{t,t+1} [A - W_{t+1}(i) + \frac{\kappa}{2} x_{t+1}^2(i) + (1 - \varphi) \kappa x_{t+1}(i)] \quad (2.14)$$

### 2.3.3 Representative Household

We make the standard assumption – following Merz (1995) and others – that the representative household consists of a continuum of individuals who insure each other completely against the idiosyncratic unemployment risk. A household pools the incomes (including the profit income) of its members before choosing consumption as well as bond holdings.

Let  $c_t$  be the real consumption bundle per capita,  $W_t$  the real wage rate, which is specified below, and  $z_t^n$  the nominal bond holding per capita. The unemployment

<sup>32</sup>See Appendix 7.1.13 for a model with Rotemberg adjustment costs and a money growth rule.

<sup>33</sup>See Appendix 7.1.1 for the derivation of the following equations.

benefits are given by  $B_t$ ,  $t_t$  are lump-sum net taxes to the government and  $\Pi_t$  are profits. Moreover,  $i_t$  is the nominal interest rate. The household maximizes its utility with respect to consumption and bonds:

$$U_t = E_t \sum_{j=0}^{\infty} \delta^j \ln(c_{t+j}) \quad (2.15)$$

subject to the flow budget constraint:

$$P_t c_t + \frac{1}{1+i_t} z_t^n + P_t t_t = P_t W_t n_t + P_t B_t u_t + z_{t-1}^n + P_t \Pi_t \quad (2.16)$$

The first-order conditions for utility maximization are:<sup>34</sup>

$$\frac{\partial \mathcal{L}_H}{\partial c_t} : \quad \frac{1}{c_t} = P_t \varrho_t \quad (2.17)$$

$$\frac{\partial \mathcal{L}_H}{\partial z_t^n} : \quad \varrho_t \frac{1}{1+i_t} = E_t \varrho_{t+1} \quad (2.18)$$

where  $\mathcal{L}_H$  is the Lagrange function with respect to the household. By combining eq. (2.17) and eq. (2.18), we get the standard consumption Euler equation:

$$1 = (1+i_t) \delta E_t \frac{c_t}{c_{t+1}} \frac{1}{1+\pi_{t+1}} \quad (2.19)$$

### 2.3.4 Wage Determination

**Surplus of the Worker** Following Gertler and Trigari (2008), all existing and newly hired workers employed at the firm receive the same wage, which is negotiated in either the current or the previous period; and the unemployed workers are allocated randomly to the posted vacancies (with wages set now or in the last period). The surplus of the employee at firm  $i$  is

$$S_t^E(i) = \Upsilon_t^N(i) - \Upsilon_t^U$$

whereas the surplus of the average employee, conditional on being a new hire, is

$$S_t^E = \Upsilon_t^N - \Upsilon_t^U$$

where  $\Upsilon_t^N(i)$  is the expected present value of being employed at firm  $i$ :

$$\Upsilon_t^N(i) = W_t(i) + \delta E_t \Lambda_{t,t+1} [(1-\varphi) \Upsilon_{t+1}^N(i) + \varphi \Upsilon_{t+1}^U]$$

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<sup>34</sup>See Appendix 7.1.2 for the derivation of the following equations.

and  $\Upsilon_t^U$  is the expected present value of being unemployed:

$$\Upsilon_t^U = B_t + \delta E_t \Lambda_{t,t+1} [s_t \Upsilon_{t+1}^N + (1 - s_t) \Upsilon_{t+1}^U]$$

where  $\Upsilon_t^N = \int_0^1 \Upsilon_t^N(i) \frac{x_{t-1}(i) N_{t-1}(i)}{x_{t-1} N_{t-1}} di$  is the average value of employment conditional on being a new worker at time  $t$ . Finally, the surplus of the worker is given by:

$$S_t^E(i) = W_t(i) - B_t + \delta E_t \Lambda_{t,t+1} [(1 - \varphi) S_{t+1}^E(i) - s_t S_{t+1}^E] \quad (2.20)$$

**Surplus of the Firm** The surplus of the firm, which is renegotiating,  $S_t^F(i)$ , is given by:

$$S_t^F(i) = \frac{\partial \Pi_t(i)}{\partial N_t(i)} = A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + (1 - \varphi) \delta E_t \Lambda_{t,t+1} S_{t+1}^F(i) \quad (2.21)$$

**Nash Bargaining** Wages are determined through bargaining under staggered wage setting à la Calvo (1983), with bargaining as in Gertler and Trigari (2008), and nominal rigidities as in Bodart et al. (2006). Bargaining is conducted by the firm and the worker. In each period a firm has a fixed probability  $(1 - \lambda_w)$  that it renegotiates the wage with its employees, where  $\lambda_w$  determines the degree of wage stickiness. Firms that do not renegotiate the wage, adjust the nominal wage just for trend inflation,  $\pi^*$ . In the remainder,  $W_t^*$  denotes the contract wage, i.e. the wage of the firm that renegotiates at  $t$ . Then, the contract wage maximizes the Nash bargaining product:

$$\max_{W_t^*} \Omega = [S_t^E(i)]^{\mu_t} [S_t^F(i)]^{1-\mu_t}$$

where  $\mu$  ( $0 < \mu < 1$ ) is the relative bargaining power of the employee.

As the contract is multi-period, the impact of the contract wage on the expected future path of firm and worker surplus has to be taken into account. In order to do this, in a first step, the employee's discounted sum of expected wage receipts,  $W_t^E(i)$ , is calculated:<sup>35</sup>

$$W_t^E(i) = \Delta_t W_t^* + (1 - \lambda_w) E_t \sum_{j=1}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} \Delta_{t+j} W_{t+j}^*$$

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<sup>35</sup>For a detailed derivation of the following equations see Appendix 7.1.3.

where  $\Delta_t$  is the worker's cumulative discount factor:<sup>36</sup>

$$\Delta_t = E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^j \frac{P_t}{P_{t+j}} \Lambda_{t,t+j} \quad (2.22)$$

Second, the firm's discounted sum of the expected future wage payments,  $W_t^F$ , is calculated:

$$W_t^F(i) = \Psi_t(i) W_t^* + (1 - \lambda_w) E_t \sum_{j=1}^{\infty} \delta^j \frac{N_{t+j}(i)}{N_t(i)} \Lambda_{t,t+j} \Psi_{t+j}(i) W_{t+j}^*$$

where  $\Psi_t$  is the firm's cumulative discount factor:<sup>37</sup>

$$\Psi_t(i) = E_t \sum_{j=0}^{\infty} \frac{N_{t+j}(i)}{N_t(i)} [\delta \lambda_w (1 + \pi^*)]^j \frac{P_t}{P_{t+j}} \Lambda_{t,t+j} \quad (2.23)$$

Third, using the expressions for  $W_t^E(i)$  and  $W_t^F(i)$ , we can rewrite eq. (2.20) and eq. (2.21), respectively. The solution of the Nash bargaining problem is given by:

$$\chi_t(i) S_t^F(i) = [1 - \chi_t] S_t^E(i) \quad \text{with: } \chi_t(i) = \frac{\mu_t}{\mu_t + (1 - \mu_t) \Psi_t(i) / \Delta_t} \quad (2.24)$$

Finally, the contract wage  $W_t^*$ , being the result of the Nash bargaining, is:

$$W_t^* = \frac{1}{\Delta_t} [W_t^T(i) + (1 - \varphi) \delta \lambda_w E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^*] \quad (2.25)$$

where  $W_t^T(i)$  denotes the target wage:

$$W_t^T(i) = \chi_t(i) \left[ A + \frac{\kappa}{2} x_t^2(i) \right] + [1 - \chi_t(i)] B_t + [1 - \chi_t(i)] s_t \kappa x_t(i) E_t \frac{\chi_{t+1}(i)}{1 - \chi_{t+1}(i)} \quad (2.26)$$

Following Bodart et al. (2006), we assume that the fraction  $\lambda_w$  of firms adjusts its nominal wage of the previous period ( $P_{t-1}W_{t-1}$ ) by trend inflation,  $1 + \pi^*$ , to get the nominal wage  $W_t^n$ . Hence, the wage index, in nominal terms, can be calculated

<sup>36</sup>See Appendix 7.1.4 for an alternative expression of  $\Delta_t$ . Observe that each term  $j$  in the worker's cumulative discount factor depends on the relative employment size ( $1 - \varphi$ ), the probability  $\lambda_w$  that the contract survives to  $t+j$ , the household's discount factor  $\delta$ , and – in addition to the determinants included in Gertler and Trigari (2008), and following Bodart et al. (2006), as explained below – a further term:  $(1 + \pi^*)^j \frac{P_t}{P_{t+j}}$ .

<sup>37</sup>See Appendix 7.1.4 for an alternative expression of  $\Psi_t$ .



as follows:

$$\begin{aligned} W_t^n &= (1 - \lambda_w) W_t^{*,n} + \lambda_w (1 + \pi^*) W_{t-1}^n \\ \Leftrightarrow \frac{W_t^n}{P_t} &= (1 - \lambda_w) \frac{W_t^{*,n}}{P_t} + \lambda_w (1 + \pi^*) \frac{W_{t-1}^n}{P_t} \end{aligned}$$

In real terms, the wage index is calculated as follows:

$$\begin{aligned} W_t &= (1 - \lambda_w) W_t^* + \lambda_w (1 + \pi^*) \frac{P_{t-1}}{P_t} W_{t-1} \\ \Leftrightarrow W_t &= (1 - \lambda_w) W_t^* + \lambda_w \frac{1 + \pi^*}{1 + \pi_t} W_{t-1} \end{aligned} \quad (2.27)$$

Along standard lines, the real unemployment benefit,  $B_t$ , is assumed to be proportional to the average wage and calculated as follows:

$$B_t = \bar{b} W_t \quad (2.28)$$

**Bargaining Power** It is widely recognized that the integration of China and other emerging economies into the world economy has reduced the bargaining power of workers in the advanced economies. The reduction of the bargaining power can be explained as follows.<sup>38</sup> The integration of China and other emerging economies into the world economy has increased the effective global labor supply. The additional effective supply has been absorbed by advanced economies through various channels.<sup>39</sup> The higher effective labor supply also affects labor demand in advanced economies. With respect to trade – being an important channel according to the IMF (2007a) – and its impact on labor demand, two factors have to be taken into account.<sup>40</sup> First, trade can change the level of demand for certain types of labor. In particular, trade with emerging economies, where low-skilled labor is abundant, weakens the position of low-skilled workers in advanced economies. Hence, low-skilled workers in advanced economies are supposed to face a high pressure on wages or – in the case of rigid wages – unemployment. Second, trade can also affect the wage sensitivity of labor demand. Due to the higher wage competition, employers in an open economy may have a higher incentive to dismiss employees when they ask for higher wages than in a closed economy. This line of reasoning has an important implication; not

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<sup>38</sup>See for empirical evidence Dumont et al. (2006). In their analysis of five EU countries (Belgium, France, Germany, Italy, and the United Kingdom) they find a significant negative impact of globalization on union bargaining power.

<sup>39</sup>See IMF (2007a) for a survey on how globalization has affected labor markets.

<sup>40</sup>See Jansen and Lee (2007) for a survey of the literature concerning the relation between trade and employment.

only the effective trade but also the mere possibility of trade – as a consequence of outsourcing production – affects the wage sensitivity of labor demand. An increasing substitutability of workers – in particular of low-skilled workers – could reduce their bargaining power.<sup>41</sup> If workers in advanced economies can be replaced more easily by workers in emerging economies due to increased trade, the bargaining power of workers in advanced economies declines.

We adopt this assumption here, with the proviso that the drop in bargaining power is temporary. In particular, we assume that the bargaining power parameter  $\mu_t$  is initially beneath its steady state value and gradually rises to that value,<sup>42</sup> as workers in the emerging countries gradually gain bargaining power themselves.<sup>43</sup>

For the sake of simplicity, we model the development of the average global bargaining power,  $\mu_t$ , as follows. Note that the global labor force is given by  $L_t$  being calculated as the sum of the labor force in advanced economies ( $L_a$ , assumed to be static) and that in the emerging economies ( $L_{e,t}$ , assumed to be growing). The bargaining power in the advanced economies is  $\mu_a$  (the base level), whereas the bargaining power in the emerging economies is  $\mu_{e,t}$  ( $< \mu_a$ , but gradually catching up). Thus the average global bargaining power,  $\mu_t$ , is calculated as follows:

$$\mu_t = \frac{L_a \mu_a + L_{e,t} \mu_{e,t}}{L_a + L_{e,t}}$$

We normalize  $L_a = 1$ . Let  $L_{e,t} = L_t - L_a$  and  $L_t = (1 + g^L)^t L_a$ . Then, we get:

$$\begin{aligned} \mu_t &= \frac{L_a \mu_a + ((1 + g^L)^t L_a - L_a) \mu_{e,t}}{(1 + g^L)^t L_a} \\ \Leftrightarrow \mu_t &= \frac{\mu_a + ((1 + g^L)^t - 1) \mu_{e,t}}{(1 + g^L)^t} \\ \Leftrightarrow \mu_t &= \frac{\mu_a - \mu_{e,t}}{(1 + g^L)^t} + \mu_{e,t} \end{aligned} \tag{2.29}$$

The bargaining power in the emerging economies, is calculated as follows:

$$\mu_{e,t} = 0.5 \phi_t \tag{2.30}$$

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<sup>41</sup>See e.g. Bhagwati (1995) and Rodrik (1997).

<sup>42</sup>In the context of a model with alternating wage offers, this assumption could be rationalized by supposing that initially the frequency of firms' offers is large relative to that of the workers, and the firms' offer frequency gradually declines to its steady state value.

<sup>43</sup>This could, e.g., be due to the development of labor market laws in favour of employees, due to the extension of the social security system in emerging economies or due to the fact that the rate of unionization of workers in urban areas who are working in the industrial sector is probably higher than the rate of unionization of workers in rural areas who are working in the agricultural sector.

with

$$\phi_t = \lambda_\mu \phi_{t-1} + (1 - \lambda_\mu) - (1 - 0.5)(1 - \lambda_\mu)\left(1 - \frac{g^L}{g_{new}^L}\right) \quad (2.31)$$

where  $\lambda_\mu$  denotes the persistence in the development of bargaining power.

Note that in the initial steady state (i.e.  $g^L = 0$ ), there is  $(1 - \frac{g^L}{g_{new}^L}) = 1$ , which guarantees that  $\phi_{t=0} = 0.5$ . This value implies that  $\mu_{e,t=0} = 0.25$  in the initial steady state. Afterwards, i.e. for  $g^L = g_{new}^L$ , there is  $(1 - 0.5)(1 - \lambda_\mu)\left(1 - \frac{g^L}{g_{new}^L}\right) = 0$ . Hence the value of  $\phi_t$  is determined only by the autoregressive process. In the new steady state (for  $j \rightarrow \infty$ ), the autoregressive process implies that  $\phi_t = \lambda_\mu^j \phi_{t-j} + (1 - \lambda_\mu)/(1 - \lambda_\mu) = 1$ , as  $\lambda_\mu^j \rightarrow 0$ .

Given the value for  $\phi$  in the initial and new steady state, respectively, allows us to determine the bargaining power in the emerging economies according to eq. (2.30) and the global bargaining power according to eq. (2.29).<sup>44</sup>

### 2.3.5 Monetary Policy

The monetary policy is based on the Taylor rule, with the target nominal interest rate determined as follows:<sup>45</sup>

$$(1 + i_t^{TR}) = (1 + i^*) \left(\frac{1 + \pi_t}{1 + \pi^*}\right)^{\alpha_\pi} \left(\frac{Y_t}{Y_t^*}\right)^{\alpha_y} \quad (2.32)$$

where  $i^*$  is the steady state nominal interest rate, with  $(1 + i^*) = (1 + r^*)(1 + \pi^*)$ ,  $r^*$  is the steady state real interest rate and  $\pi^*$  is the inflation target.  $Y_t^*$  is the steady state output,  $\alpha_y$  and  $\alpha_\pi$  are positive constants. Moreover, we assume that the actual nominal interest rate only gradually adjusts to the above target. This departure from the simple Taylor rule is motivated by recent research on central banks' policy rule, e.g. by Christiano et al. (2008) and Rudebusch (2006):

$$(1 + i_t) = [1 + i_{t-1}]^{\lambda_i} [1 + i_t^{TR}]^{1-\lambda_i}$$

The greater is the parameter  $\lambda_i$ , the higher is the sluggishness of the central bank's reaction to movements in the nominal interest rate target. Thus the central bank's reaction function is:

$$(1 + i_t) = [1 + i_{t-1}]^{\lambda_i} \left[ (1 + i^*) \left(\frac{1 + \pi_t}{1 + \pi^*}\right)^{\alpha_\pi} \left(\frac{Y_t}{Y_t^*}\right)^{\alpha_y} \right]^{1-\lambda_i} \quad (2.33)$$

<sup>44</sup>For the initial steady state, we get:  $\mu_{e,t=0} = 0.5 * 0.5 = 0.25$  and  $\mu_{t=0} = \frac{0.5-0.25}{(1+g^L)^t} + 0.25 = 0.5$ . For the new steady state, we get:  $\mu_{e,t \rightarrow \infty} = 0.5 * 1 = 0.5$  and  $\mu_{t \rightarrow \infty} = \frac{0.5-\mu_{e,t}}{(1+g^L)^t} + \mu_{e,t} = 0.5$ .

<sup>45</sup>See e.g. Ascari and Merkl (2007). See Taylor (1993) for the initial description of the equation.

where  $Y_t = n_t L_t A$  and  $Y_t^* = n^{new} L_t A$ .

### 2.3.6 Closing the Model

The model is closed by the following three equations.

Government budget constraint:<sup>46</sup>

$$B_t u_t (1 + g^L) + z_{t-1} = \frac{1}{1 + i_t} z_t (1 + g^L) + t_t (1 + g^L) \quad (2.34)$$

Product market equilibrium:

$$c_t = A n_t - \frac{\kappa}{2} x_t^2 n_t \quad (2.35)$$

Inflation rate:

$$\pi_t = \frac{P_t}{P_{t-1}} - 1 \quad (2.36)$$

In total, the economic system in the transition period is described by 22 equations.<sup>47</sup>

## 2.4 Numerical Evaluation

### 2.4.1 Calibration

The calibration is based on monthly data. For the steady state (see Table 2.1 for a summary, where ‘GT’ stands for Gertler and Trigari), we choose a standard value for the annual real steady state interest rate, which is set to 4%, or, on a monthly base,  $r^* = 0.0033$ . We define the replacement rate  $\bar{b}$  as the ratio between the level of unemployment benefits and the wage and set  $\bar{b}$  to 0.42 (see Gertler and Trigari, 2008). The renegotiation frequency,  $\lambda_w$ , (i.e. the probability that the wage is not renegotiated in period  $t$ ) is set to 0.889. The firing rate  $\phi$  is set to 0.035 and implies that the survival rate in the job is 0.965, which is the value reported by Gertler and Trigari (2008). The elasticity of matches to unemployment,  $\sigma$ , is set to 0.5. Moreover, we set  $\sigma_M = 0.386$ , which implies a steady state filling rate of  $q = 0.331$  per month, which corresponds to a filling rate of 0.7 per quarter as in Den Haan et al. (2000). The productivity,  $A$ , is normalized to 1. With respect to the bargaining power, we assume that the bargaining power in the advanced economies is time-invariant. Following the standard assumption, we set the bargaining power of the employee,  $\mu_a$ , to 0.5. With respect to the bargaining power in the emerging economies, we set the starting value to  $\mu_{e,t=0} = 0.25$ . The parameter  $\lambda_\mu$  that

<sup>46</sup>See Appendix 7.1.5 for the derivation.

<sup>47</sup>See Appendix 7.1.6.

determines the speed of convergence, is set to  $\lambda_\mu = 0.993$ . For the initial steady state, the job finding rate,  $s$ , is set to 0.45 (see Gertler and Trigari, 2008). Moreover, we set the ratio of real bond holding to output  $\bar{z} = 0.6$ .

parameter / variable	description	value	source
$r^*$	real interest rate	0.0033	to get $\delta = 0.997$
$\bar{b}$	replacement rate	0.42	GT (2008)
$\lambda_w$	renegotiation frequency	0.889	GT (2008)
$\varphi$	firing rate	0.035	GT (2008)
$\sigma$	elasticity of matches to unemployment	0.5	GT (2008)
$\sigma_M$	normalization parameter bargaining power in the advanced economies	0.386	to get $q = 0.338$
$\mu_a$	job finding probability	0.5	standard value
$s$	ratio of bonds to output	0.45	GT (2008)
$\bar{z}$	steady state inflation rate	0.6	assumption
$\pi^*$	interest rate smoothing parameter	0.0	assumption
$\lambda_i$	weight on output gap in Taylor rule	0.8	to match estimates
$\alpha_y$	weight on inflation gap in Taylor rule	0.5/12	standard value
$\alpha_\pi$	productivity	1.5	standard value
$A$	bargaining power in the emerging economies	1	normalization
$\mu_{e,t=0}$	convergence parameter	0.25	assumption
$\lambda_\mu$		0.993	assumption

Table 2.1: Calibration of the Initial Steady State

We set the steady state inflation rate  $\pi^* = 0$ . Concerning the parameters in the Taylor rule, we take the following values. The interest rate smoothing parameter,  $\mu_i$ , is set to 0.8, which corresponds to the average of the values reported by Christiano et al. (2008) and Rudebusch (2006) for the U.S. Following the standard calibration, the weight on the output gap is set to  $\alpha_y = 0.5/12$  and the weight on the inflation gap is set to  $\alpha_\pi = 1.5$ .

Given these values, it is possible to calculate the remaining parameters and variables in the initial steady state (see Table 2.2).

The horizon adjusted bargaining power,  $\chi = 0.440$ , is lower than the non-adjusted value,  $\mu = 0.5$ . As analyzed in detail by Gertler and Trigari (2008), the "horizon effect" reduces the bargaining power of the workers as it makes them more impatient. Therefore, the adjusted bargaining power,  $\chi$ , is lower than the bargaining power,  $\mu_t$ .

parameter / variable	description	value
$n$	employment rate	0.928
$u$	unemployment rate	0.072
$v$	vacancy rate ( $\frac{\text{number of vacancies}}{\text{labor supply}}$ )	0.098
$x$	hiring rate	0.035
$q$	job filling probability	0.331
$\chi$	horizon adjusted bargaining power	0.440
$c$	consumption per capita	0.904
$z$	real bond holding per capita	0.557
$W = W^* = W^T$	wage	0.970
$\delta$	discount factor	0.997
$\kappa$	labor adjustment cost parameter	41.860

Table 2.2: Implied Values in the Initial Steady State

### 2.4.2 Understanding the Key Features of the Model

Next, the macroeconomic implications of the global labor supply impulse are analyzed. The impulse represents the increase in the effective global labor supply caused by the integration of China, India, and the Eastern European countries into the global economy. It is supposed that the labor supply is initially constant and then grows permanently at 0.25% per month, which implies an annual growth rate of around 3%.<sup>48</sup> We show how the labor supply impulse contributed to the period of low inflation rates and booming macroeconomic activity. First, the dynamics of the full model are analyzed; second, the contributions of the various lagged adjustment processes are examined.

**Dynamics of the Full Model**<sup>49</sup> The results of the simulations reveal that the combination of the labor supply impulse and the dynamics of the bargaining power is the main driving force of the model, in particular of the inflation dynamics (see Figure 2.2). In the following figures, the red line denotes the new steady state. Given the initially lower bargaining power in the emerging economies, the increasing integration of the labor supply of those countries into the global markets causes a reduction of the adjusted bargaining power of the worker,  $\chi$ . This – on its own – dampens the wage (the target wage,  $W^T$ , and thereby the contract wage,  $W^*$ ). However, a lower aggregate wage would increase the hiring rate,  $x$ , according to eq. (2.14) and thereby the finding probability,  $s$ .<sup>50</sup> Both, the increase of the hiring rate and the increase of the job finding probability – on their own – cause an increase

<sup>48</sup>See Appendix 7.1.7.

<sup>49</sup>See Appendix 7.1.8 for a detailed analysis of the model dynamics and Appendix 7.1.9 for further results.

<sup>50</sup>Combining eq. (2.3) and eq. (2.10) provides:  $s = x * N/U$ .

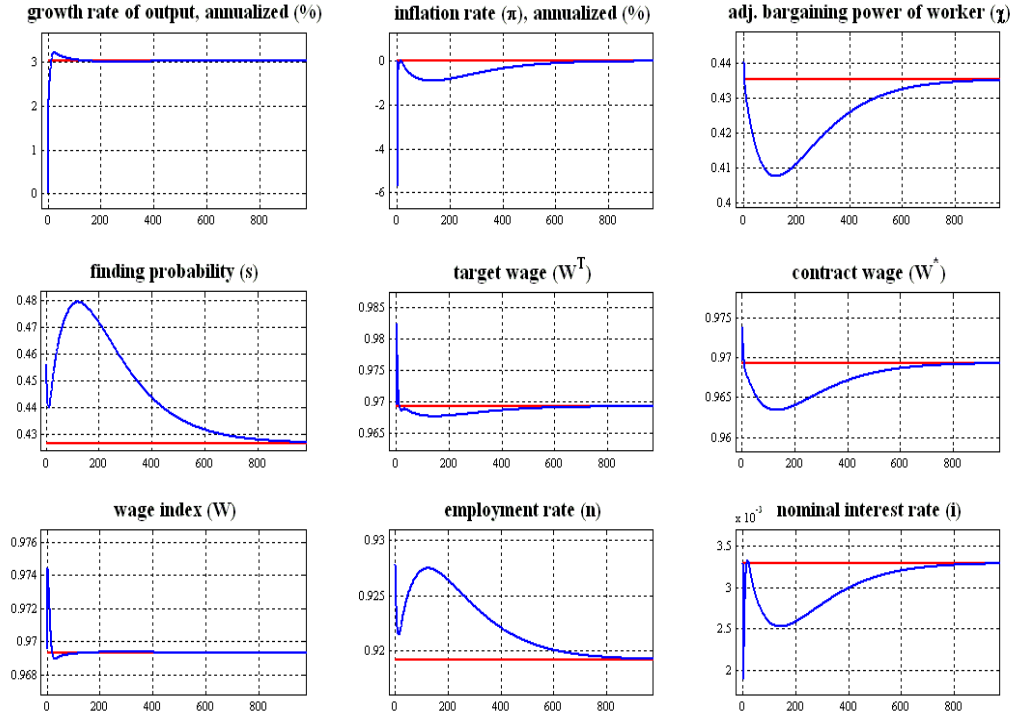


Figure 2.2: The Dynamics of the Main Variables in the Full Model

of the target wage in the same period according to eq. (2.26). Thus, with respect to the target wage, there are two opposing effects: first, a negative effect due to the declining bargaining power, and second, a positive effect due to the increasing hiring rate and the increasing job finding probability.

In the early stage of the dynamic process – after the initial reaction to the labor supply impulse –, the negative impact of the decreasing bargaining power dominates.<sup>51</sup> Moreover, after the initial decline,<sup>51</sup> the employment rate,  $n$ , and therefore also consumption per capita,  $c$ , increase. Then, the output gap is positive (as  $Y_t = A L_t n_t > Y_t^* = A L_t n^{new}$  where  $n^{new}$  is the new steady state level of the employment rate), which – on its own – implies a higher interest rate,  $i$ , i.e. an interest rate above steady state, according to the Taylor rule. However, the interest rate – as implied by the Euler equation – is below the steady state level as  $\frac{c_t}{c_{t+1}} > 1$ . Standard macroeconomic models equate the interest rate targeted by the central bank with

<sup>51</sup> Given a constant productivity, the declining wage implies a declining share of labor in national income. This result corresponds to the findings by Jaumotte and Tytell (2007): "... labor globalization has negatively affected the share of income accruing to labor in the advanced economies (the labor share)." Also in their analysis "labor globalization" refers to the integration of China, India and the Eastern European countries into the global economy.

the interest rate in the Euler equation.<sup>52</sup> Against this background, the second factor in the Taylor rule, the inflation rate,  $\pi$ , becomes relevant, as its development makes the interest rate implication of the Taylor rule on the one hand and the implication of the Euler equation on the other hand consistent. Finally, monetary policy following a Taylor rule implies that the inflation rate has to be below steady state (i.e. negative in the given calibration). Hence, due to the deflationary pressure arising from the increasing effective global labor supply, monetary policy is compatible with an inflation rate, which is lower than it would otherwise have been possible.

However, in the long run, the model dynamics are opposed to what has just been described. The bargaining power in the emerging economies starts to increase, e.g. due to labor market laws in favor of the employees. Here, it is assumed that the increase causes a convergence of the bargaining power in the emerging economies to the bargaining power in the advanced economies ( $\mu_{e,t} \rightarrow \mu_a = 0.5$ ). Hence, the global bargaining power also converges to the level of the bargaining power in the advanced economies. Finally, the variables converge to their steady states. In particular, the inflation rate increases again.

By implication, also a slowing of labor supply growth in the future would give monetary policy a more inflationary bias and thereby presumably lead monetary authorities to adopt a more restrictive monetary policy stance.

**Contributions of the Different Lagged Adjustment Processes** Next, we regard three variations of the model, designed to illustrate the contribution of each lagged adjustment process. To quantify the contribution of each process to the dynamics of the model, we simulate the dynamics of the model after having eliminated the adjustment process. The comparison of the simulation results of the full model with the simulation results in the absence of a specific adjustment process reveals the relevance of the process.

**Lagged Adjustment Process of the Bargaining Power** First,  $\lambda_\mu$  is set to 0. The comparison reveals the significance of the adjustment process as a driving force of the long-term behavior of the model variables (see Figure 2.3).<sup>53</sup> In the full model, the development of the adjusted bargaining power,  $\chi$ , is characterized by some undershooting. However, for  $\lambda_\mu = 0$ , the bargaining power,  $\mu$ , remains constant and the adjusted bargaining power,  $\chi$ , almost immediately jumps down

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<sup>52</sup>See Woodford (2003). Given this equalization, the Euler equation provides a direct link between monetary policy and consumption demand.

<sup>53</sup>In the short term, the dynamics of the modified model ( $\lambda_\mu = 0$ ) are almost identical to the dynamics of the full model. See Appendix 7.1.10 for further results.



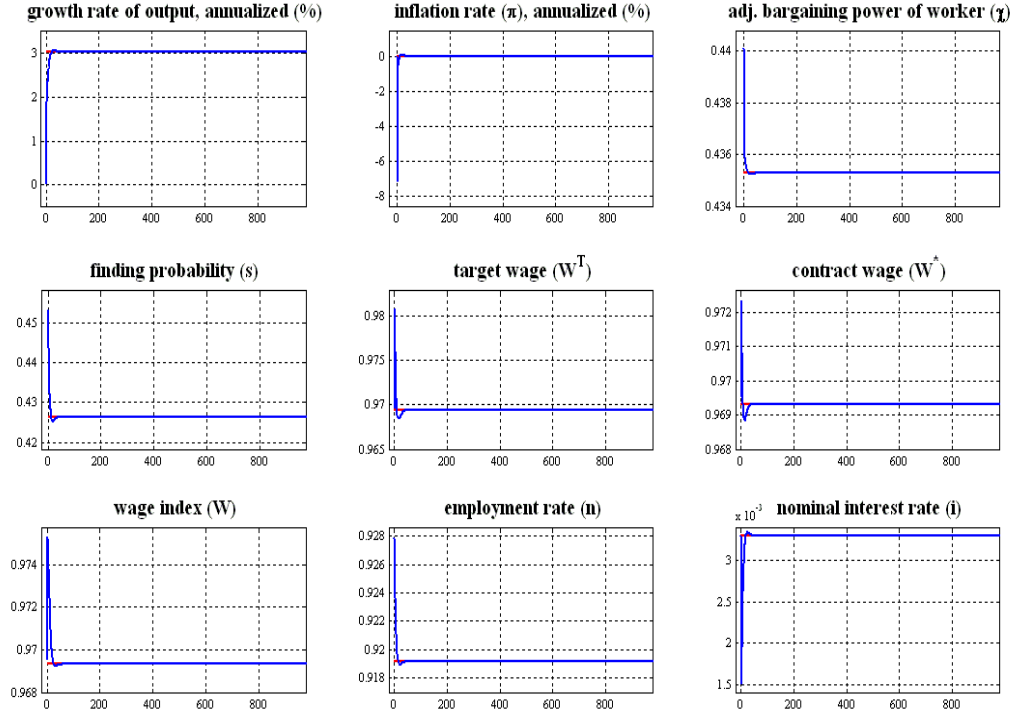


Figure 2.3: The Dynamics of the Main Variables in the Modified Model ( $\lambda_\mu = 0$ )

to its new steady state.<sup>54</sup> As already mentioned above, there are two opposing effects with respect to the target wage,  $W^T$ . Here, given the different behavior of the bargaining power compared to the full model, there is no undershooting of the target wage,  $W^T$ , and the contract wage,  $W^*$ , as well as no overshooting of the job finding probability,  $s$ , in the medium term. Instead, there is only a short undershooting at the very beginning of the dynamic process. However, the sharp decline of the target wage and the contract wage, respectively, is also observed in the full model; there, the sharp decline is followed by a further decrease. Thus,  $\lambda_\mu = 0$  can explain the missing further decrease of the wages but not the sharp decline at the very beginning. Moreover, for  $\lambda_\mu = 0$ , there is no overshooting of the hiring rate,  $x$ , which is a consequence of the non-existing undershooting of the wage. Finally, the employment rate does not overshoot. Consequently, consumption per capita does not grow after the initial drop. Hence, the Euler equation implies a constant interest rate shortly after the initial impulse. Moreover, the output gap disappears

<sup>54</sup>Recall that the adjusted bargaining power,  $\chi$ , – via  $\Psi$  and  $\Delta$  – also depends on  $\lambda_w$  and finally on the hiring rate  $x$ . Like  $x$  also the adjusted bargaining power does not achieve the new steady state level immediately.

quickly. Given these factors, monetary policy following a Taylor rule generates an inflation rate being back on the steady state level rapidly.

**Lagged Adjustment Process of the Wage** Next,  $\lambda_w$  is set to 0. Consequently, the cumulative discount factor of the firm,  $\Psi$ , according to eq. (2.23), as well as the cumulative discount factor of the worker,  $\Delta$ , according to eq. (2.22) are equal to 1 and remain constant. This has two implications. First, there is – in contrast to the full model – no horizon effect. Second, the contract wage,  $W^*$ , is no longer affected by the dynamics of the cumulative discount factor of the worker,  $\Delta$ . Due to the missing horizon effect, the adjusted bargaining power of the worker,  $\chi$ , equals the bargaining power,  $\mu$ , and is therefore higher than in the full model (see Figure 2.4).<sup>55</sup> As a consequence of this level shift, the wage level is higher and the employment level is lower than in the full model.

Moreover, there is almost no undershooting of the wages at the very beginning of the dynamic process. The missing undershooting of target wage,  $W^T$ , can be explained by the missing horizon effect. For  $\lambda_w > 0$ ,  $\chi$  immediately drops significantly but achieves the lower new steady state level only after a certain period of time; at the beginning of the dynamic process, an undershooting of the target wage can be observed. The missing undershooting of the contract wage,  $W^*$ , can be explained by two factors. One factor is the dynamics of the target wage, just described, which have an impact on  $W^*$  according to eq. (2.25). Another factor, already mentioned above, is the fact that the contract wage,  $W^*$ , is no longer affected by the dynamics of the cumulative discount factor of the worker. In this context, it is useful to look back to the full model. In the full model, the cumulative discount factor of the worker,  $\Delta_t$ , affects the contract wage,  $W^*$ , in two ways according to eq. (2.25). First, a higher discount factor  $\Delta_t$  reduces the contract wage in the same period. Second, an increasing discount factor, i.e.  $\Delta_{t+1} > \Delta_t$ , – on its own – increases  $W_t^*$ ; however, the size of the second effect is also influenced by the development of  $W_{t+1}^*$ . The impact of the product  $\Delta_{t+1}W_{t+1}^*$  on  $W_t^*$  is indefinite, but the total impact of  $\Delta$  on  $W^*$  is negative. The dynamics of  $\Delta$  and  $W^*$  in the full model are mirror inverted. Given a constant  $\Delta$ , the contract wage is also almost constant after the initial impulse.

The dynamics of the employment rate, consumption per capita and the interest rate do not change compared to the full model, so the dynamics of the inflation rate also do not change.

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<sup>55</sup>See Appendix 7.1.11 for further results.

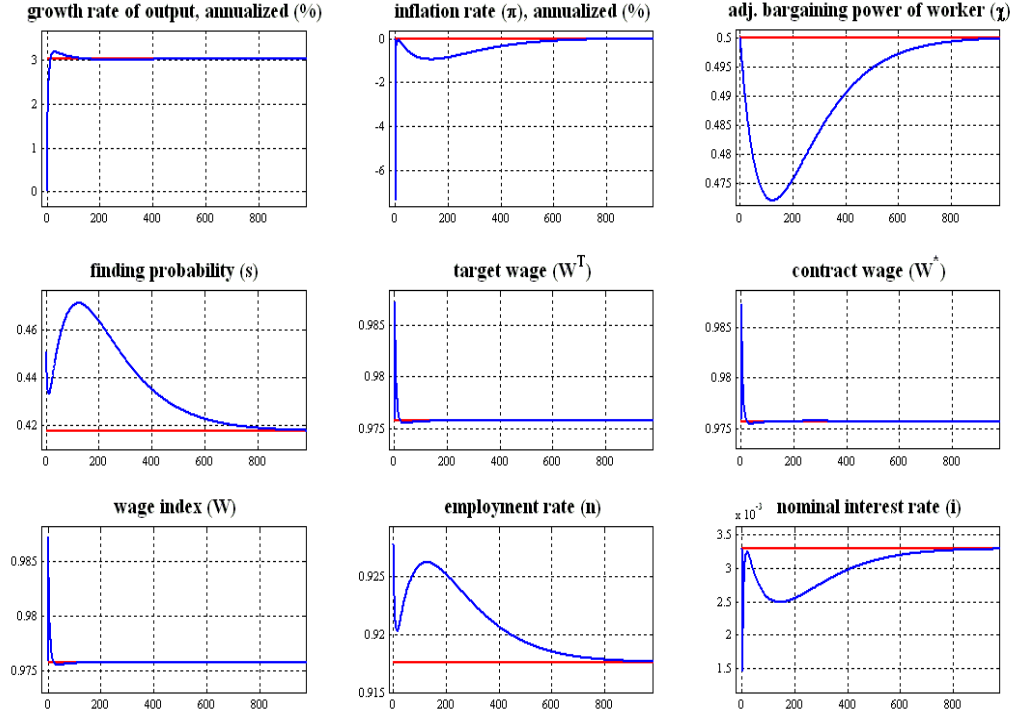


Figure 2.4: The Dynamics of the Main Variables in the Modified Model ( $\lambda_w = 0$ )

**Lagged Adjustment Process of the Interest Rate** Finally,  $\lambda_i$  is set to 0. Compared to the full model, the short-term dynamics of the cumulative discount factor of the worker,  $\Delta$ , the cumulative discount factor of the firm,  $\Psi$ , the target wage,  $W^T$ , the contract wage,  $W^*$ , and in particular, the inflation rate,  $\pi$ , are different (see Figure 2.5).<sup>56</sup> Recall that in the full model, the positive output gap on the one hand and the interest rate level below steady state on the other hand imply that monetary policy following a Taylor rule generates a negative inflation rate in the first phase and, in particular, a rapidly increasing inflation rate in the second phase ( $t = 2$  up to  $t \approx 10$ ).

For  $\lambda_i = 0$ , the increase of the inflation rate after the initial decline takes more time. The protraction is caused by the missing impact of the lagged interest rate,  $i_{t-1}$ , in the Taylor rule. In the second phase, the output gap is still positive and the Euler equation implies an interest rate level below steady state. Like in the full model, monetary policy following the Taylor rule generates a negative inflation rate. However, in the full model, also the term  $i_{t-1}$  being below its steady state level, contributes to guarantee the consistency between the positive output gap (which

<sup>56</sup>See Appendix 7.1.12 for further results.

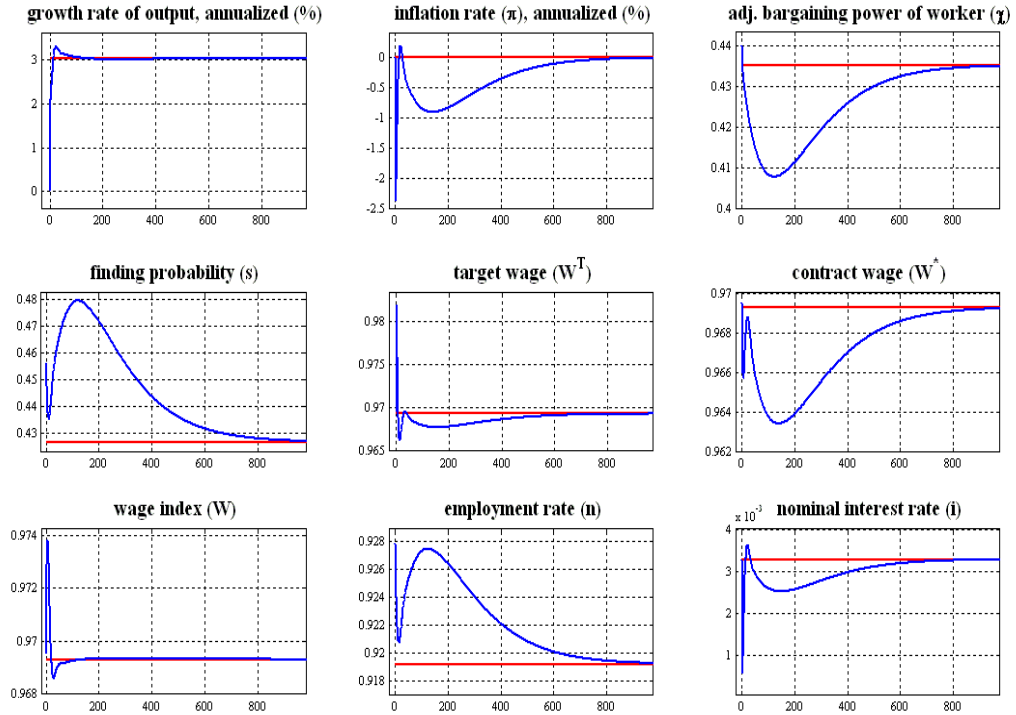


Figure 2.5: The Dynamics of the Main Variables in the Modified Model ( $\lambda_i = 0$ )

– on its own – implies a positive interest rate) and the negative interest rate as implied by the Euler equation. For  $\lambda_i = 0$ , the term  $i_{t-1}$  does not exist. Therefore, the positive output gap has to be overcompensated by an even higher negative inflation rate. Hence, for  $\lambda_i = 0$ , monetary policy following a Taylor rule generates a slower adjustment of the inflation rate after the initial impulse. Conversely, the missing lagged interest rate term also causes the overshooting of the inflation rate.

## 2.5 Concluding Thoughts

The analysis shows that it was not only the wisdom of the central banks, but the increase in global labor supply that has been responsible for the recent years of high macroeconomic activity combined with low inflation.

Since the 1990s, workers from the emerging economies, in particular from China, have joined the global labor market, producing goods and services that are traded on international markets. In this sense, the globalized world has experienced a massive rise in the effective global labor supply. Thereby, the increase in labor supply has put downward pressure on wages and finally inflation.

The analysis reveals that the main transmission channel was the development of the bargaining power of the employees in combination with the initially lower bargaining power in emerging economies. Due to the increasing volume of available labor and the increasing trade, workers in advanced economies can be more easily replaced by workers in emerging economies. Hence, the bargaining power of workers in advanced economies declines. Finally, also the wage declines.

By implication, a slowing of labor supply growth in the future in combination with an increasing bargaining power would reduce the dampening impact on wages, and finally on inflation. A slowing growth could be caused by bottlenecks in the movement of people from rural to urban areas, bottlenecks in training these people, a global recession leading to underutilization of labor; moreover, the growth could decline because the big push to integrate the emerging economies was run much of its course and future integration is likely to proceed at a slower pace. An increasing bargaining power could be caused by the development of labor market laws in favor of employees or due to the extension of the social security system in the emerging countries.

Finally, monetary policy would get a more inflationary bias and thereby lead monetary authorities to adopt a more restrictive monetary stance.

## 3 The Effect of Low-Wage Subsidies on Skill Formation, Aggregate Employment and Welfare

### 3.1 Introduction

Whereas the analysis in the previous chapter was based on global variables and finally focused on the implications of an increasing global labor supply for monetary policy, this – and also the following – chapter focuses on the implications for labor market policy. The main challenge policy makers face in this field is the deteriorating position of low-skilled people. Therefore, the following analyses are no longer based on aggregated variables; instead, different types of labor are considered.<sup>57</sup>

In many advanced economies, the relative position of employees at the bottom of the wage distribution has deteriorated over the past decades. Whereas in the U.S. this worsening has taken the form of a higher wage inequality between skilled and low-skilled labor, in continental European countries the deterioration appears in a higher relative unemployment rate of the low-skilled labor force. Against this background, policy makers and economists have been searching for labor market instruments that reduce unemployment while avoiding large disparities in income. These efforts can be summarized under the heading "Making work pay".<sup>58</sup>

A popular tool are low-wage subsidies (LWS), which have been widely advocated, in particular by Phelps (1997a). The central policy problem of low-skilled workers is that they are associated with low wages or low employment opportunities or both. Raising their wages would reduce firms' demand for them, while lowering their wages would be socially unacceptable. LWS respond to this policy problem by driving a wedge between the income these workers receive and their labor costs.<sup>59</sup> These subsidies, in various guises, have been implemented in many countries, including e.g. France (Prime pour l'Emploi),<sup>60</sup> Germany (Kombi-Lohn),<sup>61</sup> Great Britain (Working Families Tax Credit)<sup>62</sup> and the U.S. (Earned Income Tax Credit, EITC)<sup>63</sup>.

In this chapter the effects of LWS on skill formation, aggregate employment and welfare are modeled. Whereas low-skilled employment is expected to increase in the presence of LWS, it is doubtful whether also aggregate employment and welfare increase. The impact on aggregate employment may be lower or even negative if

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<sup>57</sup>For a different version of this chapter see Oskamp and Snower (2006).

<sup>58</sup>See for an early contribution OECD (2000a).

<sup>59</sup>See, for an analysis, Hamermesh (1978) as well as Haveman and Palmer (1982).

<sup>60</sup>See Stancanelli and Sterdyniak (2004).

<sup>61</sup>See Boss (2006) for a survey of different proposals and existing models.

<sup>62</sup>See, e.g. Dilnot and McCrae (2000) for a description and an analysis of the program.

<sup>63</sup>See Hotz and Scholz (2003) for a detailed description and an exhaustive review of the literature.

LWS cause a reduction in skilled employment. In order to analyze the effect on aggregate employment, a particular focus is on the effect of LWS on skill formation. The possible negative effect on the incentives to acquire human capital and thereby on skilled employment is often ignored in the macroeconomic literature. Therefore, it is commonly supposed that since LWS reduce the labor cost of low-wage workers, they must stimulate aggregate employment. This chapter calls this presumption into question. There are three important employment effects of LWS, which will be considered:

- *The direct employment effect:* The demand for low-skilled labor rises, since the cost of this type of labor falls.
- *The skill-acquisition effect:* The incentive to acquire skills falls, because when people acquire skills, their wages rise and consequently, they lose their entitlement to the LWS. This negative impact on skill formation reduces employment, since low-skilled workers have a lower employment rate than their skilled counterparts.
- *The government budget effect:* The LWS are generally financed through taxes. An increased tax burden, in particular for the skilled labor force, amplifies the negative impact on skill formation and finally on skilled employment.

This chapter presents a macro model of the labor market and the training system as well as the corresponding states, which allows us to analyze and quantify each of these three effects. The transition probabilities between the different states are governed by a Markov process. The transition probabilities, which are affected by LWS, in particular the transition rate between school and training, are analyzed in detail. Then, the model is calibrated for the German labor market and training system to reveal the relative significance of each effect and thereby to assess how LWS affect aggregate employment.

It is shown that LWS can significantly reduce medium-skilled employment. Thus, the positive effect of LWS on low-skilled employment does not cause an increase in aggregate employment to the same extent; rather, the net effect is very small. Thus, ignoring the effect on medium-skilled employment would cause an essential overstatement of the benefits of LWS. Furthermore, the shift from medium-skilled to low-skilled employment reduces aggregate welfare. The calibration also reveals that the size of the different effects depends on the hiring elasticity, the training elasticity and the degree of risk aversion.

The chapter is organized as follows. In Section 3.2, the relation to the literature is illustrated. Section 3.3 presents the theoretical model. In Section 3.4, the model

is calibrated and the impact of LWS on skill formation, employment and welfare is analyzed. Section 3.5 concludes.

## 3.2 Relation to the Literature

Pioneered by the work of Pigou (1933) and Kaldor (1936), a huge strand of the theoretical and empirical literature has focused on the impact and optimal design of LWS.<sup>64</sup> Often, the search and matching framework of Mortensen and Pissarides (1994) has been used to analyze the effects of labor market policies.<sup>65</sup> However, the matching technology<sup>66</sup> is assumed to be stable over time; but this assumption is not totally confirmed by empirical studies. Some of the studies, which estimate search and matching functions have found a negative time trend.<sup>67</sup> Moreover, given that the matching process itself may not be invariant to a policy change, it is not reasonable to use a policy-invariant matching function to analyze labor market policies. To prevent running afoul of the Lucas Critique, the analysis is not based on a policy-invariant matching function. Instead, similar to Brown et al. (2007), it is analyzed explicitly how policies affect people's incentives given an intertemporal maximization of economic agents.

Many theoretical papers use static analytical frameworks and thus have the disadvantage that they can only analyze the short-run impact of the policy but not the long-run effects.<sup>68</sup> However, there are reasons to suppose that longer-run effects are significant.<sup>69</sup> In this context, this study differs from the literature, as the dynamic effects of the LWS in the long run are captured by specifying the effect of LWS on the transition rates between the different states.

The existing dynamic frameworks for evaluating subsidies, e.g. Hoon and Phelps

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<sup>64</sup>See furthermore Phelps (1994, 1997b) as well as Orszag and Snower (2003b). With respect to existing subsidy schemes, especially the EITC in the U.S. has been analyzed intensely, see e.g., Eissa and Hoynes (2005), Meyer (2002) as well as Liebman (2001). Bassanini et al. (1999) analyze the impact of a simplified EITC model for different countries. Concerning Germany, see in particular Brown et al. (2007), SVR (2006), Sinn et al. (2006), Spermann (2003), Riphahn et al. (1999) as well as Buslei and Steiner (1999).

<sup>65</sup>See, e.g. Danthine (2005) as well as Boone and van Ours (2004). Charlot et al. (2005) use the framework to analyze the links between the labor market and the training sector.

<sup>66</sup>Like a production function, the matching technology describes the relation between input – the number of unemployed and the number of vacancies – and output given by the number of matches. Often, a Cobb-Douglas function is used:  $number\ of\ matches = (unemployment)^{\theta_1}(vacancies)^{\theta_2}$ .

<sup>67</sup>See Blanchard and Diamond (1989) for the U.S. as well as Fahr and Sunde (2001, 2004) for Germany. Besides, many empirical studies reject the hypothesis of constant returns to scale, see e.g. Warren (1996) for the U.S. and Fahr and Sunde (2001) for Germany.

<sup>68</sup>See, e.g. Layard and Nickell (1980) and Layard et al. (1991).

<sup>69</sup>Orszag and Snower (2000) show that the dynamic long-run effects of employment subsidies differ from what may be expected in the short run, once the corresponding lagged adjustment processes have worked themselves out.



(2003),<sup>70</sup> are not well-suited to analyze the impact of the policy. Mortensen and Pissarides (2003) explore the effects of taxes and subsidies on job creation, job destruction, employment and wages in a search and matching equilibrium model. However, in their model, like in the models of Albrecht and Vroman (2002) as well as Cardullo and van der Linden (2006), migration between skill groups, which is an essential component in the model, does not take place. In this context, the analysis contributes to the existing literature by explicitly allowing for migration from the low-skilled to the medium-skilled labor force. Taking migration into account allows us to illustrate the skill-acquisition effect, which is of particular importance for an overall assessment of LWS.

Nickell and Bell (1997) as well as Siebert and Stähler (1994) have already mentioned the problem that raising the income of low-skilled people may reduce the incentive to acquire skills. However, none of these studies use a theoretical framework to analyze the problem. In this context, the paper by Heckman et al. (2003) is closest to this model as they examine the impact of wage subsidies on skill formation. In particular, they focus on the EITC and analyze its impact on the incentives to accumulate skills in two different models of human capital formation. Different to Heckman et al. (2003), this analysis is not based on the EITC structure but on a more general version of a LWS. Furthermore, the focus is not only on skill formation but also on the effects of subsidies on employment and welfare. In contrast to Heckman et al. (2003), the wage bargaining process is also modeled explicitly and thereby the impact of subsidies on employment via the wage is examined.

### 3.3 The Model

The model is meant to provide a framework for analyzing the impact of LWS on skill formation, employment and welfare. In this context, it features a variety of common labor market imperfections like insider wage bargaining as well as hiring and firing costs. The model involves some judicious compromises between analytical simplicity and the depiction of heterogeneous labor market behaviors.

In particular, the analysis is based on a Markov model of the labor market and the training system. Similar to Brown et al. (2007), the dynamics are governed by a Markov matrix that summarizes the transition probabilities between the different states. However, in addition to Brown et al. (2007), we integrate a training state into the model and allow for active transition from the low-skilled state to the medium-skilled state. The transition probabilities are the solutions of an optimiza-

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<sup>70</sup>Their analysis is limited to the impact of subsidies on the worker's decision to quit the firm and thereby on the firm's incentive to invest in firm-specific training.

tion problem of the firms and the individuals, respectively.

The labor force is differentiated according to its different skill levels, which are defined by the level of educational attainment. It is assumed that each skill level corresponds to a certain productivity level. Total population is divided into eight groups (see Table 3.1): people being in school,  $S$ , people joining vocational training,  $T$ , and those being either employed,  $N_i$ , or unemployed,  $U_i$ . The employed and unemployed, respectively, are divided into three subgroups according to the skill level  $i = l, m, h$ . Here, as well as for other variables below, the subscript  $l$  stands for "low-skilled", the subscript  $m$  for "medium-skilled" and the subscript  $h$  for "high-skilled".

state	variable
low-skilled employment	$N_l$
low-skilled unemployment	$U_l$
medium-skilled employment	$N_m$
medium-skilled unemployment	$U_m$
high-skilled employment	$N_h$
high-skilled unemployment	$U_h$
vocational training	$T$
school	$S$

Table 3.1: The States in the Model

Vocational training takes  $p$  periods, so that there are  $p$  cohorts. In each period, a fraction  $\rho + \theta$  leaves the vocational training where  $\rho$  is the death rate and  $\theta$  is the drop-out rate with respect to training. So, given the inflow into vocational training,  $T_1$ , the outflow,  $p$  periods later, is given by  $T_1(1 - \rho - \theta)^p$ . The stock of people being in vocational training is given by  $T = T_1 \sum_{c=1}^p (1 - \rho - \theta)^{c-1}$ .

For simplicity, there is no capital. Moreover, returns to labor are assumed to be constant. Let  $a_i$  be the productivity of an employee with a skill level  $i = l, m, h$ . The firms face a random cost  $\epsilon_t$ , which is *iid* across workers and time.<sup>71</sup> The cost can be regarded as an operating cost or a productivity shock. With respect to all employees, its mean is normalized to zero and its cumulative distribution  $\Gamma(\epsilon_t)$  is time-invariant.

In the model, training takes place within the dual system of vocational training, the dominant form in Germany. In this context, it is assumed that the people being in training also receive a wage and that the firms pay for the non-wage costs of training.<sup>72</sup> In the following, for the sake of simplicity, the transition from school to

<sup>71</sup>See Brown et al. (2007).

<sup>72</sup>See chapter 4 for a discussion of the distribution of training costs between the firm and the apprentice within the dual system of vocational training.

training is assumed to be totally supply-driven.<sup>73</sup>

### 3.3.1 The Transitions between the States

The transitions between the different states are illustrated in Figure 3.1. In all states apart from  $S$ , people face a probability  $\rho$  of dying. With respect to the people leaving school, a fraction  $\tau_S$  decides to enter training. In the remainder,  $\tau_S$  is called "training rate". The residual fraction  $(1 - \tau_S)$  tries to get a job as a low-skilled employee; only a fraction  $\eta_l$  is hired. A low-skilled employee faces a probability  $\varphi_l$  of being fired; a fraction  $\tau_N$  decides to enter training. A fraction  $\tau_U$  of the low-skilled unemployed decides to enter training; the remaining part,  $(1 - \tau_U)$ , faces a probability  $\eta_l$  of being hired as low-skilled employee. With a probability  $\theta$  per period, an apprentice drops out of training. By assumption, apprentices cannot be fired. In this case, she is either hired as a low-skilled employee with a probability  $\eta_l$ , or becomes a low-skilled unemployed. An apprentice, who has finished training successfully and survives, is hired as a medium-skilled employee with a probability  $\eta_{T,N_m}$ . A medium-skilled employee faces a probability  $\varphi_m$  of being fired. An unemployed medium-skilled is hired with a probability  $\eta_m$ .

The high-skilled labor force  $(N_h + U_h)$  is treated as a quasi-fix factor, i.e. these states are assumed to be unaffected by the introduction of LWS. However, given the government budget constraint, it is necessary to take these states into account, because  $N_h$  also carries a part of the fiscal burden and  $U_h$  is responsible for a part of the fiscal burden. Ignoring this aspect would bias the amount of the fiscal burden, which has to be carried by the low-skilled and medium-skilled employees. Moreover, the number of deaths is assumed to be equal to the number of people entering state  $S$ , so that the relevant population  $(N_l + U_l + N_m + U_m + T + S)$  is constant. Given this, the labor market system can be described as follows:

$$Z_{t+1} = MT_{t+1} Z_t \quad (3.1)$$

where  $Z_t$  is a vector of the different states:

$$Z_t = (N_{m,t}, U_{m,t}, N_{l,t}, U_{l,t}, T_{1,t}, S_t) \quad (3.2)$$

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<sup>73</sup>See chapter 4 for a demand-driven transition. Both perspectives can be justified given the mismatch in the market for vocational training. On the one hand, not all vacancies for vocational training are filled (15,387 open vacancies at the end of september 2006). On the other hand, at the same time, 49,453 applicants have no training position, see BMBF (2007).

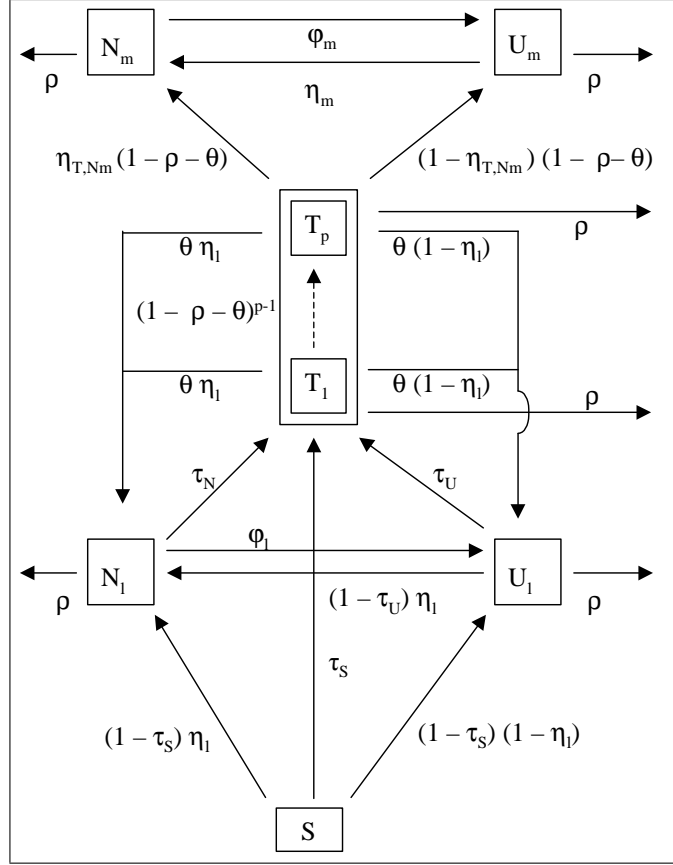


Figure 3.1: The Transitions between the States

and  $MT$  is a Markov matrix of the transition probabilities:

(3.3)

$$MT = \begin{bmatrix} (1-\varphi_m-\rho) & \eta_m & 0 & 0 & \eta_{T,Nm}(1-\rho-\theta)^p & 0 \\ \varphi_m & (1-\eta_m-\rho) & 0 & 0 & (1-\eta_{T,Nm})(1-\rho-\theta)^p & 0 \\ 0 & 0 & (1-\varphi_l-\tau_N-\rho) & (1-\tau_U)\eta_l & \theta\eta_l \sum_{c=1}^p (1-\rho-\theta)^{c-1} & (1-\tau_S)\eta_l \\ 0 & 0 & \varphi_l & (1-(1-\tau_U)\eta_l-\rho-\tau_U) & \theta(1-\eta_l) \sum_{c=1}^p (1-\rho-\theta)^{c-1} & (1-\tau_S)(1-\eta_l) \\ 0 & 0 & \tau_N & \tau_U & 0 & \tau_S \\ \rho & \rho & \rho & \rho & \rho \sum_{c=1}^p (1-\rho-\theta)^{c-1} & 0 \end{bmatrix}$$

### 3.3.2 The Characteristics of the Low-Wage Subsidies

Low-wages subsidies are directly paid to the low-skilled employee over the whole period of employment. In the bargaining process, the low-wage subsidy is considered as a constant  $\kappa$ . However, in the steady state, the subsidies are expressed in relation

to the producer wage for the low-skilled,  $w_l$ :

$$\kappa = \sigma w_l \tag{3.4}$$

where  $\sigma$  is the subsidy rate. Moreover, as the subsidy is supposed to support the income of low-skilled people, the low-wage subsidy is assumed to affect not only the level of the wage but also the level of the unemployment benefit  $b_l = \beta_l (w_l (1 - t_l) + \kappa)$  where  $\beta_l$  is the net replacement rate and  $t_l$  is the tax rate, a low-skilled worker is confronted with.

Generally speaking, there are three types of effects of LWS on employment:

(i) *direct employment effect*: Due to the Nash bargaining process, LWS reduce the producer wage for low-skilled employment,  $w_l$ . Hence, they increase the hiring rate,  $\eta_l$ , and decrease the firing rate,  $\varphi_l$ . Thus, the demand for low-skilled labor rises and low-skilled employment,  $N_l$ , increases.

(ii) *skill-acquisition effect*: LWS increase the consumer wages for low-skilled employees,  $\omega_l = w_l (1 - t_l + \sigma)$ . Thus, they reduce the incentive to acquire skills. The training rate,  $\tau_S$ , decreases. Finally, the medium-skilled labor force declines. Everything else equal, low-skilled employment increases and medium-skilled employment decreases.

(iii) *government budget effect*: LWS have to be financed via taxes on wages. This may cause an increasing tax burden, in particular for the skilled labor force. Consequently, the negative impact of LWS on skill formation and finally on skilled employment is amplified. However, it may be possible that due to the implementation of LWS the tax burden will decline. As a consequence of the LWS, the number of people requiring unemployment benefits may decrease and the number of people paying taxes may increase. In total, the LWS may induce revenues, which can be used to reduce the tax rates.

Naturally however, the effects are interdependent, i.e. the direct employment effect has an impact on the skill-acquisition effect because a variation of the hiring and firing rate, respectively, also influences the expected lifetime utility of a low-skilled and thereby the decision of people being in state  $S$  whether to remain low-skilled or not.

The agents follow – similar to Brown et al. (2007) – a certain sequence of decisions. First, the government sets the tax rates to ensure that the tax receipts are equal to its expenditures, which are the sum of unemployment benefits and LWS. Second, the random costs are detected. Third, wages are determined through Nash bargaining. Fourth, employment decisions are made and finally, the training decision is made.

### 3.3.3 Government Budget Constraint

When analyzing the government budget constraint, three policy instruments have to be taken into account: (i) the payroll tax with a rate  $t_i$ , (ii) the unemployment benefit  $b_i$  and (iii) the low-wage subsidy  $\kappa = \sigma w_l$ , where  $\sigma$  is the subsidy rate. The tax rate has three levels to match a progressive tax system ( $t_h > t_m > t_l$ ). The ratios are assumed to be exogenous, whereas the levels are set so that the tax receipts are equal to the government's expenditures. When LWS are implemented, also the tax rate of the low-skilled,  $t_l$ , is assumed to be affected. Moreover, it is assumed that people being engaged in vocational training do not pay taxes. The government budget constraint is expressed as follows:

$$\sum_{i=l,m,h} t_i w_i N_i = \sum_{i=l,m,h} b_i U_i + \sigma w_l N_l \quad (3.5)$$

The left-hand side stands for the tax receipts of the government, generated by the tax on labor income. The term on the right-hand side represents the sum of the unemployment benefits and the amount of LWS paid to all low-skilled employees over the whole period of employment.

### 3.3.4 Wage Determination

The producer wage  $w_{i,t}$  for each skill level  $i$  is assumed to be the outcome of a Nash bargain between the median insider of that skill level and the firm in period  $t$ .<sup>74</sup> The median insider faces no risk of dismissal at the negotiated wage. The wage is renegotiated in each period. First, the relevant surplus of the employee and the firm, respectively, is calculated. Second, the wage for the low-skilled worker,  $w_{l,t}$ , is calculated to illustrate the impact of the low-wage subsidy. Then, by setting the subsidy rate  $\sigma = 0$ , it is easy to derive the wage for the medium-skilled and the high-skilled worker.

**Surplus of the Employee** Each low-skilled person has the following utility function:

$$u_{l,t}(C_{l,t}) = \frac{1}{1-\gamma} [C_{l,t}]^{1-\gamma} \quad (3.6)$$

where  $\gamma$  is the coefficient of relative risk aversion. Utility depends positively on consumption  $C_{l,t}$ . In this model, for simplicity, workers consume all their income, i.e. either the consumer wage in the case of employment or the unemployment benefit in the case of unemployment. For simplicity, it is assumed that there is no

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<sup>74</sup>The wage of the apprentice,  $w_v$ , is assumed to be set unilaterally by the firm.

disutility of labor. Under bargaining agreement, the employee receives the consumer wage  $\omega_l = w_l(1 - t_l) + \kappa$  in each period. The present value of the employee's expected lifetime utility in period  $t$ ,  $V_{l,t}^N$ , is:

$$V_{l,t}^N = \frac{1}{1 - \gamma} [w_{l,t} (1 - t_{l,t}) + \kappa]^{1-\gamma} + \delta E_t [(1 - \varphi_l - \rho - \tau_N) V_{l,t+1}^N + \varphi_l V_{l,t+1}^U + \tau_N V_{t+1}^T] \quad (3.7)$$

where  $\delta$  is the discount factor and  $V_{l,t+1}^U$  is the expected lifetime utility for an unemployed in period  $t + 1$ . (Here, as well as for other variables below, the superscript  $N$  stands for "employed" and the superscript  $U$  for "unemployed").  $V_{t+1}^T$  is the expected lifetime utility given that the person starts a vocational training. In the case of disagreement, the employee's fallback position is assumed to be equal to the unemployment benefit,  $b_{l,t}$ . It is assumed that disagreement in the current period does not affect the expected future lifetime utility. Thus, in the case of disagreement, the present value of the expected lifetime utility in period  $t$ ,  $V_{l,t}^{d,N}$ , is:

$$V_{l,t}^{d,N} = \frac{1}{1 - \gamma} [b_{l,t}]^{1-\gamma} + \delta E_t [(1 - \varphi_l - \rho - \tau_N) V_{l,t+1}^N + \varphi_l V_{l,t+1}^U + \tau_N V_{t+1}^T] \quad (3.8)$$

Given the expected present value in the case of agreement and disagreement, respectively, the bargaining surplus of the employee,  $S_{l,t}^E (= V_{l,t}^N - V_{l,t}^{d,N})$ , can be calculated:

$$S_{l,t}^E = \frac{1}{1 - \gamma} [w_{l,t} (1 - t_{l,t}) + \kappa]^{1-\gamma} - \frac{1}{1 - \gamma} [b_{l,t}]^{1-\gamma} \quad (3.9)$$

**Surplus of the Firm** Under bargaining agreement, the firm, which employs a low-skilled worker, receives the expected profit  $(a_l - w_{l,t})$  in each period  $t$ . The present value of the expected profits in time  $t$ ,  $\pi_{l,t}$ , is:

$$\pi_{l,t} = (a_l - w_{l,t}) + \delta E_t (1 - \varphi_l - \rho - \tau_N) \pi_{l,t+1} + \delta \varphi_l (-\varsigma_{l,t+1}) \quad (3.10)$$

where  $\varsigma_l$  are the firing costs.<sup>75</sup> In the case of disagreement the employee imposes the maximal cost on the firm (e.g. by strike, work-to-rule, sabotage) short of inducing dismissal. The firm's fallback position is negative; it is approximated by the firing costs. Again, it is assumed that disagreement in the current period does not affect future profits. Thus, the present value of the expected profits in the case of

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<sup>75</sup>The way, in which the transition rate  $\tau_N$  is introduced into the calculation implies that the transition is linked to a change of the firm. A low-skilled worker, who decides to enter training, has to leave the firm. This is based on the assumption that there are two types of firms: (*i*) firms, which only employ low-skilled workers and (*ii*) firms, which are engaged in training and employ medium-skilled workers. This can be justified by the assumption that the firms are engaged in different sectors with different requirements with respect to human capital.

disagreement is:

$$\pi_{l,t}^d = -\varsigma_{l,t} + \delta E_t (1 - \varphi_l - \rho - \tau_N) \pi_{l,t+1} + \delta \varphi_l (-\varsigma_{l,t+1}) \quad (3.11)$$

Finally, the bargaining surplus of the firm,  $S_{l,t}^F (= \pi_{l,t} - \pi_{l,t}^d)$  can be calculated:

$$S_{l,t}^F = (a_{l,t} - w_{l,t}) + \varsigma_{l,t} \quad (3.12)$$

**Nash Bargaining** The negotiated wage  $w_{l,t}$  maximizes the Nash product,  $\Lambda_{l,t}$ , which is given by:

$$\Lambda_{l,t} = (S_{l,t}^E)^\mu (S_{l,t}^F)^{1-\mu} \quad (3.13)$$

where  $\mu \in \langle 0, 1 \rangle$  denotes the bargaining power of the employee and  $1 - \mu$  represents the bargaining power of the firm.

To determine the wage, the following equation has to be solved:

$$\frac{\partial \Lambda_{l,t}}{\partial w_{l,t}} \stackrel{!}{=} 0$$

The result is:

$$(1-t_l) (a_l - w_l + \varsigma_l) (w_l - t_l w_l + \kappa)^{-1+\xi} \mu \xi = (1-\mu) (-b_l^\xi + (w_l - t_l w_l + \kappa)^\xi) \quad (3.14)$$

with  $\xi = (1 - \gamma)$ . In the steady state, (i) the firing costs are given by  $\varsigma_l = c_\varphi w_l$ , (ii) the low-wage subsidy is given by  $\kappa = \sigma w_l$  and (iii) the unemployment benefit level is defined on the basis of the economy-wide average net wage for this skill level:  $b_l = \beta_l w_l (1 - t_l + \sigma)$ . Finally, the negotiated wage is:

$$w_l = a_l (1-t_l) \mu \xi / \left[ \begin{array}{l} 1 - t_l (1 - \beta_l^\xi (1 - \mu) - \mu (1 - \xi + c_\varphi \xi)) \\ + \sigma - \beta_l^\xi (1 - \mu)(1 + \sigma) - \mu (1 - (1 - c_\varphi)\beta_l^\xi + \sigma) \end{array} \right] \quad (3.15)$$

It can be shown that:  $\frac{\partial w_l}{\partial \sigma} < 0$ , i.e. an increasing low-wage subsidy rate reduces the producer wage of the low-skilled.

Concerning medium-skilled and high-skilled employment, respectively, the wage is calculated in the same way, but with one exception:  $\kappa = 0 = \sigma$ . Hence, the wage is given by:

$$w_i = \frac{a_i \mu (1 - \gamma)}{(1 - \beta_i^{1-\gamma}) (1 - \mu) + \mu (1 - \gamma) (1 - c_\varphi)} \text{ for } i = m, h \quad (3.16)$$



### 3.3.5 Transition Rates

Having analyzed the impact of LWS on the wage,  $w_l$ , next, the relevant transition rates are derived, i.e. the hiring rate and the firing rate concerning low-skilled employment,  $\eta_l$  and  $\varphi_l$ , respectively, as well as the training rate,  $\tau_S$ .<sup>76</sup> They are influenced by the implementation of LWS.

**Hiring and Firing Rates** According to eq. (3.15), LWS reduce the producer wage and thereby have a positive impact on the firing and the hiring rate, respectively. In a first step, consider the present value of the expected profits in period  $t$ , generated by a low-skilled employee:

$$\begin{aligned} \pi_{l,t} = & -\epsilon_{k,t} + (a_l - w_l) \sum_{j=0}^{\infty} \delta^j (1 - \varphi_l - \rho - \tau_N)^j \\ & - \delta \varphi_l \varsigma_l \sum_{j=0}^{\infty} \delta^j (1 - \varphi_l - \rho - \tau_N)^j \end{aligned}$$

with  $k = \eta_l, \varphi_l$  (3.17)

Recall that the hiring and firing decision, respectively, is made after the random cost,  $\epsilon_{k,t}$ , is revealed. The random cost can be interpreted as an operating cost or a productivity shock. Its mean is normalized to zero and its cumulative distribution  $\Gamma_k(\epsilon_{k,t})$ , with  $k = \eta_l, \varphi_l$ , is time-invariant. After rewriting eq. (3.17), the profit is given by:

$$\pi_{l,t} = -\epsilon_{k,t} + \frac{(a_l - w_l) - \delta \varphi_l c_\varphi w_l}{1 - \delta(1 - \varphi_l - \rho - \tau_N)} \quad \text{with } k = \eta_l, \varphi_l \quad (3.18)$$

For a given hiring cost per worker,  $\chi_l$ , an unemployed is hired whenever  $\pi_l > \chi_l$ . After substituting  $\pi_l$  according to eq. (3.18), and taking into account that  $\chi_l = c_\eta w_l$ , the hiring rate is given by:<sup>77</sup>

$$\eta_l = \Gamma_{\eta_l} \left( \frac{(a_l - w_l) - \delta \varphi_l c_\varphi w_l}{1 - \delta(1 - \varphi_l - \rho - \tau_N)} - c_\eta w_l \right) \quad (3.19)$$

For a given firing cost per worker,  $\varsigma_l$ , an employee is fired whenever  $\pi_l < -\varsigma_l$ . After substituting  $\pi_l$  according to eq. (3.18), and taking into account that  $\varsigma_l = c_\varphi w_l$ , the

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<sup>76</sup>In the following, the transition rates  $\tau_N$  and  $\tau_U$  are treated as constants. Thus, these rates are assumed to be not affected by the low-wage subsidies. As  $\tau_N$  and  $\tau_U$  are small compared to  $\tau_S$ , the quantitative impact is low. However, taking this impact into account, would significantly increase the complexity of the model.

<sup>77</sup>See Appendix 7.2.1 for a derivation of the hiring rate.

firing rate is given by:<sup>78</sup>

$$\varphi_l = 1 - \Gamma_{\varphi_l} \left( \frac{(a_l - w_l) - \delta \varphi_l c_\varphi w_l}{1 - \delta(1 - \varphi_l - \rho - \tau_N)} + c_\varphi w_l \right) \quad (3.20)$$

**Training Rate** The training rate,  $\tau_S$ , quantifies the transition from school,  $S$ , to training,  $T$ . It is modeled as a function of the difference between the expected lifetime utility of being low-skilled and the expected lifetime utility of being medium-skilled. Therefore, the relevant utility equations are described and then, the training rate,  $\tau_S$ , is derived.

Each person being in stage  $S$  has to decide whether to enter training or whether to remain low-skilled. In the first case, the person will be hired as a medium-skilled employee with a probability,  $\eta_{T,N_m}$ , after having finished vocational training successfully. In the second case, the person will be hired as a low-skilled employee with a probability  $\eta_l$  immediately.

Each worker maximizes the expected lifetime utility,  $V$ , given the wages as well as the hiring and firing rates when being low-skilled or medium-skilled, respectively. The notations for the utilities in the different states are listed in Table 3.2.

expected lifetime utility of a ...	variable
low-skilled employee	$V_l^N$
low-skilled unemployed person	$V_l^U$
medium-skilled employee	$V_m^N$
medium-skilled unemployed person	$V_m^U$
person entering training	$V^T$

Table 3.2: The Expected Lifetime Utility in the Different States

The expected lifetime utility of remaining low-skilled is:

$$V_{l,t} = \eta_l V_{l,t}^N + (1 - \eta_l) V_{l,t}^U \quad (3.21)$$

A person, who decides to enter the low-skilled labor market, will be hired with probability  $\eta_l$ . In this case, the expected lifetime utility is given by  $V_{l,t}^N$ :<sup>79</sup>

$$V_{l,t}^N = \frac{1}{1 - \gamma} (\omega_l)^{1-\gamma} + \delta E_t [(1 - \varphi_l - \rho) V_{l,t+1}^N + \varphi_l V_{l,t+1}^U] \quad (3.22)$$

<sup>78</sup>See Appendix 7.2.2 for a derivation of the firing rate.

<sup>79</sup>In the following, it is – in contrast to eq. (3.7) – not taken into account that also a low-skilled person can decide to enter training (which is illustrated by the rate  $\tau_N$  for the low-skilled employed and by the rate  $\tau_U$  for the low-skilled unemployed). This is justified by the idea that the decision-making in state  $S$  is the motivation of this calculation. A person being in state  $S$  is assumed to not take into account the possibility to enter training at a later point in time. Moreover, addressing also this effect would significantly increase the complexity of the model.

With a probability  $(1 - \eta_l)$ , the person will be unemployed and will realize an expected lifetime utility  $V_{l,t}^U$ , which is given by:

$$V_{l,t}^U = \frac{1}{1 - \gamma} (b_l)^{1-\gamma} + \delta E_t [(1 - \eta_l - \rho) V_{l,t+1}^U + \eta_l V_{l,t+1}^N] \quad (3.23)$$

In the steady state,  $V_{l,t}^N = V_{l,t+1}^N$  and  $V_{l,t}^U = V_{l,t+1}^U$ . By substituting  $V_{l,t}^N$  and  $V_{l,t}^U$  in eq. (3.21) by the corresponding eq. (3.22) and eq. (3.23), respectively, the steady state expression for the expected lifetime utility of remaining low-skilled is obtained:

$$V_l = \frac{b_l^\xi (1 - \eta_l - \delta ((1 - \eta_l) (1 - \rho) - \varphi_l)) + \eta_l (1 + \delta \rho) \omega_l^\xi}{\xi (1 - \delta (1 - \rho)) (1 - \delta (1 - \eta_l - \rho - \varphi_l))} \quad \text{with: } \xi = 1 - \gamma \quad (3.24)$$

A person, who decides to enter training, realizes the following expected lifetime utility in the steady state:

$$\begin{aligned} V^T &= \frac{1}{1 - \gamma} (w_v)^{1-\gamma} \sum_{c=1}^p \delta^{c-1} (1 - \rho - \theta)^{c-1} \\ &+ \theta \delta [\eta_l V_l^N + (1 - \eta_l) V_l^U] \sum_{c=1}^p \delta^{c-1} (1 - \rho - \theta)^{c-1} \\ &+ \delta^p (1 - \rho - \theta)^p [\eta_{T,Nm} V_m^N + (1 - \eta_{T,Nm}) V_m^U] \end{aligned} \quad (3.25)$$

The expression in the first row on the right-hand side illustrates the utility generated by the income in the phase of vocational training. The second row shows the utility generated by the expected income in the case of dropping out of training. Finally, the third row illustrates the utility generated by the expected income in the case of being a medium-skilled person after having finished training successfully.

People are assumed to face a disutility of training,  $e$ , i.e. some people e.g. face high mobility costs if the place of training is far away from home.<sup>80</sup> People are assumed to be heterogeneous in terms of their disutility of training. A person in  $S$  only decides to enter training, if

$$V^T - e \geq V_l \quad (3.26)$$

By substituting  $V^T$  and  $V_l$  by the expressions given in eq. (3.25) and eq. (3.24), respectively, an equation for  $e^* = V^T - V_l$ , is obtained, where  $e^*$  represents the costs of the marginal worker, i.e. the costs of the worker who is indifferent between entering training and remaining low-skilled. Only people with  $e < e^*$  decide to enter training. As the fraction of the people in  $S$ , who enter training (i.e. the training rate  $\tau_S$ ), is of special interest, the relationship between  $e^*$  and  $\tau_S$  has to be modeled.

<sup>80</sup>Here, it is assumed that disutility of training is only caused by the individual's intrinsic costs.

The higher the marginal costs,  $e^*$ , the higher is  $\tau_S$ . The workers are ordered in terms of their individual disutility  $e$ , from the lowest to the highest. The training rate,  $\tau_S$ , is given by the following function:  $\tau_S(e^*)$ , with  $(\partial\tau_S/\partial e^*) > 0$ . For simplicity, it is assumed that  $\tau_S = x (e^*)^\alpha$  with  $x, \alpha > 0$ , where  $\alpha$  denotes the elasticity of the training rate with respect to the utility difference. Finally, the training rate,  $\tau_S$ , is given by:

$$\tau_S = x (V^T - V_l)^\alpha \quad (3.27)$$

The intuition is straightforward. The implementation of LWS, with a rate  $\sigma$ , increases the consumer wage of the low-skilled worker,  $\omega_l$ . According to eq. (3.24), the expected utility in the case of remaining low-skilled,  $V_l$ , increases. So, the value on the right-hand side in eq. (3.27) and finally  $\tau_S$  declines. The higher the expected utility being associated with remaining low-skilled, the lower is the disutility of training of the marginal worker (i.e. the disutility for which  $V^T - e^* = V_l$ ) for a given value of  $V^T$ . Thus, the fraction of people for which entering training is still profitable declines and  $\tau_S$  decreases.

It may be possible that varying the difference in utility ( $V^T - V_l$ ) does not cause a linear reduction in the training rate. Therefore, a parameter  $\alpha$  is introduced, which is the elasticity of the training rate  $\tau_S$  with respect to the difference ( $V^T - V_l$ ). The lower  $\alpha$ , the lower is the reduction in  $\tau_S$  for a given variation of ( $V^T - V_l$ ).

### 3.3.6 Labor Market Equilibrium

The following system of equations constitutes the labor market equilibrium:

- the steady state expressions of the six dynamic equations given by the transition matrix (3.3),<sup>81</sup>
- the government budget constraint: eq. (3.5),<sup>82</sup>
- the equation for the wage of the low-skilled  $w_l$ : eq. (3.15),
- the equation determining the transition rate  $\tau_S$ : eq. (3.27), and finally
- the equations determining the hiring rate  $\eta_l$  and the firing rate  $\varphi_l$ : eq. (3.19) and eq. (3.20), respectively.

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<sup>81</sup>Recall that the total number of people being in training is given by  $T = T_1 \sum_{c=1}^p (1 - \rho - \theta)^{c-1}$ . Moreover, the relevant population is normalized to 1:  $S + T + N_l + U_l + N_m + U_m = 1$ .

<sup>82</sup>As the equation, which describes the government budget constraint contains three tax rates, it is necessary to introduce two additional equations in order to close the model. They describe the ratios between the tax rates,  $t_h$ ,  $t_m$  and  $t_l$ .

## 3.4 Numerical Evaluation

### 3.4.1 Calibration

In the initial steady state (i.e. in the absence of LWS), some variables are treated as exogenous, but in the presence of subsidies, they are treated as endogenous. One example is the training rate  $\tau_S$ . In the initial steady state, the training rate is treated as an exogenous variable so that the necessary parameter of the corresponding distribution for the random costs can be derived. However, in the presence of subsidies, the parameter will be treated as given and the training rate will be a function of the subsidies.

The model is calibrated for Germany with a year as unit of time (see Table 3.3 for a summary of the calibration). The real annual interest rate is set at 4.0%, which leads to a discount factor of  $\delta = 0.962$ . For simplicity, the coefficient of relative risk aversion (CRRA) is set at  $\gamma = 0$ .<sup>83</sup> The death rate is set at 0.023, which corresponds to an average working lifetime of about 44 years.<sup>84</sup> The number of periods,  $p$ , a person is engaged in vocational training is set at 3.<sup>85</sup> The drop-out rate,  $\theta$ , is set at 0.037. The value of the death rate and the value of the drop-out rate imply that roughly 17% of the apprentices do not finish vocational training successfully, which is in line with the empirical data.<sup>86</sup> According to Wilke's Kaplan-Meier functions for Germany (Wilke, 2005), the hiring rates for the high-skilled, the medium-skilled and the low-skilled are set at  $\eta_h = 0.55$ ,  $\eta_m = 0.59$  and  $\eta_l = 0.49$ . Moreover, according to the BMBF (2004, 2007) about 25% of the people who have successfully finished vocational training become unemployed, thus the corresponding hiring rate,  $\eta_{T,N_m}$  is set at 0.75.

The labor market states are defined and quantified as follows. The low-skilled labor force ( $N_l + U_l$ ) includes people with an educational attainment corresponding to less than upper-secondary education.<sup>87</sup> The medium-skilled labor force ( $N_m + U_m$ ) contains all people with vocational upper secondary education. People with post-secondary and tertiary education are considered as being high-skilled ( $N_h + U_h$ ). The corresponding values can be calculated on the basis of data from the OECD

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<sup>83</sup>This value implies risk neutrality.

<sup>84</sup>The value is roughly in line with the empirical data. Working life begins at the age of 17 and according to Brussig and Wojtkowski (2006), retirement takes places between 62 and 63 years.

<sup>85</sup>This corresponds to the typical length of training within the dual system in Germany.

<sup>86</sup>Given the data for the number of new apprentices and the number of successful apprentices (Statistisches Bundesamt, 2006), the value can be confirmed.

<sup>87</sup>This classification corresponds to the conventional definition, which classifies people with an educational attainment corresponding to at most level 2 of the International Standard Classification of Education as low-skilled.

(1999 to 2005).<sup>88</sup>

Based on data from the German national accounts, the aggregate productivity,  $a$ , is set at 54,243 EUR and the aggregate producer wage,  $w$ , which is calculated as average gross wage per employee plus social security contributions, is set at 32,520 EUR.<sup>89</sup> In order to get the wages for the different skill groups, the corresponding OECD indices for the relative earnings of the population with income from employment for different skill groups are used. They yield the following ratios:  $w_h/w = 1.27$ ,  $w_m/w = 0.92$  and  $w_l/w = 0.72$ .<sup>90</sup> According to Beicht and Walden (2002), the wage of a person being engaged in vocational training is set at  $w_v = 8,269$  EUR and the productivity of an apprentice is set at  $a_v = 7,730$  EUR. Moreover, according to Beicht and Walden (2002) the annual, non-wage costs of training are 8,166 EUR. As 30% (see Dohmen and Hoi, 2004) are tax-deductible, the relevant costs are set at  $k_v = 5,717$  EUR.

The net replacement rates are set at  $\beta_l = 0.7825$ ,  $\beta_m = 0.6825$  and  $\beta_h = 0.6467$ .<sup>91</sup> According to Chen and Funke (2005), the hiring cost is set at 10% of the wage and the firing cost is set at 60% of the wage, thus the corresponding parameters are  $c_\eta = 0.1$  and  $c_\varphi = 0.6$ . In order to calculate the tax rates, the income tax scale of the year 2002, described in Boss and Elendner (2003), is used. It illustrates the progressive character of the German tax system. The following ratios are obtained:  $t_h/t_l = 1.437$  and  $t_m/t_l = 1.178$ . Given the data for the transition rates between the training system and the labor market according to Reinberg and Hummel (2006), the training rate,  $\tau_S = 0.70$ , and the ratio  $\tau_U/\tau_N = 3.6$ , can be calculated.

Based on these values and the equations of the model, also the bargaining power, the productivities for the different skill levels, the tax rates and the missing transition rates for the initial steady state can be calculated. Then,  $V^T$  can be determined according to eq. (3.25),  $V_l$  according to eq. (3.24) and finally  $e^* = V^T - V_l$  for the initial state state. Setting the training elasticity  $\alpha = 1$  and given the initial values for  $e^*$  and  $\tau_S$ , it is possible to calculate the value of the parameter  $x$ . It is independent of the level of subsidies and thus remains constant.

Finally, the values of the first derivative of the cumulative density functions in the model,  $\Gamma'_{\eta_l}$  and  $\Gamma'_{\varphi_l}$ , are calculated. They determine the elasticity of the hiring and firing rate, respectively, with respect to the wage of the low-skilled. In this

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<sup>88</sup>See Appendix 7.2.3.

<sup>89</sup>Statistisches Bundesamt (2008). The values are calculated as the averages of the corresponding annual data for the period 2000 - 2007.

<sup>90</sup>See OECD (1999-2005). These values imply a ratio  $w_m/w_l = 1.26$ , which is in line with the corresponding data reported by Wienert (2006).

<sup>91</sup>The values are net replacement rates (unweighted average across six family types) of workers with 67, 100 and 150 percent of average productivity, see OECD (2006).

variable / parameter	description	value	source
$\delta$	discount factor	0.962	standard value
$\gamma$	CRRA	0.0	assumption
$p$	periods of vocational training	3	standard value for Germany
$\rho$	death rate	0.023	to match the working life
$\theta$	drop-out rate of training	0.037	to match the empirical data
$\eta_h$	hiring rate (high-skilled)	0.55	Wilke (2005)
$\eta_m$	hiring rate (medium-skilled)	0.59	
$\eta_l$	hiring rate (low-skilled)	0.49	
$\eta_{T,N_m}$	hiring rate after training	0.75	BMBF (2004, 2007)
$\tau_S$	training rate	0.70	own calculations based on Reinberg and Hummel (2006)
$\tau_U / \tau_N$	ratio of transition rates	3.6	
$a$	aggregate productivity	54,243	Statistisches Bundesamt (2008)
$w$	aggregate producer wage	32,520	
$w_h/w$	relative earnings (high-skilled)	1.27	OECD (1999-2005)
$w_m/w$	relative earnings (medium-skilled)	0.92	
$w_l/w$	relative earnings (low-skilled)	0.72	
$a_v$	productivity of an apprentice	7,730	Beicht and Walden (2002)
$w_v$	wage of an apprentice	8,269	
$k_v$	non-wage costs of training	5,717	Beicht and Walden (2002), Dohmen and Hoi (2004)
$\beta_h$	replacement rate (high-skilled)	0.6467	OECD (2006)
$\beta_m$	replacement rate (medium-skilled)	0.6825	
$\beta_l$	replacement rate (low-skilled)	0.7825	
$c_\eta$	hiring cost in relation to the wage	0.1	Chen and Funke (2005)
$c_\varphi$	firing cost in relation to the wage	0.6	
$t_h / t_l$	ratio of tax rates (1)	1.437	Boss and Elendner (2003)
$t_m / t_l$	ratio of tax rates (2)	1.178	
$\alpha$	elasticity of the training rate	1	assumption

Table 3.3: Exogenous Values in the Initial Steady State

context, the model is linearized around the initial steady state,<sup>92</sup> and the long-run effect of the wage reduction, as permanent deviation from the initial steady state, is calculated. The wage reduction corresponds to the implementation of LWS and illustrates the new steady state. For this purpose, empirical estimates summarized in Orszag and Snower (1999b) are used. The first derivative of the cumulative function for the hiring rate,  $\Gamma'_{\eta_l,0}$ , is set in such a way that the hiring elasticity with respect to the wage,  $ela(\eta_l)$ , is equal to  $-2.25$ .<sup>93</sup> Also in line with the aforementioned literature, the first derivative of the cumulative density function with respect to the firing rate,  $\Gamma'_{\varphi_l,0}$ , is set in such a way that the firing elasticity with respect to the wage,  $ela(\varphi_l)$ , is 1. The derived values are summarized in Table 3.4.

variable / parameter	description	value	basis of calculation
$U_l$	low-skilled unemployment	0.034	see Appendix 7.2.3
$N_l$	low-skilled employment	0.150	
$U_m$	medium-skilled unemployment	0.067	
$N_m$	medium-skilled employment	0.670	
$T$	people in vocational training	0.057	
$S$	people in school	0.022	
$\mu$	bargaining power	0.200	eq. (3.16)
$a_h$	productivity (high-skilled)	75,877	for $i = l, m, h$
$a_m$	productivity (medium-skilled)	50,621	and $a =$
$a_l$	productivity (low-skilled)	30,364	$\frac{a_l N_l + a_m N_m + a_h N_h + a_v T}{N_l + N_m + N_h + T}$
$t_h$	tax rate (high-skilled)	0.070	ratios of tax rates
$t_m$	tax rate (medium-skilled)	0.057	and eq. (3.5)
$t_l$	tax rate (low-skilled)	0.049	with $\sigma = 0$
$\varphi_m$	firing rate (medium-skilled)	0.055	see Appendix 7.2.3
$\varphi_l$	firing rate (low-skilled)	0.094	3rd and 4th eq.
$\tau_U$	training rate (low-skilled unempl.)	0.061	of matrix $MT$ and
$\tau_N$	training rate (low-skilled empl.)	0.017	and ratio of the
$x$	parameter of the $\tau_S$ - function	$2.03 * 10^{-5}$	transition rates
$\Gamma'_{\eta_l,0}$	1 <sup>st</sup> derivative of the cumulative density function (hiring rate)	$6.24 * 10^{-6}$	$x = \frac{\tau_S}{(e^*)^\alpha}$
$\Gamma'_{\varphi_l,0}$	1 <sup>st</sup> derivative of the cumulative density function (firing rate)	$5.85 * 10^{-7}$	eq. (A2.1.2a)
			eq. (A2.2.2a)

Table 3.4: Derived Values in the Initial Steady State

The calibration implies that the employment rate of the low-skilled labor force is  $er_l = 0.815$  and that the employment rate of the medium-skilled labor force is

<sup>92</sup>See Appendix 7.2.1 for the hiring rate and Appendix 7.2.2 for the firing rate.

<sup>93</sup>According to Orszag and Snower (1999b), the elasticity of the hiring rate with respect to a permanent change in wage ranges between  $-4.0$  and  $-0.5$ .



$er_m = 0.910$ . In the following simulations the employment rate of the low-skilled will increase significantly but will not exceed  $er_m = 0.910$ .

### 3.4.2 Numerical Results

Next, the impact of LWS on skill formation, employment and welfare is analyzed in detail. Concerning the hiring rate and the firing rate, the linearized versions of the corresponding equations are used.<sup>94</sup>

**Impact on Skill Formation and Employment** Figure 3.2 illustrates the impact of the LWS on employment for different subsidy rates,  $\sigma$  (benchmark simulation). Recall that the relevant population ( $N_l + U_l + N_m + U_m + T + S$ ) is normalized to 1. As expected, low-skilled employment rises with an increasing subsidy rate,  $\sigma$ .

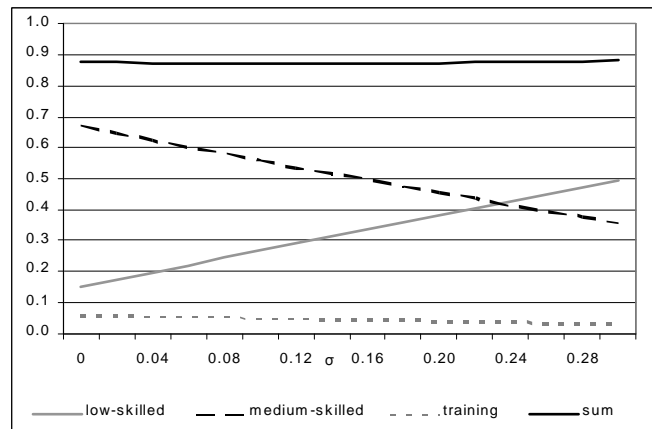


Figure 3.2: Employment as a Function of  $\sigma$

However, medium-skilled employment decreases simultaneously. The introduction of LWS reduces the difference between the relevant consumer wages as  $\omega_l$  increases and  $\omega_m$  decreases. Thus, the incentive to enter training and thereby the transition rate,  $\tau_S$ , decreases. As a consequence of the skill-acquisition effect, the medium-skilled labor force and finally medium-skilled employment decreases significantly. However, the low-skilled labor force increases strongly. Moreover, also the demand for low-skilled labor increases, as the introduction of the LWS increases the hiring rate,  $\eta_l$ , and reduces the firing rate,  $\varphi_l$ . Altogether, the effect on aggregate employment is imperceptible.<sup>95</sup>

<sup>94</sup>See Appendix 7.2.1 and Appendix 7.2.2.

<sup>95</sup>In the graph, the sum only contains low-skilled and medium-skilled employment as well as people being in training. To get total employment, high-skilled employment has to be added. However, this component is assumed to be constant, so the dynamics do not change.

### Efficiency of the Subsidies

When analyzing the impact of LWS, the impact on the tax rates is important to know. In this context, there are two opposing effects of LWS. On the one hand, the implementation of LWS increases the expenditures of the government and therefore requires higher tax rates, given the government budget constraint. However, on the other hand, it has to be taken into account that LWS also reduce the number of unemployed people and so the number of people requiring unemployment benefits. Hence, the tax rates may decrease if the reduction in the payment of unemployment benefits is higher than the expenditures for LWS. The numerical analysis reveals that the expenditures for unemployment benefits decrease when LWS are implemented. However the reduction is not sufficient to compensate the expenditures for LWS. Thus, LWS are not self-financing and their implementation raises the tax rates. The missing self-financing of LWS can be explained by two factors.

First, there is a deadweight effect (DW), which is defined as follows:<sup>96</sup>

$$DW = 1 - \frac{\text{additional employment}}{\text{subsidized employment}}$$

The implementation of low-skilled subsidies causes a high deadweight effect. The reason is that in the absence of LWS, a high fraction of the low-skilled labor force ( $er_l = 0.815$ ) is already employed, which however also gets LWS.

Second, there is the wage effect. LWS can contribute to a reduction of unemployment if they cause a reduction in the producer wage, which would increase the hiring incentives. However, in the wage bargaining process, the firms are able to reap only a part of the additional surplus caused by the subsidies. So the decline of the producer wage (in absolute terms) is lower than the amount of the subsidy. Hence, the increase in low-skilled employment is lower than it could be. The wage effect not only reduces the positive impact of subsidies on the demand side. It also affects the supply side, as LWS reduce the incentive to become medium-skilled and therefore reduce skilled employment. Thus, the increase in low-skilled employment has to be adjusted by the decline in medium-skilled employment. This is done by calculating the additional aggregate employment. In this case the deadweight effect is roughly 94% (for  $\sigma = 0.3$ ). When taking only the additional low-skilled employment into account, the deadweight effect is only 31%.

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<sup>96</sup>If the implementation of subsidies does not create additional employment, i.e. subsidies are only paid to people who would have been employed also in the absence of subsidies, then there is only deadweight (i.e.  $DW = 1$ ). If the implementation of subsidies causes an increase in employment that is equal to the number of subsidized persons, only persons get subsidies who would not have been employed in the absence of subsidies (i.e.  $DW = 0$ ).

## Robustness of the Results

In the benchmark simulation, the results are based on the exogenously given values for the coefficient of relative risk aversion,  $\gamma = 0$ , the elasticity of the hiring rate,  $ela(\eta_l) = -2.25$ , and the elasticity of the training rate,  $\alpha = 1$ . The robustness of the simulation results is checked by modifying these parameter values. In all cases, the subsidy rate is set at  $\sigma = 0.1$ .

For the elasticity of the hiring rate, Orszag and Snower (1999b) report a range,  $-4 \leq ela(\eta_l) \leq -0.5$ . Therefore, the impact of LWS on employment is calculated for these boundary values (see Table 3.5).

$ela(\eta_l)$	transition rates			employment rate	employment			
	$\eta_l$	$\varphi_l$	$\tau_S$	$er_l$	$N_l$	$T$	$N_m$	$sum$
-0.5	0.5068	0.0873	0.4576	0.8290	0.2442	0.0493	0.5763	0.8698
-2.25	0.5655	0.0873	0.4283	0.8469	0.2647	0.0480	0.5611	0.8738
-4	0.6242	0.0873	0.4037	0.8620	0.2829	0.0469	0.5479	0.8777

Table 3.5: Robustness Check with Respect to the Hiring Elasticity

The higher  $ela(\eta_l)$  in absolute terms, the higher is the hiring rate  $\eta_l$ . The positive impact on the demand for low-skilled labor is illustrated by the employment rate  $er_l$ .<sup>97</sup> Moreover, the increase in the hiring rate also increases the expected lifetime utility in the case of remaining low-skilled relative to the expected lifetime utility in the case of being trained. Thus, the training rate,  $\tau_S$ , decreases with an – in absolute terms – increasing hiring elasticity. Therefore the low-skilled labor force increases. Finally, the higher  $ela(\eta_l)$ , the higher is the low-skilled employment and the lower is the medium-skilled employment. The robustness check reveals that the positive *direct employment effect* is strengthened relative to the other effects. So, a higher  $ela(\eta_l)$  increases aggregate employment.

With respect to risk aversion, a second value,  $\gamma = 0.5$ , is assumed, which implies risk aversion instead of risk neutrality. First, in the case of risk aversion, the relative

$\gamma$	transition rates			employment rate	employment			
	$\eta_l$	$\varphi_l$	$\tau_S$	$er_l$	$N_l$	$T$	$N_m$	$sum$
0	0.5655	0.0873	0.4283	0.8469	0.2647	0.0480	0.5611	0.8738
0.5	0.5651	0.0873	0.2743	0.8467	0.3239	0.0430	0.5021	0.8690

Table 3.6: Robustness Check with Respect to the Degree of Risk Aversion

difference between the expected lifetime utility being associated with remaining low-

<sup>97</sup>Recall that in absence of LWS the employment rate of the low-skilled labor force is 0.815.

skilled,  $V_l$ , and the expected lifetime utility being associated with being medium-skilled,  $V^T$ , is lower than in the benchmark simulation. Risk aversion reinforces the negative impact of LWS on the transition rate  $\tau_S$  (see Table 3.6). Hence, low-skilled employment increases, training as well as medium-skilled employment decrease more strongly compared to the benchmark simulation. However, total employment is relatively robust.

Finally, a robustness check with respect to the elasticity of the training rate,  $\alpha$ , is conducted. According to eq. (3.27),  $\alpha$  determines to which extent a variation of the utility difference ( $V^T - V_l$ ) is translated into a variation of the training rate  $\tau_S$ . A lower elasticity of the training rate,  $\alpha$ , reduces the impact of a given low-wage subsidy on the training rate and thereby the skill-acquisition effect. The effect of the LWS on employment, given two different values of  $\alpha$ , is shown in Table 3.7.

$\alpha$	transition rates			employment rate	employment			
	$\eta_l$	$\varphi_l$	$\tau_S$	$er_l$	$N_l$	$T$	$N_m$	$sum$
1	0.5655	0.0873	0.4283	0.8469	0.2647	0.0480	0.5611	0.8738
0.5	0.5652	0.0873	0.5515	0.8468	0.2173	0.0520	0.6083	0.8777

Table 3.7: Robustness Check with Respect to Training Elasticity

LWS raise low-skilled employment and reduce medium-skilled employment. For  $\alpha = 0.5$ , both movements are significantly weaker than in the benchmark simulation ( $\alpha = 1$ ). However, aggregate employment is again quite robust.

Summing up, the introduction of LWS, low-skilled employment increases and medium-skilled employment decreases. The size of the positive direct employment effect (illustrated by the impact on the employment rate,  $er_l$ ) depends in particular on the elasticity of the hiring rate. The size of the negative skill-acquisition effect (illustrated by the impact on the training rate,  $\tau_S$ ) depends on the elasticity of the hiring rate, the degree of risk aversion and the elasticity of the training rate.

### Impact on Aggregate Employment over Different Channels

In the following the relative strengths of the different channels, through which LWS affect aggregate employment, are analyzed in detail. This is done by conducting the same calculation as in the previous section; however, in each calculation, one effect is suppressed.

In the following it has to be taken into account that the different channels do overlap, as there are several interactions between the channels, i.e. the employment effect has a strong impact on the skill-acquisition effect because a variation of the hiring and firing rate also influences the expected lifetime utility of a low-skilled

and thereby affects the decision of people being in state  $S$  whether to remain low-skilled. Moreover, the government budget constraint can be regarded as part of the skill-acquisition effect. Finally, due to the overlapping, the cumulative effect of the different channels is not equal to the total effect. Figure 3.3 shows aggregate

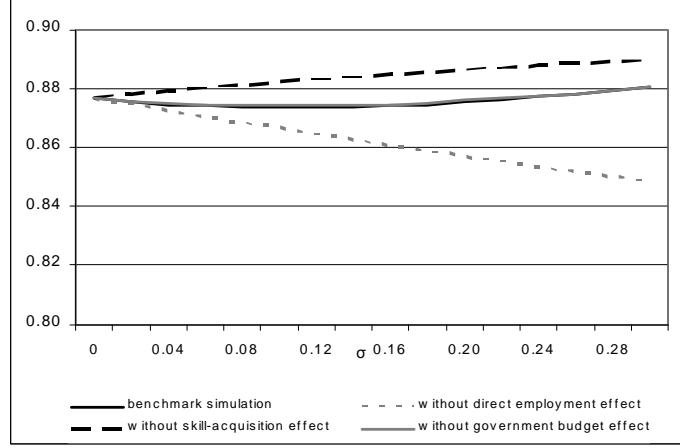


Figure 3.3: Employment as Function of  $\sigma$  in the Absence of Different Effects

employment as a function of LWS for four different types of modeling. The black line corresponds to the black line in Figure 3.2 and serves as a benchmark. In addition, three modifications are considered. In order to explain the results, it is also helpful to regard Table 3.8, which shows the results for  $\sigma = 0.2$ .

parameter	benchmark simulation	without direct employment effect	without skill-acquisition effect	without government budget effect
$\eta_l$	0.634098	0.49000	0.630925	0.629565
$\varphi_l$	0.081433	0.09400	0.081703	0.081819
$er_l$	0.871053	0.814692	0.870024	0.869580
$t_m$	0.097542	0.097496	0.069558	0.069749
$\omega_m$	26924.7	26926.1	27759.6	27753.9
$\omega_l$	22890.2	22891.2	23454.4	23526.0
$\tau_S$	0.18429	0.27549	0.70000	0.23649
$w_l$	20489.0	20489.1	20556.8	20585.9
$N_m$	0.45972	0.51159	0.66184	0.48063
$N_l$	0.37695	0.30248	0.16810	0.35477
$T$	0.03933	0.04377	0.056626	0.041122
$N_m + N_l + T$	0.87601	0.85784	0.88656	0.87652

Table 3.8: Strengths of the Different Effects

For the analysis, it is useful to distinguish between the effects on the demand side and the effects on the supply side. The *direct employment effect* affects in

particular the demand for low-skilled labor. The effect is illustrated by a variation of the employment rate  $er_l$ . Recall that LWS reduce the producer wage according to eq. (3.15) and therefore affect the hiring rate,  $\eta_l$ , and the firing rate,  $\varphi_l$ , and finally the employment rate. The effect on the supply side is illustrated by a variation of the training rate,  $\tau_S$ , i.e. the fraction of people in state  $S$  who decide to become medium-skilled. Recall that the training rate,  $\tau_S$ , is a function of the difference between the expected lifetime utility being associated with becoming medium-skilled and the expected lifetime utility being associated with remaining low-skilled. The difference, again, is also a function of the consumer wages,  $\omega_m$  and  $\omega_l$ . Given this, two effects can be identified on the supply side. The difference between the consumer wages and ultimately the training rate is directly influenced by the subsidies (*skill-acquisition effect*) but also indirectly as the taxes have to be adjusted (*government budget effect*). As the subsidies influence unemployment and finally the number of people requiring unemployment benefits, the tax rates have to be adjusted due to the implementation of LWS. Finally, it has to be taken into account that also on the supply side, the *direct employment effect* is working, as the variation of the hiring rate,  $\eta_l$ , and the firing rate,  $\varphi_l$ , respectively, affects the expected lifetime utilities and ultimately the training rate,  $\tau_S$ .

In order to analyze and quantify the size of the different effects separately, one effect after the other is suppressed in the remainder. Comparing each result with the benchmark simulation allows us to quantify the size of each effect.

First, the *direct employment effect* is suppressed.<sup>98</sup> Compared to the benchmark simulation, the demand for low-skilled workers (illustrated by  $er_l$ ) is lower because the hiring rate,  $\eta_l$ , remains on the lower initial level (i.e. level in the absence of subsidies: 0.49) and the firing rate remains on the higher initial level. Moreover, the supply of low-killed labor is lower; as the training rate,  $\tau_S$ , does not decrease as much as in the benchmark simulation, the reduction in medium-skilled labor supply is lower. The second impact on the supply side is quantitatively negligible. Due to the absence of the direct employment effect, the unemployment and finally the number of people requiring unemployment benefits is higher. Therefore, the tax rates are supposed to be higher and the consumer wages,  $\omega_m$  and  $\omega_l$ , are supposed to be lower than in the benchmark simulation. However, here, this effect is almost nonexistent as the variations of tax rates and thereby of the consumer wages are roughly the same. In total, medium-skilled employment is higher and low-skilled employment is lower than in the benchmark simulation, aggregate employment is

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<sup>98</sup>Here, the hiring rate,  $\eta_l$ , and the firing rate,  $\varphi_l$ , are assumed to be unaffected by the presence of subsidies.

lower. The effect of LWS on aggregate employment in the absence of the direct employment effect is illustrated by the gray dashed line in Figure 3.3. Thus, the *direct employment effect* (i.e. the difference between the black and the gray dashed line), has a significantly positive effect on aggregate employment. Recall that the size of the effect is strongly influenced by the hiring elasticity.

In a second case, the *skill-acquisition effect* is suppressed.<sup>99</sup> Compared to the benchmark simulation, there is – with respect to the demand side – no perceptible difference, i.e. the employment rate of the low-skilled hardly changes. However, there is a crucial difference on the supply side. The training rate,  $\tau_S$ , remains on the higher initial level. Thus, the medium-skilled labor force is not reduced in favor of the low-skilled labor force. Given the same employment rates but a higher medium-skilled labor force as in the benchmark simulation, now, medium-skilled employment is higher and low-skilled employment is lower than in the benchmark simulation. As the labor force component with the higher employment rate has a higher weight than in the benchmark simulation, aggregate employment is higher than in the benchmark simulation. In other words, the *skill-acquisition effect*, if considered separately, has a significantly negative effect on aggregate employment (difference between black line and black dashed line in Figure 3.3). Recall that the size of the effect is influenced by the elasticity of the hiring rate, the degree of risk aversion and the elasticity of the training rate.

In a third case, the *government budget effect* is suppressed.<sup>100</sup> This effect can be regarded as a part of the skill-acquisition effect. When analyzing this effect, a direct and an indirect effect of LWS have to be taken into account. First, the implementation of LWS increases the expenditures of the government and therefore requires – on its own – higher tax rates. Second, it has to be taken into account that LWS may also reduce the number of unemployed people and so the number of people requiring unemployment benefits. If the reduction in the payment of unemployment benefits is higher than the expenditures for LWS, the tax rates can be reduced. However, the results reveal that the reduction in the expenditures for unemployment benefits is not sufficient to compensate the expenditures for LWS. Ultimately, the implementation of LWS causes an increase in the tax rates.

In the absence of the government budget constraint, the result with respect to the demand side (illustrated by the employment rate  $er_l$ ) hardly changes compared to the benchmark simulation. With respect to the supply side, there is a small variation. Due to the constant tax rates in the absence of the government budget

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<sup>99</sup>Here, the training rate,  $\tau_S$ , is assumed to be unaffected by low-wage subsidies. It remains constant.

<sup>100</sup>Here, the tax rates  $t_i$  (with  $i = l, m, h$ ) are assumed to be constant.

constraint, the fiscal burden for the employees does not increase with the implementation of subsidies. Due to the progressive tax system, the tax relief is higher for the medium-skilled employees than for the low-skilled employee. In the absence of the government budget constraint, the expected lifetime utility of the medium-skilled relative to the expected lifetime utility of the low-skilled is higher than in the benchmark simulation. Therefore the training rate,  $\tau_S$ , does not decrease as much as in the benchmark simulation. Finally, medium-skilled employment is higher and low-skilled employment is lower than in the benchmark simulation. Again, as in the previous simulation, the labor force component with the higher employment rate has a higher weight than in the benchmark simulation. Hence, aggregate employment is higher compared to the benchmark simulation. However, the effect is quite small, so that the result for aggregate employment (see the gray line in Figure 3.3) is almost the same as in the benchmark simulation, which is illustrated by the black line.

Figure 3.4 illustrates to which extent each effect contributes to the change of aggregate employment compared to the initial steady state (absence of subsidies). Recall that the effects do overlap, so the contributions of the different effects do not add up to the total effect (illustrated by the black line). The (positive) *direct employment effect* is the most important. However, the (negative) *skill-acquisition effect* is too significant to be ignored.

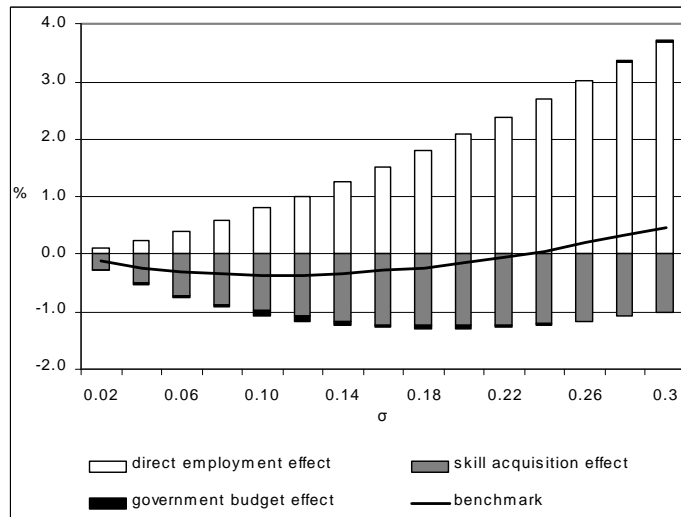


Figure 3.4: The Contribution of Each Effect on Employment for Different  $\sigma$

**Impact on Welfare** Next, the impact of LWS on welfare is analyzed. The impact on welfare is quantified by using the concept of "consumption equivalents",<sup>101</sup> i.e.

<sup>101</sup>This is a common concept in the literature. See, e.g. Conesa and Krueger (1999).



it is examined by how much an individual's consumption has to be adjusted in the initial steady state (i.e. in the absence of subsidies) so that the expected present value of utility is equal to the utility in the presence of subsidies. In the following, the variable  $\lambda$  denotes the consumption equivalent, i.e. it gives the change (in %) of consumption that makes utility in the new steady state equal to the utility in the initial steady state. For example,  $\lambda = 0.1$  implies that for a given level of LWS, a person in the population considered will experience an increase in welfare due to the subsidies, which is equivalent to a 10% higher consumption in the initial steady state. The welfare of the population,  $\Omega$ , is calculated as follows:

$$\Omega = \frac{1}{1-\gamma} [(1+\lambda) w_v]^{1-\gamma} T + \sum_{i=l,m,h} \frac{1}{1-\gamma} [(1+\lambda) \omega_i]^{1-\gamma} N_i + \frac{1}{1-\gamma} [(1+\lambda) b_i]^{1-\gamma} U_i \quad (3.28)$$

Figure 3.5 illustrates the results for different levels of LWS (given by  $\sigma$ ) and for  $\gamma = 0$  and  $\gamma = 0.5$ . The implementation of LWS reduces welfare; e.g. for  $\sigma = 0.3$ ,

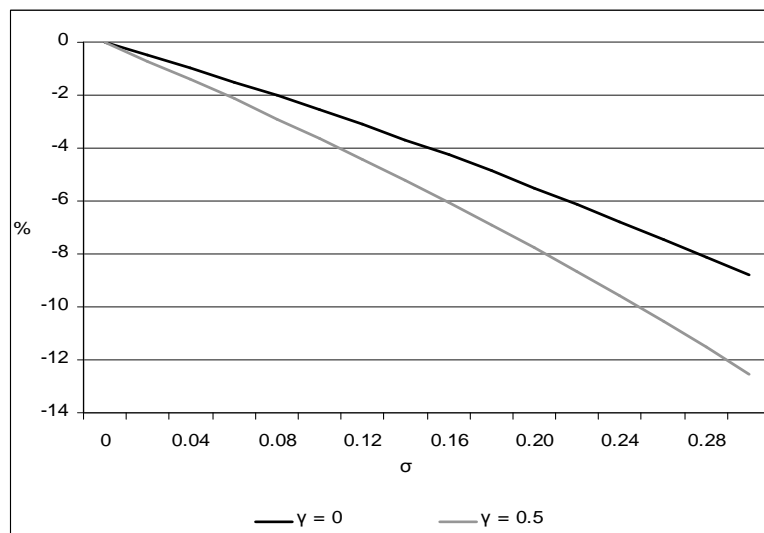


Figure 3.5: The Impact of LWS on Welfare for Different  $\gamma$

per capita consumption in the initial steady state has to be reduced by about 9% (for  $\gamma = 0$ ) to be equal to the per capita consumption in the new steady state (i.e. in the presence of the subsidies). In contrast to aggregate employment (see Figure 3.2) welfare declines significantly. This decline can be explained by the fact that the quality of employment decreases. As low-skilled employment increases and medium-skilled employment decreases, the average wage per person and finally, given an almost robust level of aggregate employment, welfare decreases.

### Robustness of the Results

The calculations also reveal that the negative impact of LWS on welfare increases with a higher degree of risk aversion,  $\gamma$ . In this context, two opposing effects have to be taken into account. First, as already mentioned, the higher the degree of risk aversion, the higher is the utility of remaining low-skilled relative to the utility of becoming medium-skilled. Therefore a higher risk aversion amplifies the negative impact of LWS on the training rate  $\tau_S$ . There are less people with a higher, medium-skilled income. Hence, this effect – on its own – reduces welfare. Second, there is an aggregation effect, which goes into the opposite direction. When calculating welfare according to eq. (3.28), a higher degree of risk aversion is equal to a relatively higher weight on low income. Due to the first effect, there are more people earning a low wage. Given a higher degree of risk aversion, the low wage is translated into a relatively higher utility compared to the utility being generated by a medium-skilled wage. Hence, the aggregation effect – on its own – increases welfare. In total, the first, negative impact is larger.

With respect to the elasticity of the hiring rate,  $ela(\eta_l)$ , the results are quite robust (see Figure 3.6). Within the range  $-4 \leq ela(\eta_l) \leq -0.5$ , the results for a certain level of  $\sigma$  are almost identical. Again, the result is caused by two opposing effects. On the one hand, a higher hiring elasticity – in absolute terms – has a positive impact on aggregate employment (see Table 3.5). On the other hand, there are more people with a low-skilled wage and less people with a medium-skilled wage. Hence, the average wage per person declines. In total, both effects almost compensate each other.

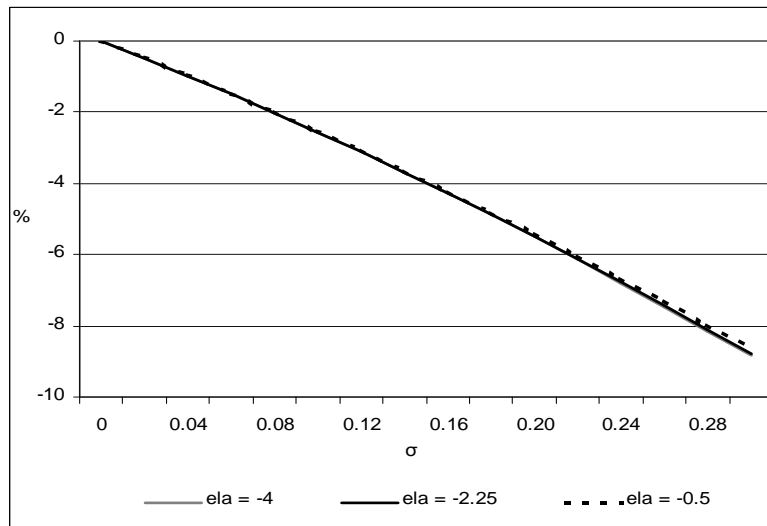


Figure 3.6: The Impact of LWS on Welfare for Different  $ela(\eta_l)$

With respect to a variation of the training elasticity  $\alpha$ , the impact of LWS on welfare is illustrated in Figure 3.7. For a lower training elasticity ( $\alpha = 0.5$ ), the negative impact of LWS on welfare is smaller. As already mentioned, a lower training elasticity causes a lower increase in low-skilled employment and a lower decrease in medium-skilled employment for a given subsidy rate  $\sigma$ . Finally, the negative impact on welfare is smaller.

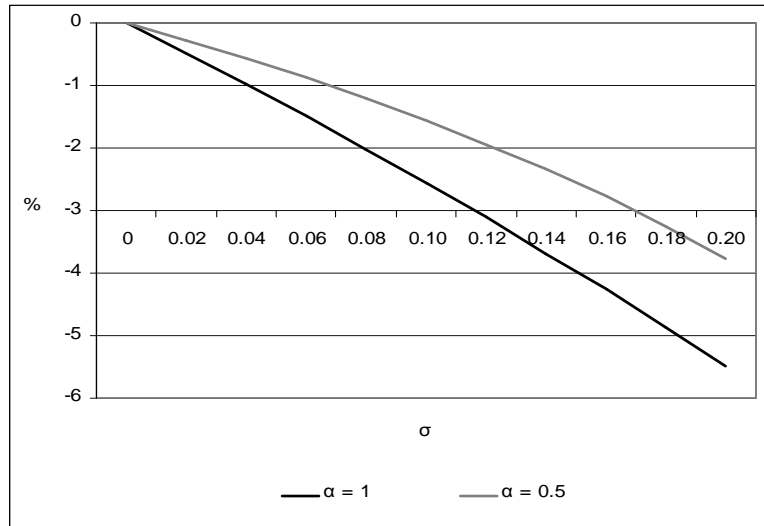


Figure 3.7: The Impact of LWS on Welfare for Different  $\alpha$

### 3.5 Concluding Thoughts

Unemployment, in particular of low-skilled people, is a big problem in advanced economies. It is often argued that low-wage subsidies (LWS) improve the situation of the low-skilled labor force as they assure a certain income level for low-skilled and at the same time support the employment situation of the low-skilled labor force. However, the crucial dimension of the labor market performance is aggregate employment. In this context, it is also important to take the impact of LWS on the skilled labor force into account.

In particular, three channels whereby LWS affect aggregate employment are examined: (i) the direct employment effect, (ii) the skill-acquisition effect and (iii) the government budget effect. LWS raise low-skilled employment because of the direct employment effect. At the same time, they reduce the incentives to acquire human capital because the payment of LWS directly reduces the wage differential between the low-skilled and the skilled employees. This effect is amplified by the fact that the subsidies need to be financed through taxes, which increase in particular the tax

burden of the skilled employees. These latter two effects imply that LWS reduce the skilled labor force. This implication is important for aggregate employment since skilled workers have a much higher employment probability than low-skilled workers.

To analyze the impact of LWS on aggregate employment, a Markov model of the labor market and the training system is built. The dynamics are governed by a Markov matrix that summarizes the transition probabilities between the different states. The transition probabilities are the result of an optimization principle of the people, who have to decide whether to become skilled, and the firms, respectively. The model features a variety of common labor market imperfections like insider wage bargaining as well as hiring and firing costs. Moreover, the labor force is differentiated according to its different skill levels, which are defined by the level of educational attainment. It is assumed that each skill level corresponds to a certain productivity level.

The model is calibrated for Germany. The numerical analysis reveals that LWS significantly reduce medium-skilled employment. Thus, the positive effect of LWS on low-skilled employment does not cause an increase in aggregate employment to the same extent; rather the net effect is small. Thus, ignoring the negative effect on medium-skilled employment would cause an essential overstatement of the benefits of LWS. Furthermore, the shift from medium-skilled to low-skilled employment reduces aggregate welfare. However, the size of the effects depends on several aspects. Whereas the size of the direct employment effect is in particular influenced by the hiring elasticity, the size of the skill-acquisition effect depends on the elasticity of the hiring rate, the degree of risk aversion and the elasticity of the training rate.

## 4 Interactions between Employment and Training Policies

### 4.1 Introduction

In the previous chapter, the impact of one special policy was analyzed. However, when analyzing the impact of labor market policies, it is also important to take possible interactions between different policies into account.<sup>102</sup> In this context, one important aspect are complementarities between two policies, i.e. the fact that the impact of each policy, e.g. on aggregate income, is larger when it is implemented in conjunction with the other policy than in isolation. However, two policies, like training subsidies and hiring subsidies, may be substitutes because (i) they both raise the trained labor force and (ii) – in the presence of the government budget constraint – they both may cause an increase in the tax rate, which reduces aggregate income. Ignoring possible interactions could distort the evaluation of these policies.

This chapter offers a methodology that captures potential interactions between labor market policies. As an example, two important policies are considered: training subsidies and hiring subsidies.<sup>103</sup> In the following analysis hiring subsidies are paid to firms, which hire successful apprentices as employees; training subsidies are paid to firms, which hire school leavers as apprentices.

Most OECD countries have implemented such policies to encourage both, employment and training. To varying degrees, both policies serve a similar purpose, namely, to improve the employment and income perspectives, particularly for low-skilled workers. However, the policies focus on different transitions in the labor market. Whereas training policies are meant to ease the transition from school to training, hiring subsidies are meant to facilitate the transition from training to work. Against this background, this chapter deals with two questions:

- How do the interactions between hiring subsidies and training subsidies look?
- Given the existence of complementarities, on what institutional and policy features of the economy does the size of complementarities depend?

One possible channel whereby both policies are complementary is the following: hiring subsidies facilitate the transition from training to work and thereby stimulate

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<sup>102</sup>For a different version of this chapter see Oskamp and Snower (2007).

<sup>103</sup>Sometimes, "hiring subsidies" are also called "employment subsidies" or "employment vouchers" and are implemented through a wide variety of policy instruments, such as tax breaks or grants. As they all – given that they are awarded only for a limited period of time – have analogous effects on labor market activities and government expenditures, this chapter groups them together under the heading "hiring subsidies".

the employment rate, as they raise the probability that an apprentice continues working after having finished training successfully. Hence, hiring subsidies improve the effectiveness of training policies. As hiring subsidies increase the expected profits being generated by a former apprentice, the training incentives of the firms rise. Thus, hiring subsidies increase the number of people being hired as apprentices. This broadens the target group for training subsidies.

However, both subsidies may be substitutes because they both raise the trained labor force and reduce the non-trained labor force. They only differ with respect to the transition they are targeted at. Whereas training subsidies aim at increasing the number of people being in training (first transition), hiring subsidies aim at increasing the hiring of successful apprentices as trained employees (second transition). Moreover, the higher the government expenditures for hiring subsidies and training subsidies, the higher the taxes, which are necessary to finance these expenditures, could be. Higher taxes reduce the expected lifetime income. On account of these effects, employment and training policies may be complementary policies or they are substitutes with respect to employment and expected lifetime income, respectively.

Again, as in the previous chapter, the analysis in this chapter is based on a macro model of the labor market and the training system, in which the transition probabilities between the different states are governed by a Markov process. The transition probabilities that are affected by the subsidies are analyzed in detail. Moreover, the model takes some important labor market imperfections – such as wage bargaining, hiring and firing costs as well as imperfections related to the tax and transfer system – as given. The impact of the two subsidies is analyzed in the presence of these institutions. The model is calibrated for the German labor market and training system.

The main message of the chapter is that there are significant interactions between both policies. In the absence of the government budget constraint, there are complementarities with respect to aggregate income. However, in the presence of the government budget constraint, the policies become substitutes. The analysis provides a methodology for examining policy interactions, which may be useful well beyond the bounds of hiring and training subsidies.

The chapter is organized as follows. Section 4.2 presents the relation to the literature. Section 4.3 describes the theoretical model of the labor market and the training system. Section 4.4 presents a purely analytical evaluation of a simplified model. In Section 4.5, the model is calibrated and the numerical results are discussed. Finally, Section 4.6 concludes.

## 4.2 Relation to the Literature

The analysis of complementarities between labor market institutions and policies is prevalent in the literature (see e.g. Belot and van Ours, 2001). Theoretical analyses of complementarities can be found in Coe and Snower (1997), Orszag and Snower (1999a) as well as Burda and Weder (2002). However, they focus on complementarities between institutions or policies other than in this chapter. In particular, they do not deal with the question by how far the size of complementarities is affected by other features of the economy.

This chapter investigates the interactions between employment and training policies. As an example, the impacts of hiring subsidies and training subsidies are analyzed because they play a prominent role within the active labor market policy in OECD countries. Both, hiring subsidies and training subsidies, have been studied in detail in the literature, in particular the hiring subsidies. In this context, this study is related to a variety of previous studies analyzing the impact and optimal design of employment subsidies. The initial work was done by Pigou (1933) and Kaldor (1936).<sup>104</sup>

Again, to prevent running afoul of the Lucas Critique, this analysis – as the previous one – is not based on a policy-invariant matching function. Instead, it is explicitly analyzed how policies affect people’s incentives given an intertemporal maximization of the economic agents. In this analysis, the focus is on the firms. This has two reasons: (*i*) labor demand, especially with respect to the low-skilled labor force, is the short side of the market in economies with high unemployment and (*ii*) the subsidies, which are analyzed, are paid to firms. The households get involved through the wage bargaining.

Again, the dynamic effects of subsidies are explicitly captured by specifying the transition rates between employment, unemployment and training as a function of the hiring and training incentives of the firms. This approach allows us to capture the adjustment processes and thereby to analyze the long-run effects of training and hiring subsidies as well as their interactions.<sup>105</sup>

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<sup>104</sup>For a survey of the empirical literature, see e.g. Katz (1998). For U.S. evidence, see Woodbury and Spiegelman (1987) and O’Leary et al. (2005). For British evidence, see Bell et al. (1999). For an analysis of training subsidies, see e.g. Görg and Strobl (2006) as well as Filges et al. (2007).

<sup>105</sup>Orszag and Snower (2003a and 2003b) stress that the literature has disregarded the total impact of employment subsidies on the government budget constraint. On the one hand, aggregate payroll taxes finance subsidies but on the other hand, payroll taxes can be reduced if the subsidies reduce unemployment and thereby unemployment benefit payments. In this chapter, their line of reasoning is pursued.

### 4.3 The Model

The model is meant to provide a framework for analyzing interactions between hiring and training subsidies with respect to employment, income and welfare. Even though the intention of the analysis is different, the model is almost similar to the model in the previous chapter; however, there are some differences, in particular concerning the transition rates. Given this and for the sake of traceability, the total model is illustrated in detail.

The analysis is based on a Markov model of the labor market and the training system. The dynamics are governed by a Markov matrix that summarizes the transition probabilities between the different states. The transition probabilities are the result of an optimization principle of the firms. People in the labor force are differentiated according to their skill levels, which are defined by the level of educational attainment. Each skill level is assumed to correspond to a certain productivity level. The population is divided into eight groups (see also Table 3.1 in the previous chapter): people being in school,  $S$ , people joining vocational training,  $T$ , and those being either employed,  $N_i$ , or unemployed,  $U_i$ . The employed and unemployed, respectively, are divided into three subgroups according to the skill level  $i = l, m, h$ . Here, as well as for other variables below, the subscript  $l$  stands for "low-skilled", the subscript  $m$  for "medium-skilled" and the subscript  $h$  for "high-skilled". The transitions between the different states, i.e. the dynamic structure of the model, are described below. Vocational training takes  $p$  periods, so that there are  $p$  cohorts. In each period, a fraction  $\rho + \theta$  leaves the vocational training where  $\rho$  is the death rate and  $\theta$  is the drop-out rate of training. So, given the inflow into vocational training,  $T_1$ , the outflow,  $p$  periods later, is given by  $T_1(1 - \rho - \theta)^p$ . The stock of people being in vocational training is given by  $T = T_1 \sum_{c=1}^p (1 - \rho - \theta)^{c-1}$ . People who drop out of training or die are assumed to leave the labor force. However, it is assumed that the number of births equals the number of deaths. As the newborn as well as the people who have dropped out of training are assumed to enter state  $S$  before going back to the labor market or to training, the population remains constant.

For simplicity, there is no capital. Moreover, returns to labor are assumed to be constant. Let  $a_i$  be the productivity of an employee with a skill level  $i = l, m, h$ . When making their employment decisions, firms face a random cost  $\epsilon_t$ , which is *iid* across workers and time. The cost may be interpreted as an operating cost or a productivity shock. With respect to all employees, its mean is normalized to zero and its cumulative distribution  $\Gamma(\epsilon_t)$  is time-invariant.

In the model, training takes place within a dual system of vocational training. This is a combination of vocational training provided by a private employer (on-



the-job-training) and theoretical education in vocational schools. With respect to the latter, the associated costs (e.g. for school buildings, salaries of the teachers) are distributed among the population. These costs are assumed to be fix, so that a change in the number of apprentices does not influence their level. For the sake of simplicity, these costs are ignored in the remainder. The costs, which are important in the model are the direct costs for the employers that are caused by their engagement in vocational training (e.g. wages of additional employees being in charge of the instruction of apprentices within the firm). With respect to the distribution of these costs, it is necessary to distinguish two types of training: general training and specific training.<sup>106</sup> Against the background of the German system of vocational training, one can argue that training has a mostly general character. Due to comprehensive curricula determining the content of training and centralized examinations, vocational training within the dual system is highly standardized.<sup>107</sup> According to the original theory by Becker (1964), in the presence of competitive markets, the employee receives all the returns from general training and thus also has to pay for training. However, German employers also invest in the training of apprentices and thus – from a theoretical point of view – also pay for general training.<sup>108</sup> It can be shown that firms have an incentive to invest in general vocational training, given that there are imperfections in the labor market.<sup>109</sup>

### 4.3.1 The Dynamic Structure

The transitions between the different states are summarized in Figure 4.1. In all states apart from  $S$ , people face a probability  $\rho$  of dying. With respect to the school leavers, a fraction  $\eta_{S,T}$  is hired as apprentice. The residual part,  $(1 - \eta_{S,T})$ , tries to get a job as a low-skilled employee; only a fraction  $\eta_l$  is hired. A low-skilled employee faces a probability  $\varphi_l$  of being fired and a probability  $\eta_{N,T}$  of being hired as an apprentice. A low-skilled unemployed faces a probability  $\eta_{U,T}$  of being hired as an apprentice and a probability  $(1 - \eta_{U,T}) \eta_l$  of being hired as a low-skilled employee. With a probability  $\theta$  per period, an apprentice drops out of training. It is assumed that an apprentice cannot be fired. An apprentice who has finished training successfully and survives,<sup>110</sup> is hired as a medium-skilled employee with

<sup>106</sup>See Becker (1964). For a survey of the literature on private sector training see Leuven (2005).

<sup>107</sup>See for further details Harhoff and Kane (1993) and Lindner (1998).

<sup>108</sup>According to an analysis of Beicht and Walden (2002) for the year 2000, the costs caused by vocational training are significantly higher than the benefits, i.e. the output of the apprentice.

<sup>109</sup>See e.g. Acemoglu and Pischke (1999) as well as Harhoff and Kane (1993). Appendix 7.3.1 shows that firms have an incentive to invest in general vocational training.

<sup>110</sup>Every apprentice who survives and did not drop out of training finishes training successfully after  $p$  periods.

probability  $\eta_{T,N_m}$ . A medium-skilled employee faces a probability  $\varphi_m$  of being fired. An unemployed medium-skilled is hired with probability  $\eta_m$ .

In order to keep the model simple, the sum of apprentices dropping out of training and deaths is assumed to be equal to the number of people being in state  $S$ . Hence, the relevant population ( $N_l + U_l + N_m + U_m + T + S$ ) is constant. Moreover, the high-skilled labor force ( $N_h + U_h$ ) is treated as a quasi-fix factor, i.e. these states are assumed to be unaffected by the implementation of subsidies. However, given the government budget constraint, it is necessary to take these states into account, because  $N_h$  also carries a part of the fiscal burden and  $U_h$  is responsible for a part of the fiscal burden. Ignoring this aspect would bias the amount of the fiscal burden, which has to be carried by the low-skilled and medium-skilled employees. Given

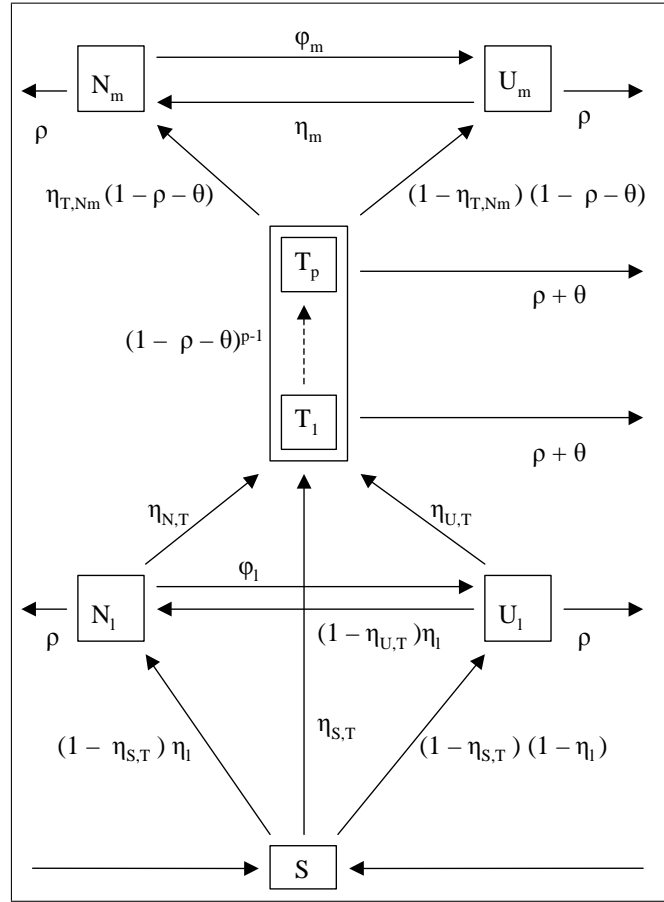


Figure 4.1: The Transitions between the States

this, the model can be described as follows:

$$Z_{t+1} = MT_{t+1} Z_t \quad (4.1)$$

where  $Z_t$  is a vector of the different states:

$$Z_t = (N_{m,t}, U_{m,t}, N_{l,t}, U_{l,t}, T_{1,t}, S_t) \quad (4.2)$$

and  $MT$  is a Markov matrix of the transition probabilities:

$$MT = \begin{bmatrix} (1 - \varphi_m - \rho) & \eta_m & 0 & 0 & \eta_{TN_m} (1 - \rho - \theta)^p & 0 \\ \varphi_m & (1 - \eta_m - \rho) & 0 & 0 & (1 - \eta_{TN_m})(1 - \rho - \theta)^p & 0 \\ 0 & 0 & (1 - \varphi_l - \eta_{NT} - \rho) & (1 - \eta_{UT}) \eta_l & 0 & (1 - \eta_{ST}) \eta_l \\ 0 & 0 & \varphi_l & (1 - (1 - \eta_{UT}) \eta_l - \eta_{UT} - \rho) & 0 & (1 - \eta_{ST})(1 - \eta_l) \\ 0 & 0 & \eta_{NT} & \eta_{UT} & 0 & \eta_{ST} \\ \rho & \rho & \rho & \rho & 1 - (1 - \rho - \theta)^p & 0 \end{bmatrix} \quad (4.3)$$

It is assumed that a transition from low-skilled employment to training is linked with a change of the firm. This is based on the assumption that there are two types of firms: (*i*) firms that employ only low-skilled and (*ii*) firms that employ only medium-skilled and are engaged in vocational training.<sup>111</sup> Moreover, it has to be noted that not all transition rates are exogenous. The transition rates, which are affected by the subsidies, are endogenous. They are analyzed in detail below.

Agents in the model pursue the following sequence of decisions. First, the government sets the income tax rate to ensure that its tax receipts equal its expenditures. Second, the random costs are revealed. Third, wages are determined through bargaining and finally employment decisions are made.

### 4.3.2 The Characteristics of the Subsidies

In the following, two kinds of subsidies are analyzed:

- The hiring subsidy,  $\sigma^{\eta_{T,N^m}}$ , is paid to firms, which hire successful apprentices as medium-skilled employees. It is paid during the first period of the employment spell.
- The training subsidy,  $\sigma^{\eta_{S,T}}$ , is paid to firms, which hire school leavers as apprentices. It is paid per apprentice and per period over the whole phase of vocational training.

The hiring subsidy aims at improving the employment situation of the successful apprentices by increasing the hiring incentive of the firms. The training subsidy

<sup>111</sup>This can be justified by the assumption that the firms are engaged in different sectors with different requirements with respect to human capital.

aims at improving the human capital in a first step and then, in a second step, the long-term employment perspective, given that the employment rate of the medium-skilled labor force is higher than the employment rate of the low-skilled labor force.

### 4.3.3 Government Budget Constraint

When analyzing the government budget constraint, four policy instruments have to be taken into account: (i) the payroll tax with a rate  $t_i$ , (ii) the unemployment benefit  $b_i$ , (iii) the hiring subsidy,  $\sigma^{\eta_{T,N_m}}$  and (iv) the training subsidy,  $\sigma^{\eta_{S,T}}$ . The tax rate has three levels to match a progressive tax system ( $t_h > t_m > t_l$ ). The ratios are assumed to be exogenous, whereas the levels are set so that the tax receipts equal the government's expenditures. It is assumed that people being engaged in vocational training do not pay taxes. Given the presence of the subsidies, the government budget constraint is expressed as follows:

$$\begin{aligned} \sum_{i=l,m,h} t_i w_i N_i &= \sum_{i=l,m,h} \beta_i w_i (1 - t_i) U_i & (4.4) \\ &+ \sigma^{\eta_{S,T}} \eta_{S,T} S \sum_{c=1}^p (1 - \rho - \theta)^{c-1} \\ &+ \sigma^{\eta_{T,N_m}} \eta_{T,N_m} T_1 (1 - \rho - \theta)^p \end{aligned}$$

The left-hand side stands for the tax receipts of the government that are generated by the taxes on labor income. The term on the right-hand side represents the sum of the unemployment benefits with the net replacement rate  $\beta_i$ , the training subsidies  $\sigma^{\eta_{S,T}}$ , paid to firms for hiring school leavers as apprentices, and finally the hiring subsidies,  $\sigma^{\eta_{T,N_m}}$ , paid to firms for hiring successful apprentices as medium-skilled employees.<sup>112</sup>

### 4.3.4 Wage Determination

For simplicity, the wage of the apprentice,  $w_v$ , is assumed to be set unilaterally by the firm. In the remainder, the focus is therefore on the wage  $w_i$  for each skill level  $i$ , which is the outcome of a Nash bargain between the median insider of that skill level and the firm. The median insider faces no risk of dismissal at the negotiated wage. The wage is renegotiated in each period.

**Surplus of the Employee** A person with a skill level  $i$  has the following utility function:

$$u_{i,t}(C_{i,t}) = \frac{1}{1 - \gamma} [C_{i,t}]^{1-\gamma} \quad (4.5)$$

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<sup>112</sup>Recall that  $T_1$  is the inflow into training and  $T_1 (1 - \rho - \theta)^p$  is the outflow from training.

where  $\gamma$  is the coefficient of relative risk aversion. Utility depends positively on consumption  $C_{i,t}$ . For simplicity, workers consume all their income, i.e. either the consumer wage in the case of employment or the unemployment benefit in the case of unemployment. Moreover, it is assumed that there is no disutility of labor. Under bargaining agreement, the employee receives the consumer wage,  $\omega_i = w_i(1 - t_i)$ , in each period. The present value of the employee's expected lifetime utility in period  $t$ ,  $V_{i,t}^N$ , is:

$$V_{i,t}^N = \frac{1}{1 - \gamma} [w_i (1 - t_{i,t})]^{1 - \gamma} + \delta E_t [(1 - \varphi_i - \rho - \underbrace{\eta_{N,T}}_{\text{only for } i=l}) V_{i,t+1}^N + \varphi_i V_{i,t+1}^U + \underbrace{\eta_{N,T} V_{t+1}^T}_{\text{only for } i=l}] \quad (4.6)$$

where  $\delta$  is the discount factor and  $V_{i,t+1}^U$  is the present value of the expected future lifetime utility for an unemployed. (Here, as well as for other variables below, the superscript  $N$  stands for "employed" and the superscript  $U$  for "unemployed"). Given that the person is a low-skilled employee, also the transition into training, being illustrated by  $\eta_{N,T}$ , has to be taken into account. Training is associated with an expected future lifetime utility  $V_{t+1}^T$ . In the case of disagreement, the employee's fallback position is assumed to be equal to the unemployment benefit,  $b_{i,t}$ . It is assumed that disagreement in the current period does not affect the expected future lifetime utility. Hence, in the case of disagreement, the present value of the expected lifetime utility in period  $t$ ,  $V_{i,t}^{d,N}$ , is:

$$V_{i,t}^{d,N} = \frac{1}{1 - \gamma} [b_i]^{1 - \gamma} + \delta E_t [(1 - \varphi_i - \rho - \underbrace{\eta_{N,T}}_{\text{only for } i=l}) V_{i,t+1}^N + \varphi_i V_{i,t+1}^U + \underbrace{\eta_{N,T} V_{t+1}^T}_{\text{only for } i=l}] \quad (4.7)$$

Given the expected present value in the case of agreement and disagreement, respectively, the bargaining surplus of the employee,  $S_{i,t}^E (= V_{i,t}^N - V_{i,t}^{d,N})$  can be calculated as follows:

$$S_{i,t}^E = \frac{1}{1 - \gamma} [w_i (1 - t_i)]^{1 - \gamma} - \frac{1}{1 - \gamma} [b_i]^{1 - \gamma} \quad (4.8)$$

**Surplus of the Firm** Under bargaining agreement, the firm receives the profit  $(a_i - w_i)$  per period. The present value of the expected profits  $\pi_{i,t}$  with respect to an employee with skill level  $i$  is therefore:

$$\pi_{i,t} = (a_i - w_i) + \delta E_t (1 - \varphi_i - \rho - \underbrace{\eta_{N,T}}_{\text{only for } i=l}) \pi_{i,t+1} + \delta \varphi_i (-s_i) \quad (4.9)$$

where  $\varsigma_i$  are the firing costs. Again, in the case of a low-skilled employee, also the transition into training has to be taken into account.<sup>113</sup> In the case of disagreement the employee imposes the maximal cost on the firm (e.g. by strike, work-to-rule, sabotage) short of inducing dismissal. The firm's fallback position is negative; it is approximated by the firing costs. Again, it is assumed that disagreement in the current period does not affect future profits. Thus, in the case of disagreement, the present value of the expected profits in period  $t$ ,  $\pi_{i,t}^d$ , is given by:

$$\pi_{i,t}^d = -\varsigma_i + \delta E_t \left( 1 - \varphi_i - \rho - \underbrace{\eta_{N,T}}_{\text{only for } i=l} \right) \pi_{i,t+1} + \delta \varphi_i (-\varsigma_i) \quad (4.10)$$

Finally, the bargaining surplus of the firm,  $S_{i,t}^F (= \pi_{i,t} - \pi_{i,t}^d)$  can be calculated as follows:

$$S_i^F = (a_i - w_i) + \varsigma_i \quad (4.11)$$

**Nash Bargaining** The negotiated wage  $w_i$  maximizes the Nash product,  $\Lambda_i$ :

$$\Lambda_i = (S_i^E)^\mu (S_i^F)^{1-\mu} \quad (4.12)$$

where  $\mu \in \langle 0, 1 \rangle$  denotes the bargaining power of the employee and  $1 - \mu$  represents the bargaining power of the firm. Thus, the following equation has to be solved:

$$\frac{\partial \Lambda_i}{\partial w_i} \stackrel{!}{=} 0$$

The result is given by:

$$(1-t_i) (a_i - w_i + \varsigma_i) (w_i - t_i w_i)^{-\gamma} \mu (1-\gamma) = (1-\mu) (-b_i^{1-\gamma} + (w_i - t_i w_i)^{1-\gamma}) \quad (4.13)$$

In the steady state, the firing costs are given by  $\varsigma_i = c_\varphi w_i$ , and the unemployment benefit level is defined on the basis of the economy-wide average net wage:  $b_i = \beta_i w_i (1 - t_i)$ . Finally, the negotiated wage,  $w_i$ , is given by:

$$w_i = \frac{a_i \mu (1 - \gamma)}{(1 - \beta_i^{1-\gamma}) (1 - \mu) + \mu (1 - c_\varphi) (1 - \gamma)} \quad \text{for } i = l, m, h \quad (4.14)$$

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<sup>113</sup>The way, in which the transition rate,  $\eta_{N,T}$ , is introduced into the calculation of the profit implies that – as mentioned above – the transition from low-skilled employment to training is linked with a change of the firm.

### 4.3.5 Transition Rates

Next, the two transition rates, which are affected by the subsidies, are analyzed in detail. Although both transition rates can be regarded as hiring rates, in the remainder,  $\eta_{S,T}$  is called *training rate* to avoid confusion with the other hiring rate  $\eta_{T,N_m}$ . Whereas the hiring rate,  $\eta_{T,N_m}$ , is only affected by the hiring subsidy, the training rate,  $\eta_{S,T}$ , is affected by the training subsidy but also by the hiring subsidy.<sup>114</sup> All remaining transition rates, especially the hiring and firing rates of the low-skilled and the medium-skilled, respectively, ( $\eta_i$  and  $\varphi_i$  with  $i = l, m$ ) are not affected by the implementation of subsidies. They are treated as constants.

**Hiring Rate** The present value of the expected profits (after the random cost  $\epsilon_{\eta_{T,N_m},t}$  is revealed), generated by a medium-skilled employee, who was an apprentice before, is given by:<sup>115</sup>

$$\begin{aligned} \pi_{T,N_m,t} = & -\epsilon_{\eta_{T,N_m},t} + \sigma^{\eta_{T,N_m}} \\ & + (a_m - w_m) \sum_{j=0}^{\infty} \delta^j (1 - \varphi_m - \rho)^j - \delta \varphi_m \varsigma_m \sum_{j=0}^{\infty} \delta^j (1 - \varphi_m - \rho)^j \end{aligned} \quad (4.15)$$

As – by assumption – the hiring decision is made by the firm, which has also conducted the vocational training, the hiring costs are zero because the apprentice to be hired as a medium-skilled employee is already in the firm. Given this, the person is taken over, if the present value of the expected profits is positive:  $\pi_{T,N_m,t} > 0$ . After substituting  $\pi_{T,N_m,t}$  according to eq. (4.15), the equation is solved for the random cost:

$$\epsilon_{\eta_{T,N_m},t} < \sigma^{\eta_{T,N_m}} + \frac{a_m - w_m - \delta \varphi_m \varsigma_m}{1 - \delta (1 - \varphi_m - \rho)} \quad (4.16)$$

The random cost,  $\epsilon_{\eta_{T,N_m},t}$ , is assumed to be uniformly distributed between  $\epsilon_{\eta_{T,N_m}}^-$  and  $\epsilon_{\eta_{T,N_m}}^+$ . Then, the hiring rate is:

$$\eta_{T,N_m} = \frac{(\sigma^{\eta_{T,N_m}} + \frac{a_m - w_m - \delta \varphi_m \varsigma_m}{1 - \delta (1 - \varphi_m - \rho)}) - \epsilon_{\eta_{T,N_m}}^-}{\epsilon_{\eta_{T,N_m}}^+ - \epsilon_{\eta_{T,N_m}}^-} \quad (4.17)$$

The critical reader may argue that not all successful apprentices are taken over by the firm, which has conducted the vocational training. Some of the successful

<sup>114</sup>Recall that training subsidies are not paid for hiring low-skilled employees,  $N_l$ , and low-skilled unemployed,  $U_l$ , respectively, as apprentices. Hence, the corresponding transition rates,  $\eta_{N,T}$  and  $\eta_{U,T}$ , are not affected by the low-wage subsidies. As  $\eta_{N,T}$  and  $\eta_{U,T}$ , are small compared to  $\eta_{S,T}$ , the quantitative impact would be low. However, addressing also this effect would significantly increase the complexity of the model.

<sup>115</sup>Recall that eq. (4.15) is equal to eq. (4.9) for  $i = m$ ,  $\sigma^{\eta_{T,N_m}} = 0$  and  $-\epsilon_{\eta_{T,N_m},t} = 0$ .

apprentices will get a job in a firm, which is not engaged in vocational training. So far, it has been assumed that the hiring rate,  $\eta_{T,N_m}$ , equals the take-over rate. In the remainder, it will be assumed that there are two hiring rates: (i)  $\eta_{T,N_m}^1$  being associated with the firm that is engaged in vocational training, and (ii)  $\eta_{T,N_m}^2$  being associated with the firm that is not engaged in vocational training. Now, only  $\eta_{T,N_m}^1$  can be interpreted as take-over rate and is given by eq. (4.17) for  $\eta_{T,N_m} = \eta_{T,N_m}^1$ . With respect to  $\eta_{T,N_m}^2$  and in contrast to eq. (4.17), hiring costs,  $\chi_{T,N_m}$ , have to be taken into account, as the apprentice is hired by another firm for which the successful apprentice is an outsider. Therefore, the hiring rate,  $\eta_{T,N_m}^2$ , is calculated as follows:

$$\eta_{T,N_m}^2 = \frac{(-\chi_{T,N_m} + \sigma^{\eta_{T,N_m}} + \frac{a_m - w_m - \delta \varphi_m s_m}{1 - \delta(1 - \varphi_m - \rho)}) - \epsilon_{\eta_{T,N_m}^2}^-}{\epsilon_{\eta_{T,N_m}^2}^+ - \epsilon_{\eta_{T,N_m}^2}^-} \quad (4.18)$$

**Training Rate** Next, the training rate is considered, i.e. the probability for a school leaver of being hired as apprentices. If the training rate would only depend on the profit in the phase of vocational training, there would be no hiring. As the output  $a_v$  generated by the apprentice is supposed to be smaller than the sum of the wage,  $w_v$ , and the additional, non-wage costs of vocational training,  $k_v$ , the profit of the firm in the training phase is negative. However, the training decision is not only based on the financial outcome in the training phase. In fact, the firms regard the costs of vocational training as an investment, which causes the profit  $\pi_{T,N_m}$ , once the person, who has started training  $p$  periods before, continues working in the firm as a medium-skilled employee with the probability  $\eta_{T,N_m}^1 (1 - \rho - \theta)^p$ . Therefore, also the expected profit in the latter phase has to be taken into account when deriving the training rate. The present value of the expected profits, generated by an apprentice, who was in school before,  $\pi_{S,T,t}$ , is given by:<sup>116</sup>

$$\begin{aligned} \pi_{S,T,t} = & -\epsilon_{\eta_{S,T},t} + (a_v - w_v - k_v + \sigma^{\eta_{S,T}}) \sum_{j=0}^{p-1} \delta^j (1 - \rho - \theta)^j \\ & + \eta_{T,N_m}^1 (1 - \rho - \theta)^p \delta^p E_t \pi_{T,N_m} \end{aligned} \quad (4.19)$$

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<sup>116</sup>Note that  $E_t \pi_{T,N_m}$  is given by eq. (4.15) with  $-\epsilon_{\eta_{T,N_m},t} = 0$ .



Given the hiring costs,  $\chi_{S,T}$ , a school leaver is hired as apprentice if  $\pi_{S,T} > \chi_{S,T}$ . After solving eq. (4.19) for  $\epsilon_{\eta_{S,T},t}$ , the random cost is given by:

$$\begin{aligned} \epsilon_{\eta_{S,T},t} < -\chi_{S,T} + (a_v - w_v - k_v + \sigma^{\eta_{S,T}}) \sum_{j=0}^{p-1} \delta^j (1 - \rho - \theta)^j \quad (4.20) \\ + \eta_{T,N_m}^1 (1 - \rho - \theta)^p \delta^p E_t \pi_{T,N_m} \end{aligned}$$

The random cost,  $\epsilon_{\eta_{S,T},t}$ , is assumed to be uniformly distributed between  $\epsilon_{\eta_{S,T}}^-$  and  $\epsilon_{\eta_{S,T}}^+$ . The corresponding hiring rate is:

$$\eta_{S,T} = \left[ \begin{array}{c} -\chi_{S,T} + (a_v - w_v - k_v + \sigma^{\eta_{S,T}}) \sum_{j=0}^{p-1} \delta^j (1 - \rho - \theta)^j \\ + \eta_{T,N_m}^1 (1 - \rho - \theta)^p \delta^p E_t \pi_{T,N_m} \end{array} \right] / \left[ \epsilon_{\eta_{S,T}}^+ - \epsilon_{\eta_{S,T}}^- \right] \quad (4.21)$$

Whereas training subsidies only have a direct effect – they increase the training rate  $\eta_{S,T}$  –, hiring subsidies have a direct and an indirect effect. Primarily, hiring subsidies aim at easing the transition from training to work, i.e. they increase the hiring rates  $\eta_{T,N_m}^1$  and  $\eta_{T,N_m}^2$  according to eq. (4.17) for  $\eta_{T,N_m} = \eta_{T,N_m}^1$  and eq. (4.18) for  $\eta_{T,N_m}^2$ . Moreover, hiring subsidies also have an indirect effect. They also increase the training rate due to their impact on the hiring rate,  $\eta_{T,N_m}^1$ , which – according to eq. (4.21) – has an impact on the training rate,  $\eta_{S,T}$ . The decision to hire an apprentice also depends on the probability that the person continues working in the firm as medium-skilled. The higher the hiring rate,  $\eta_{T,N_m}^1$ , the higher is this probability and the higher is the incentive to hire a person as apprentice. Thus, hiring subsidies do not only increase the fraction of apprentices who are hired as medium-skilled employees, they also increase the number of apprentices.

#### 4.3.6 Labor Market Equilibrium

The following system of equations constitutes the equilibrium of the model:<sup>117</sup>

- the steady state expressions of the six dynamic equations given by the transition matrix (4.3),<sup>118</sup>
- the government budget constraint, eq. (4.4),<sup>119</sup> and finally

<sup>117</sup>As the producer wages are not affected by the subsidies, the corresponding equations are not necessary to describe the model. However, the wage equations are necessary for the initial calibration.

<sup>118</sup>Recall that the total number of people being in training is given by  $T = T_1 \sum_{c=1}^p (1 - \rho - \theta)^{c-1}$ . Moreover, the population ( $S + T + N_l + U_l + N_m + U_m$ ) is normalized to 1.

<sup>119</sup>As the equation that describes the government budget constraint contains three tax rates, it

- the equations determining the hiring rates, eq. (4.17) with  $\eta_{T,N_m} = \eta_{T,N_m}^1$ , eq. (4.18), and eq. (4.21).

## 4.4 A Simple Analytical Evaluation

In the following, a simple model is presented, which allows for an analytical solution. The simplified model, is – after the calibration in the following section – used as a starting point for the numerical analysis.

### 4.4.1 The Simplified Model

In order to get an analytically traceable solution, the model is simplified as follows: (i) there are no taxes:<sup>120</sup>  $t_i = 0$  with  $i = l, m, h$ , (ii) training takes one period:  $p = 1$ , (iii) apprentices do not drop out of training:  $\theta = 0$  and (iv) agents are risk neutral:  $\gamma = 0$ .

According to Coe and Snower (1997) "policies are complementary in the sense that the effect of each policy is greater when implemented in conjunction with the other policy than in isolation". In the following, it is examined whether there are complementarities with respect to aggregate income,  $\Phi$ , i.e. the income over all states:<sup>121</sup>

$$\Phi = T w_v + \sum_{i=m,l,h} N_i w_i (1 - t_i) + U_i \beta_i w_i (1 - t_i) \quad (4.22)$$

The cross derivative of  $\Phi$  for the two subsidies,  $\sigma^{\eta_{S,T}}$  and  $\sigma^{\eta_{T,N_m}}$ , is calculated as follows:<sup>122</sup>

$$\begin{aligned} & \frac{\partial^2 \Phi}{\partial \sigma^{\eta_{S,T}} \partial \sigma^{\eta_{T,N_m}}} \quad (4.23) \\ & = \underbrace{\left[ a_m (1 - \beta_m) \Xi_\epsilon \mu_m (1 - \rho) \rho^2 (\eta_l + \eta_{N,T} (1 - \eta_l) + \rho + \varphi_l) \right]}_{<0} / \\ & \quad \underbrace{\left[ \Pi_\epsilon (1 - \beta_m (1 - \mu_m) - c_\phi \mu_m) (1 + \rho) \right]}_{<0} \\ & \quad \underbrace{\left( \eta_l (1 - \eta_{U,T}) (\eta_{N,T} + \rho) + (\eta_{U,T} + \rho) (\eta_{N,T} + \rho + \varphi_l) \right)}_{>0} \underbrace{\left( \eta_m + \rho + \varphi_m \right)}_{>0} \end{aligned}$$

with:

$$\Xi_\epsilon = \left( \epsilon_{\eta_{T,N_m}}^- - \epsilon_{\eta_{T,N_m}}^+ + \epsilon_{\eta_{T,N_m}}^- - \epsilon_{\eta_{T,N_m}}^+ \right) < 0 \text{ and}$$

is necessary to introduce two additional equations in order to close the model. They describe the ratios between the tax rates,  $t_h$ ,  $t_m$  and  $t_l$ .

<sup>120</sup>In the presence of taxes, a purely analytical examination is not possible. Therefore, a different, 2-period-model is constructed, which is presented in Appendix 7.3.2.

<sup>121</sup>The income in state  $S$  is 0.

<sup>122</sup>See Appendix 7.3.3 for the derivation.

$$\Pi_\epsilon = (\epsilon_{\eta_{T,N_m}^1}^- - \epsilon_{\eta_{T,N_m}^1}^+)(\epsilon_{\eta_{T,N_m}^2}^- - \epsilon_{\eta_{T,N_m}^2}^+)(\epsilon_{\eta_{S,T}}^- - \epsilon_{\eta_{S,T}}^+) < 0.$$

The cross derivative is unambiguously positive. Hence, the result reveals – at least for a very simple version of the model – the existence of complementarities with respect to aggregate income in the sense that the impact of each subsidy on aggregate income is higher when it is implemented together with the other policy than in isolation.

The intuition behind this is as follows: hiring subsidies facilitate the transition from vocational training to work. They increase the probability that an apprentice continues working in the firm as a medium-skilled employee after having finished vocational training successfully. Thereby, hiring subsidies improve the effectiveness of training policies, as the higher probability will amplify the positive impact of training subsidies. Hiring subsidies indirectly increase the number of people being hired as apprentices. This broadens the target group for training subsidies.

#### 4.4.2 Robustness Checks

Next, the impact of different parameter values on the size of the complementarity is discussed. In this context, the derivative of the cross derivative,  $\frac{\partial^2 \Phi}{\partial \sigma^{\eta_{S,T}} \partial \sigma^{\eta_{T,N_m}}}$ , first, with respect to the elasticity of the hiring rate and second, with respect to the elasticity of the training rate, is calculated.

**Hiring Elasticity** When analyzing the impact of the elasticity of the hiring rate with respect to the wage,  $ela(\eta_{T,N_m}) = (\partial \eta_{T,N_m} / \eta_{T,N_m}) / (\partial w_m / w_m)$ , it has to be taken into account that the elasticity does not directly enter eq. (4.17) and eq. (4.18), respectively, which determine the hiring rates. Rather the hiring elasticity is implicitly fixed by the choice of the limits,  $\epsilon_{\eta_{T,N_m}^q}^-$  and  $\epsilon_{\eta_{T,N_m}^q}^+$  (for  $q = 1, 2$ ) of the uniform distribution. A higher  $\epsilon_{\eta_{T,N_m}^q}^-$  implies a higher hiring elasticity (in absolute terms). In the following, the impact of  $\epsilon_{\eta_{T,N_m}^q}^-$  (with  $q = 1, 2$ ) on the size of the complementarity is calculated:

$$\begin{aligned} \partial \left( \frac{\partial^2 \Phi}{\partial \sigma^{\eta_{S,T}} \partial \sigma^{\eta_{T,N_m}}} \right) / \partial \epsilon_{\eta_{T,N_m}^q}^- &= \frac{\partial^2 \Phi}{\partial \sigma^{\eta_{S,T}} \partial \sigma^{\eta_{T,N_m}}} \frac{-1}{\Xi_\epsilon} \frac{\epsilon_{\eta_{T,N_m}^{2/q}}^- - \epsilon_{\eta_{T,N_m}^{2/q}}^+}{\epsilon_{\eta_{T,N_m}^q}^- - \epsilon_{\eta_{T,N_m}^q}^+} \quad (4.24) \\ &> 0 \end{aligned}$$

The impact of a higher  $\epsilon_{\eta_{T,N_m}^q}^-$  on the size of the complementarity is unambiguously positive. Hence, a higher elasticity of the hiring rate with respect to the wage amplifies the size of the complementarity for a given level of the subsidy.

**Training Elasticity** Also the elasticity of the training rate with respect to the wage,  $ela(\eta_{S,T}) = (\partial\eta_{S,T}/\eta_{S,T})/(\partial w_v/w_v)$ , does not directly affect the size of the complementarity. However, there is an indirect impact via the limits of the uniform distribution. Therefore, the impact the parameter  $\epsilon_{\eta_{S,T}}^-$  on the size of the complementarity is calculated:

$$\partial\left(\frac{\partial^2 \Phi}{\partial \sigma^{\eta_{S,T}} \partial \sigma^{\eta_{T,Nm}}}\right)/\partial \epsilon_{\eta_{S,T}}^- = \frac{\partial^2 \Phi}{\partial \sigma^{\eta_{S,T}} \partial \sigma^{\eta_{T,Nm}}} \frac{-1}{\epsilon_{\eta_{S,T}}^- - \epsilon_{\eta_{S,T}}^+} > 0 \quad (4.25)$$

Again, the impact of a higher  $\epsilon_{\eta_{S,T}}^-$  on the size of the complementarity is unambiguously positive. Hence, a higher elasticity of the training rate with respect to the wage amplifies the size of the complementarity for a given level of the subsidy.

## 4.5 Numerical Evaluation

### 4.5.1 Calibration

The calibration is almost similar to the calibration in the previous chapter. However, there are differences, in particular with respect to the transition rates. Given this and for the sake of traceability, the full calibration is illustrated.

In the initial steady state (i.e. in the absence of subsidies), some variables are treated as exogenous. However, in the presence of subsidies, these variables are treated as endogenous. One example is the training rate  $\eta_{S,T}$ . With respect to the initial steady state, the training rate is treated as an exogenous variable so that the limits of the corresponding distribution for the random costs can be derived. However, in the presence of subsidies, the limits are treated as given and the training rate is a function of the subsidies. Table 4.1 and Table 4.2 summarize all variables and parameters, which are set exogenously in the initial steady state.

The model is calibrated for Germany with a year as unit of time. The real annual interest rate is set at 4.0%, which leads to a discount factor of  $\delta = 0.962$ . For simplicity, the coefficient of relative risk aversion is set at  $\gamma = 0$ . The death rate is set at  $\rho = 0.023$ , which corresponds to an average working lifetime of about 44 years.<sup>123</sup> The number of periods,  $p$ , a person is engaged in vocational training is set at 3.<sup>124</sup> The drop-out rate  $\theta$ , is set at 0.037. The value for the death rate and the drop-out rate imply that roughly 17% of the apprentices do not finish vocational training successfully, which is in line with the empirical data.<sup>125</sup> According to Wilke's

<sup>123</sup>The value is roughly in line with the empirical data. Working life begins at the age of 17 and according to Brussig and Wojtkowski (2006), retirement takes places between 62 and 63.

<sup>124</sup>This corresponds to the typical length of training within the dual system in Germany.

<sup>125</sup>Given the data for the number of new apprentices and the number of successful apprentices

Kaplan-Meier functions for Germany (Wilke, 2005), the hiring rates for the high-skilled, medium-skilled and the low-skilled are set at  $\eta_h = 0.55$ ,  $\eta_m = 0.59$  and  $\eta_l = 0.49$ , respectively. Moreover, according to the BMBF (2004, 2007) about 25% of the people who have successfully finished vocational training become unemployed, thus the corresponding hiring rate,  $\eta_{T,N_m}$  is set at 0.75. However, about 53% of all successful apprentices stay in the firm in which they have been trained,<sup>126</sup> this part of the hiring rate,  $\eta_{T,N_m}^1 = 0.3975$ , can be regarded as take-over rate. The residual fraction is hired by another firm,  $\eta_{T,N_m}^2 = 0.3525$ .

The labor market states are defined and quantified as in the previous chapter. The low-skilled labor force ( $N_l + U_l$ ) includes people with an educational attainment corresponding to less than upper-secondary education.<sup>127</sup> The medium-skilled labor force ( $N_m + U_m$ ) contains all people with vocational upper secondary education. People with post-secondary and tertiary education are considered as being high-skilled ( $N_h + U_h$ ). The corresponding values can be calculated on the basis of data from the OECD (1999 to 2005).<sup>128</sup>

Based on data from the German national accounts, the aggregate productivity,  $a$ , is set at 54,243 EUR and the aggregate producer wage,  $w$ , which is calculated as average gross wage per employee plus social security contributions, is set at 32,520 EUR.<sup>129</sup> In order to get the wages for different skill groups, the corresponding OECD indices for the relative earnings of the population with income from employment are used. They yield the following ratios:  $w_h/w = 1.27$ ,  $w_m/w = 0.92$  and  $w_l/w = 0.72$ .<sup>130</sup> According to Beicht and Walden (2002), the wage of a person being engaged in vocational training is set at  $w_v = 8,269$  EUR and the productivity of an apprentice is set at  $a_v = 7,730$  EUR. Moreover, according to Beicht and Walden (2002) the annual non-wage costs of training are 8,166 EUR. As 30% (see Dohmen and Hoi, 2004) are tax-deductible, the relevant costs are set at  $k_v = 5,717$  EUR.

The net replacement rates are set at  $\beta_l = 0.7825$ ,  $\beta_m = 0.6825$  and  $\beta_h = 0.6467$ .<sup>131</sup> According to Chen and Funke (2005), the hiring cost is set at 10% of the wage and the firing cost is set at 60% of the wage, thus the corresponding parameters

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(Statistisches Bundesamt, 2006), the value can be confirmed.

<sup>126</sup>BMBF (2004, 2007).

<sup>127</sup>This classification corresponds to the conventional definition which classifies people with an educational attainment corresponding to at most level 2 of the International Standard Classification of Education as low-skilled.

<sup>128</sup>See Appendix 7.2.3.

<sup>129</sup>Statistisches Bundesamt (2008). The values are calculated as averages of the corresponding annual data for the period 2000-2007.

<sup>130</sup>See OECD (1999-2005). These values imply a ratio  $w_m/w_l = 1.26$ , which is in line with the corresponding data reported by Wienert (2006).

<sup>131</sup>The values are net replacement rates (unweighted average across six family types) of workers with 67, 100 and 150 percent of average productivity, see OECD (2006).

are  $c_\eta = 0.1$  and  $c_\varphi = 0.6$ . In order to calculate the tax rates, the income tax scale of the year 2002, described in Boss and Elendner (2003), is used. It illustrates the progressive character of the German tax system. The following ratios are obtained:  $t_h/t_l = 1.437$  and  $t_m/t_l = 1.178$ . Given the data for the transition rates between the training system and the labor market according to Reinberg and Hummel (2006), the training rate,  $\eta_{S,T} = 0.70$ , and the ratio  $\eta_{U,T}/\eta_{N,T} = 3.6$ , can be calculated.

variable / parameter	description	value	source
$\delta$	discount factor	0.962	standard value
$\gamma$	CRRA	0	assumption
$p$	periods of vocational training	3	standard value
$\rho$	death rate	0.023	to match the working life
$\theta$	drop-out rate of training	0.037	to match the empirical data
$\eta_h$	hiring rate (high-skilled)	0.55	Wilke (2005)
$\eta_m$	hiring rate (medium-skilled)	0.59	
$\eta_l$	hiring rate (low-skilled)	0.49	
$\eta_{T,N_m}^1$	take-over rate	0.3975	BMBF (2004, 2007)
$\eta_{T,N_m}^2$	hiring rate after training	0.3525	to match the empirical data
$\eta_{S,T}$	training rate	0.70	own calculations
$\eta_{U,T}/\eta_{N,T}$	ratio of the training rates	3.6	based on Reinberg and Hummel (2006)
$a$	aggregate productivity	54, 243	Statistisches Bundesamt (2008)
$w$	aggregate producer wage	32, 520	
$w_h/w$	relative earnings (high-skilled)	1.27	OECD (1999-2005)
$w_m/w$	relative earnings (medium-skilled)	0.92	
$w_l/w$	relative earnings (low-skilled)	0.72	

Table 4.1: Exogenous Values in the Initial Steady State (1)

Based on these values and the equations of the model, the bargaining power, the productivities for the different skill levels, the tax rates, and the missing transition rates for the initial steady state, can be calculated. Finally, the parameters with respect to the uniform distribution of the random costs  $\epsilon_t$ , have to be determined, e.g. the lower and upper limits of the distribution functions. For the sake of simplicity, the lower limits,  $\epsilon_{\eta_{S,T}}^-$  and  $\epsilon_{\eta_{T,N_m}^q}^-$  for  $q = 1, 2$ , are set at 0. The upper limits are not set exogenously; rather they are the implied results of the calibration. As all other variables and parameters of the equations determining the hiring rates and the training rate, respectively, as well as the hiring rates and the training rate themselves are given for the initial steady state, one can easily solve the equations determining

variable / parameter	description	value	source
$a_v$	productivity of an apprentice	7,730	Beicht and Walden (2002)
$w_v$	wage of an apprentice	8,269	
$k_v$	non-wage costs of training	5,717	Beicht and Walden (2002), Dohmen and Hoi (2004)
$\beta_h$	replacement rate (high-skilled)	0.6467	OECD (2006)
$\beta_m$	replacement rate (medium-skilled)	0.6825	
$\beta_l$	replacement rate (low-skilled)	0.7825	
$c_\eta$	hiring cost in relation to the wage	0.1	Chen and Funke (2005)
$c_\varphi$	firing cost in relation to the wage	0.6	
$t_h / t_l$	tax rate ratio (1)	1.437	Boss and Elendner (2003)
$t_m / t_l$	tax rate ratio (2)	1.178	
$\epsilon_{\eta_{S,T}}^-$	lower limit of the distribution	0	assumptions
$\epsilon_{\eta_{T,N_m}^1}^-$	lower limit of the distribution	0	
$\epsilon_{\eta_{T,N_m}^2}^-$	lower limit of the distribution	0	

Table 4.2: Exogenous Values in the Initial Steady State (2)

the transition rates to get the corresponding upper limits: eq. (4.21) for  $\epsilon_{\eta_{S,T}}^+$ , eq. (4.17) for  $\epsilon_{\eta_{T,N_m}^1}^+$  and eq. (4.18) for  $\epsilon_{\eta_{T,N_m}^2}^+$ .

To check, whether the values of the limits are appropriate, the corresponding elasticities with respect to the subsidies (i.e. temporary wage reductions) are calculated:  $ela(\eta_{T,N_m}^1) = -0.170$ ,  $ela(\eta_{T,N_m}^2) = -0.173$  and  $ela(\eta_{S,T}) = -0.669$ . Given the empirical estimates, as summarized in Orszag and Snower (1999b) the elasticities range between  $-4.0$  and  $-0.5$ . However, these values refer to a permanent change of the wage. The elasticities with respect to the short-term subsidies are significantly smaller.<sup>132</sup> Thus, the calculated elasticities can be justified.

All derived values are summarized in Table 4.3.

#### 4.5.2 Numerical Results

In the following calculations it is assumed that for each subsidy either 0 or 5,000 EUR per person can be spent. As the hiring subsidy is paid only for one period the possible amounts are therefore also 0 or 5,000 EUR. In contrast, the training subsidy is paid over the whole phase of vocational training, therefore the annual payment for each apprentice is 1,771 EUR, which implies – for the full model – a total amount of 5,000 EUR over the whole phase of training.<sup>133</sup> Then, the impact of the subsidies

<sup>132</sup>See Snower (1996).

<sup>133</sup>Recall that an apprentice continues training with a probability of  $(1 - \rho - \theta)$  after each period. Given the values for  $\rho$  and  $\theta$  as well as the fact that training takes 3 periods, there is: 5,000 / [

variable / parameter	description	value	basis of calculation
$U_l$	low-skilled unemployment	0.034	see Appendix 7.2.3
$N_l$	low-skilled employment	0.150	
$U_m$	medium-skilled unemployment	0.067	
$N_m$	medium-skilled employment	0.668	
$T$	people in vocational training	0.057	
$S$	people in school	0.024	
$\mu$	bargaining power	0.20	eq. (4.14)
$a_h$	productivity (high-skilled)	75, 877	for $i = l, m, h$
$a_m$	productivity (medium-skilled)	50, 621	and $a =$
$a_l$	productivity (low-skilled)	30, 364	$\frac{a_l N_l + a_m N_m + a_h N_h + a_v T}{N_l + N_m + N_h + T}$
$t_h$	tax rate (high-skilled)	0.070	ratios of tax rates
$t_m$	tax rate (medium-skilled)	0.057	and eq. (4.4), with:
$t_l$	tax rate (low-skilled)	0.049	$\sigma^{\eta_{S,T}} = \sigma^{\eta_{T,N_m}} = 0$
$\varphi_m$	firing rate (medium-skilled)	0.055	see Appendix 7.2.3
$\varphi_l$	firing rate (low-skilled)	0.096	3rd and 4th eq. of
$\eta_{U,T}$	training rate (low-skilled unempl.)	0.041	matrix $MT$ and ratio
$\eta_{N,T}$	training rate (low-skilled empl.)	0.012	of the training rates
$\epsilon_{\eta_{S,T}}^+$	upper limit of the distribution	48, 063	eq. for the transition
$\epsilon_{\eta_{T,N_m}}^+$	upper limit of the distribution	441, 211	rate for 2 different
$\epsilon_{\eta_{T,N_m}^2}^+$	upper limit of the distribution	489, 072	wage levels and
			eq. for the elasticity

Table 4.3: Derived Values in the Initial Steady State



on aggregate income is calculated for three alternatives: either only one subsidy is implemented or both subsidies are implemented simultaneously. The size of the complementarity is calculated as follows: First, the percentage increase in aggregate income is calculated for the two cases, in which only one subsidy is implemented, and then, the sum is calculated. Second, the percentage increase in aggregate income is calculated given that both subsidies are implemented simultaneously. Third, it is calculated by how much (in percent) the increase in aggregate income, given that both subsidies are implemented simultaneously, is higher than the sum of the separate effects. Moreover, a similar calculation is conducted for employment.

Next, the interactions (illustrated by the size of the complementarity) between the hiring and training subsidy are analyzed for the simplified model, presented in Section 4.4.1. Then, the complexity of the model is gradually increased. The approach allows us to analyze the effects of different components of the model.

**Simplified Model** First, the numerical solution of the simplified model, presented in Section 4.4.1, is calculated, i.e. it is assumed that (i) there are no taxes:  $t_i = 0$  with  $i = l, m, h$ , (ii) training takes only one period:  $p = 1$ , (iii) apprentices do not drop out of training:  $\theta = 0$ , and (iv) agents are risk neutral:  $\gamma = 0$ .<sup>134</sup> For this case, the impact of the subsidies on aggregate income and employment is shown in Table 4.4.<sup>135</sup> The analytical solution is confirmed by the numerical results. The

increase in ...	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,Nm}} = 0$	$\sigma^{\eta_{S,T}} = 0$ $\sigma^{\eta_{T,Nm}} = 5,000$	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,Nm}} = 5,000$	size of the complementarity in %
	in %			
income	0.693245	1.2743	1.9703	0.139917
employment	0.486976	1.01081	1.50759	0.654614

Table 4.4: The Size of the Complementarity for a Simplified Version of the Model

two subsidies are complementary concerning aggregate income. However, the size of the complementarity is quite weak. The size of the complementarity is significantly higher concerning employment.

To explain the result, in a first step, the effect of the three policies on the income

$$\sum_{c=1}^3 (1 - \rho - \theta)^{c-1} = 1,771.$$

<sup>134</sup>Recall that the elasticities of the hiring rates and the training rate are not set exogenously but they are the result of the calibration. However, for  $\theta = 0$  and  $p = 1$ , the values would change. In order to avoid this effect, the lower limits of the distribution with respect to the random costs are modified so that the initial values for the elasticities are achieved.

<sup>135</sup>With respect to the full model,  $\sigma^{\eta_{S,T}} = 1,771$  EUR implies that the total amount of training subsidies corresponds to the total amount of hiring subsidies. For  $\theta = 0$  and  $p = 1$ , this is not the case. Setting also  $\sigma^{\eta_{S,T}} = 5,000$  EUR increases the size of complementarity to 1.2 % with respect to employment and to 0.2 % with respect to income.

of the employed only is analyzed. For every policy, the increase in income of the employed is higher than the increase in employment. The result is not surprising as the group of employees, which has the higher weight (i.e. income) when calculating aggregate income, increases (i.e. the medium-skilled employees). However, the size of the complementarity with respect to the income of the employees is lower than the size of the complementarity with respect to employment. This can be explained by the impact of the subsidies on the average income per employee. The increase in the average income given a simultaneous implementation of the two subsidies is lower than in sum of the separate effects.

Second, it has to be taken into account that aggregate income also contains the income of the unemployed. Therefore, also the impact of the three policies on the income of the unemployed only is analyzed. All three policies have a negative effect on unemployment and thereby a negative effect on the income of the unemployed. Moreover, the negative impact (in absolute terms) in the case of a simultaneous implementation is higher than the sum of the separate effects.

Finally, both factors – the lower complementarity concerning the income of the employed and the negative impact with respect to the income of the unemployed – explain, why the complementarity of the policies concerning aggregate income is lower than concerning employment.

**Model with Realistic Calibration of the Training Phase** Next, the absence of taxes is still assumed. However, with respect to vocational training, the values are adjusted to realistic ones ( $\theta = 0.037$  and  $p = 3$ ). The impact of the subsidies on aggregate income and employment, respectively, is shown in Table 4.5. As in the

increase in ...	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 0$	$\sigma^{\eta_{S,T}} = 0$ $\sigma^{\eta_{T,N_m}} = 5,000$	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 5,000$	size of the complementarity
	in %			in %
income	0.674265	0.428262	1.10883	0.572237
employment	0.469391	0.334023	0.81044	0.874502

Table 4.5: The Size of the Complementarity for a Realistic Calibration of the Training Phase

previous simulation, there are complementarities with respect to employment and aggregate income. Moreover, the complementarity with respect to employment is again lower than the complementarity with respect to aggregate income. However, now, the complementarities are significantly higher than in the previous simulation. The difference can be explained as follows. Now, as training takes  $p = 3$  periods and training subsidies are paid in every period of training, the amount of training

subsidies is higher than in the simplified model (with  $p = 1$ ). In particular, the total effective amount of training subsidies per person corresponds to the amount of hiring subsidies per person; hence the total effective amount of training subsidies is larger than in the previous simulation. Given this, one may expect that the effect of training subsidies on employment and aggregate income is significantly higher than in the previous simulation. However, this is not the case. It has to be taken into account that – for  $p = 3$  – also the total deficit of the employer with respect to vocational training is higher as the phase of training is longer. In contrast to the higher amount of training subsidies, this effect – on its own – has a negative impact on the training rate,  $\eta_{S,T}$ . The analysis of the training rate,  $\eta_{S,T}$ , reveals that in total, both effects almost compensate each other. Finally, the modified calibration also influences the initial levels of the different labor market states, which explains the difference of the growth rates of employment and finally of income compared to the previous simulation.

The critical reader may argue that the fraction of apprentices, which drops out of vocational training,  $\theta$ , is not exogenous but has to be treated as a function of the hiring subsidy,  $\sigma^{\eta_{T,N_m}}$ , i.e. hiring subsidies do not only influence the demand for successful apprentices but via  $\theta$  they also influence the number of apprentices. The reasoning would be as follows: a subsidy rate raises the hiring rates  $\eta_{T,N_m}^1$  and  $\eta_{T,N_m}^2$  and thereby the probability of the apprentice to get a medium-skilled job. The improvement of the income perspective could be expected to reduce the incentive to drop out of training. Therefore  $\theta$  should be treated as an endogenous variable with  $\frac{\partial \theta}{\partial \sigma^{\eta_{T,N_m}}} < 0$ . However, studies trying to explain, why apprentices drop out of training, do not give any argument to think that financial incentives would reduce  $\theta$ .<sup>136</sup> Thus,  $\theta$  is not treated as a function of the hiring subsidy.

**Model with Taxes** The next step is the introduction of taxes. For the moment, it is assumed that only the expenditures for unemployment benefits have to be financed via taxes. According to eq. (4.4), the tax rates are set in a way, which ensures that the tax receipts of the government equal its expenditures for unemployment benefits; however, the expenditures for subsidies do not affect the tax rates, i.e. subsidies are assumed to be 0 in eq. (4.4). The impact of the subsidies on aggregate income and employment is shown in Table 4.6. Again, there are complementarities and the complementarities with respect to employment are higher than the complementarities

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<sup>136</sup>See BMBF (2003) for a survey of reasons and their importance. One main reason to drop out of training is a problem in the relationship between the apprentice and the instructor in the firm. Many apprentices who drop out of training do not intend to finally stop training but they try to get a training position somewhere else.

increase in ...	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 0$	$\sigma^{\eta_{S,T}} = 0$ $\sigma^{\eta_{T,N_m}} = 5,000$	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 5,000$	size of the complementarity
	in %			in %
income	0.974119	0.642619	1.62761	0.67228
employment	0.469391	0.334023	0.81044	0.874502

Table 4.6: The Size of the Complementarity in the Presence of Taxes

with respect to aggregate income. For employment, the results are absolutely equal to the results in the previous simulation. The introduction of taxes does not affect the producer wages according to eq. (4.14). Hence, also the hiring rates,  $\eta_{T,N_m}^1$  and  $\eta_{T,N_m}^2$ , as well as the training rate,  $\eta_{S,T}$ , are not affected. Finally, the introduction of taxes has no impact on employment. With respect to aggregate income, the effect of all three policies is higher than in the previous simulation. The result is not surprising because only the unemployment benefits have to be financed via taxes but not the subsidies. As in the previous simulation, the implementation of subsidies increases aggregate employment and reduces aggregate unemployment. Thus, the number of people getting (higher) wages increases and the number of people requiring the lower unemployment benefits decreases. Moreover, and in contrast to the previous simulation, there is an additional positive effect on aggregate income. By leading to a fall in the number of people requiring unemployment benefits, subsidies generate a revenue for the government. Consequently, – compared to the previous simulation, in which tax rates were ignored and therefore not directly affected by subsidies – the tax rates can be reduced, so the consumer wages and finally aggregate income increases. Finally, also the size of the complementarity with respect to aggregate income is higher than in the previous simulation.

**Model with a Government Budget Constraint** In the next step, the impact of the government budget constraint is analyzed. In contrast to the previous simulation, also subsidies have to be financed by taxes. According to eq. (4.4), the tax rates are set in a way, which ensures that the tax receipts of the government equal its total expenditures, i.e. the sum of unemployment benefits and subsidies. The impact of the subsidies on aggregate income and employment is shown in Table 4.7. With respect to employment, the results are absolutely equal to the results in the previous simulation for the same reason as before. With respect to aggregate income, there are two differences.

First, the effects of the three policies are smaller than in the previous simulation. As before, the subsidies induce a reduction in the tax rates, as they (i) reduce unemployment and thereby the number of unemployment benefit recipients and (ii)

increase in ...	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 0$	$\sigma^{\eta_{S,T}} = 0$ $\sigma^{\eta_{T,N_m}} = 5,000$	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 5,000$	size of the complementarity
	in %			in %
income	0.730406	0.474419	1.18343	-1.77584
employment	0.469391	0.334023	0.81044	0.874502

Table 4.7: The Size of the Complementarity in the Presence of the Government Budget Constraint

raise employment and thereby the number of tax payers. Hence, aggregate income increases. However, the positive effect is now reduced by a negative effect. In the presence of the government budget constraint and in contrast to the previous simulation, not only the unemployment benefits but also the subsidies have to be financed by taxes. The subsidy-induced reduction of the expenditures for unemployment benefits can be reduced or even overcompensated by the expenditures for the subsidies. As in the previous simulation, the tax rates are reduced, but the reduction of the tax rates and thus the increase in aggregate income are lower. In the previous simulation the implementation of subsidies created a government budget deficit as the tax receipts only had to cover the expenditures for the unemployment benefits but not the expenditures for subsidies. If the aggregate income in the previous simulation would have been adjusted by the government deficit, the effect of the three policies on aggregate income would be the same as in the simulation being based on a government budget constraint.

The second difference is the absence of the complementarity with respect to aggregate income. To explain this result, the impact of the subsidies on the subsidy-induced revenues for the government is analyzed. As the revenues are transferred to the people via a tax reduction, the size of the revenues equals the increase in aggregate income. The absence of the complementarity is caused by the non-linearity of the subsidy-induced revenues for the government (see Figure 4.2).<sup>137</sup> The higher the level of one subsidy, the lower is the additional revenue caused by the other subsidy. Moreover, the additional impact of the second subsidy on the revenues can also be negative. Moreover, for higher levels, the subsidies do not create revenues and thereby they do not contribute to an increase in income; instead, they are no more self-financing. In particular, the full implementation of both subsidies requires additional tax receipts. Hence, the tax rates cannot decrease as much as in the previous simulation. Therefore, the increase in aggregate income in the case of a simultaneous implementation of the subsidies is lower than the sum of the increases

<sup>137</sup>Recall that the relevant population is normalized to 1, which has an impact on the size of the revenues. The relevant aspect being illustrated by the figure is not the absolute size of the revenues but the relative size for different combinations of the subsidies.

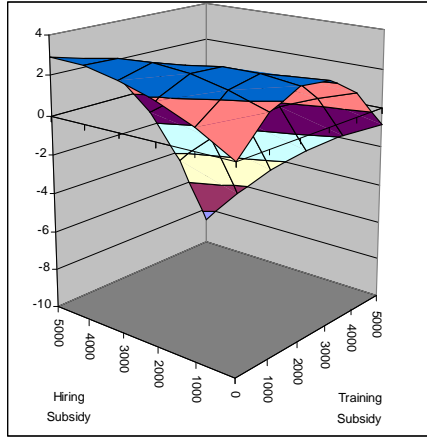


Figure 4.2: Subsidy-Induced Revenues (in EUR) for Different Subsidy Levels

in the case of a separate implementation of each subsidy.

#### 4.5.3 Robustness Checks

Next, robustness checks with respect to the hiring elasticities and the training elasticity are conducted.<sup>138</sup>

**Hiring Elasticities** First, we regard the hiring rate,  $\eta_{T,Nm}^1$  (take-over rate), and modify its elasticity with respect to the subsidy. The results for the effects of the three different policies on aggregate income and employment are illustrated in Table 4.8. A higher elasticity (in absolute terms),<sup>139</sup>  $ela(\eta_{T,Nm}^1)$ , increases the effect of the

$ela$ ( $\eta_{T,Nm}^1$ )	increase in ...	$\sigma^{\eta_{S,T}} = 1,771$	$\sigma^{\eta_{S,T}} = 0$	$\sigma^{\eta_{S,T}} = 1,771$	size of the complementarity in %
		$\sigma^{\eta_{T,Nm}} = 0$	$\sigma^{\eta_{T,Nm}} = 5,000$	$\sigma^{\eta_{T,Nm}} = 5,000$	
		in %			
-0.170	income	0.730406	0.474419	1.18343	-1.77584
-0.500		0.730406	1.10374	1.80350	-1.67113
-0.170	employ- ment	0.469391	0.334023	0.81044	0.874502
-0.500		0.469391	0.670322	1.15386	1.24144

Table 4.8: The Effect of Subsidies for Different Levels of the Hiring Elasticity (1)

hiring subsidy on aggregate income and employment. However, the impact of the training subsidy on income and employment is independent of the elasticity of the

<sup>138</sup>The elasticities are modified indirectly. With respect to the initial steady state, the lower limit of the corresponding uniform distribution is modified so that the new value for the elasticity is obtained. The same procedure has been used in section 4.4.2.

<sup>139</sup>Also in the following the notion "elasticity" stands for elasticity in absolute terms.

hiring rate. With respect to employment, the size of the complementarity increases. With respect to aggregate income the negative size of the complementarity decreases.

Second, the elasticity of the hiring rate,  $\eta_{T,Nm}^2$ , is modified. It determines the hiring of successful apprentices by firms, which do not conduct vocational training. The results for the effects of the three different policies on aggregate income and employment, respectively, are illustrated in Table 4.9. Again, a higher elasticity,

$ela$ ( $\eta_{T,Nm}^2$ )	increase in ...	$\sigma^{\eta_{S,T}} = 1,771$	$\sigma^{\eta_{S,T}} = 0$	$\sigma^{\eta_{S,T}} = 1,771$	size of the complementarity in %
		$\sigma^{\eta_{T,Nm}} = 0$	$\sigma^{\eta_{T,Nm}} = 5,000$	$\sigma^{\eta_{T,Nm}} = 5,000$	
in %					
-0.173	income	0.730406	0.474419	1.18343	-1.77584
-0.50		0.730406	0.507838	1.21930	-1.52984
-0.173	employ- ment	0.469391	0.334023	0.81044	0.874502
-0.50		0.469391	0.373991	0.853341	1.18085

Table 4.9: The Effect of Subsidies for Different Levels of the Hiring Elasticity (2)

$ela(\eta_{T,Nm}^2)$ , increases the effect of the hiring subsidy on aggregate income and employment. Moreover, with respect to employment, the size of the complementarity increases. With respect to aggregate income the negative size of the complementarity decreases. However, compared to a variation of the hiring elasticity,  $ela(\eta_{T,Nm}^1)$ , the effects are smaller. The difference can be explained by regarding eq. (4.21). The training rate is affected by the hiring rate  $\eta_{T,Nm}^1$ , but not by the hiring rate  $\eta_{T,Nm}^2$ . Thus, in contrast to a higher hiring elasticity,  $ela(\eta_{T,Nm}^2)$ , a higher hiring elasticity,  $ela(\eta_{T,Nm}^1)$  has an additional positive effect on employment and aggregate income as it also increases the impact of the hiring subsidies on the training rate.<sup>140</sup>

**Training Elasticity** Next, the elasticity of the training rate,  $\eta_{S,T}$ , with respect to the subsidy is modified. The results for the effects of the three different policies on aggregate income and employment are illustrated in Table 4.10. A higher elasticity of

$ela$ ( $\eta_{S,T}$ )	increase in ...	$\sigma^{\eta_{S,T}} = 1,771$	$\sigma^{\eta_{S,T}} = 0$	$\sigma^{\eta_{S,T}} = 1,771$	size of the complementarity in %
		$\sigma^{\eta_{T,Nm}} = 0$	$\sigma^{\eta_{T,Nm}} = 5,000$	$\sigma^{\eta_{T,Nm}} = 5,000$	
in %					
-0.669	income	0.730406	0.474419	1.18343	-1.77584
-1.25		1.55918	0.995328	2.52677	-1.08592
-0.669	employ- ment	0.469391	0.334023	0.81044	0.874502
-1.25		0.882265	0.589173	1.49092	1.32421

Table 4.10: The Effect of Subsidies for Different Levels of the Training Elasticity

<sup>140</sup>The fact that the initial value for  $\eta_{T,Nm}^1$  (0.3975) is higher than the initial value for  $\eta_{T,Nm}^2$  (0.3525) does not explain the difference.

the training rate,  $ela(\eta_{S,T})$ , increases the effects of the training subsidy on aggregate income and employment. Moreover, with respect to employment, the size of the complementarity increases. Compared to the previous robustness check with respect to the hiring elasticity, there is one difference, which deserves attention. The effect of a higher hiring elasticity only occurs in the presence of hiring subsidies. In contrast, the effect of a higher training elasticity also occurs in the absence of training subsidies. A higher training elasticity causes an additional increase in the number of people entering vocational training and thereby the number of people getting hiring subsidies rises. Finally, given a higher training elasticity, even the effect of the hiring subsidies on employment and aggregate income increases.

#### 4.5.4 Welfare Analysis

The critical reader may argue that aggregate income given by eq. (4.22) is not an appropriate measure of welfare as it is not based on utility. Therefore, the impact of the subsidies is calculated on a utility-based concept of welfare, where  $\Omega$  denotes welfare. The variation of welfare is quantified by using the concept of "consumption equivalents".<sup>141</sup> In particular, the variation of welfare due to a given policy reform is quantified by asking by how much an individual's consumption has to be increased in the absence of the policy reform so that her present value of lifetime utility equals that under a specific policy reform. The utility function is given by:

$$u_{i,t}(C_{i,t}) = \frac{1}{1-\gamma} [C_{i,t}(1+\lambda)]^{1-\gamma} \text{ with } i = l, m, h \quad (4.5a)$$

Given this, eq. (4.22) has to be modified as follows:

$$\begin{aligned} \Omega = T \frac{1}{1-\gamma} (w_v(1+\lambda))^{1-\gamma} \\ + \sum_{i=m,l,h} N_i \frac{1}{1-\gamma} (w_i(1-t_i)(1+\lambda))^{1-\gamma} + U_i \frac{1}{1-\gamma} (\beta_i w_i(1-t_i)(1+\lambda))^{1-\gamma} \end{aligned} \quad (4.22a)$$

Here,  $\lambda$  is the consumption equivalent, e.g.  $\lambda = 0.1$  implies that if a certain subsidy is implemented, an individual in the population considered will experience an increase in welfare due to the subsidy that is equivalent to receiving a 10% higher consumption in the initial steady state.

The impact of the subsidies on the consumption equivalent and thereby on welfare is shown in Table 4.11 for different degrees of risk aversion, i.e. the coefficient of relative risk aversion,  $\gamma$  is also set at 1.5 and 2, respectively.<sup>142</sup>

<sup>141</sup>This is a common concept in the literature. See e.g. Conesa and Krueger (1999).

<sup>142</sup>The values are located within a reasonable scope. According to Rodepeter (1999) and Dohmen



These values are relatively low, but taking into account the whole calibration, they can be justified. The period of analysis and thus the minimum duration of unemployment in the model is one year. Thus, the risk of unemployment is much higher than in the real world where agents could leave unemployment before the end of a year. In reality they therefore have a higher possibility to smooth income. Taking this into account, calibrating the utility function with a relatively low degree of risk aversion is justified as it compensates the higher risk in the model.

$\lambda$ in % for	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 0$	$\sigma^{\eta_{S,T}} = 0$ $\sigma^{\eta_{T,N_m}} = 5,000$	$\sigma^{\eta_{S,T}} = 1,771$ $\sigma^{\eta_{T,N_m}} = 5,000$	size of the complementarity in %
$\gamma = 0$	0.730406	0.474419	1.18343	-1.77584
$\gamma = 1.5$	0.674668	0.442559	1.10189	-1.37317
$\gamma = 2$	0.502534	0.336615	0.822919	-1.93411

Table 4.11: The Size of the Complementarity with Respect to Welfare

The results for  $\gamma = 0$  correspond to the results for aggregate income in the previous simulation. The results reveal that a higher degree of risk aversion reduces the impact of each policy. This result can be explained by the aggregation effect. When calculating welfare according to eq. (4.22a), a higher degree of risk aversion is equal to a relatively higher weight on low income. However, both policies reduce the number of low-skilled people and thereby the number of people with a low income. Finally, a higher degree of risk aversion increases the weight of the decreasing group of people with a low income. Hence, aggregate welfare declines.

## 4.6 Concluding Thoughts

This chapter examines the interactions between employment policies and training policies. In particular, it is analyzed, whether there are complementarities with respect to income and employment. Here, the definition of complementarity is straightforward: two policies are complementary, when the effect of each policy on, say, aggregate income is larger when it is implemented in conjunction with the other policy than in isolation. Ignoring possible interactions could distort the evaluation of the policies.

As an example for employment and training policies, hiring subsidies and training subsidies are considered. They play a prominent role within the active labor market policy in many OECD countries, where high unemployment is one of the most pressing economic problems, especially, for the low-skilled people. In the model, et al. (2006), the limits for CRRA are 1 and 5.

the effects of subsidies, which are expected to mitigate this problem, are analyzed. Training subsidies are paid to employers to increase their incentive for providing vocational training. Hiring subsidies are meant to increase the transition from apprenticeship to work. They are provided for a limited period of time, in which they drive a wedge between the income, the worker receives, and the labor costs the employer is confronted with.

This analysis tackles, in particular, the assessment of interactions by presenting a macro model of the labor market and the training system that allows us to quantify each effect being associated with the two subsidies when implemented in isolation and when implemented in conjunction. Taking the possibility of interactions into account helps to avoid distortions in the evaluation of labor market policies, policy makers are increasingly interested in. Moreover, to make the analysis useful for policy makers, the model takes a variety of common labor market imperfections as given.

By evaluating the policies within a simplified model, it is shown that there are good theoretical reasons for these policies to be complementary. The simulation results reveal that there are significant interactions between hiring and training subsidies. However, complementarities between the two policies are quite weak or even absent (with respect to income). When comparing the results for different institutional and policy features of the economy, significant differences can be observed. In particular, the existence of complementarities with respect to aggregate income depends on the financial constraints of the government. In the absence of the government budget constraint, there are complementarities. Independent of the results for the specific policy examples, this analysis provides a methodology for examining policy interactions, which may be useful well beyond the bounds of hiring and training subsidies.

## 5 Conclusion

This dissertation analyzes the impact of the ongoing globalization of labor markets and its policy implications. In particular, an enhanced global engagement of emerging economies is supposed to have important macroeconomic effects. These effects have drawn increasing attention from policy makers. One significant and already long-lasting debate refers to the impact of an increasing globalization on wages and employment. In this context, already Freeman (1995) asked: "Are Your Wages Set in Beijing?" and provided a survey of the underlying controversial debate at that time. A recent contribution by Fehr et al. (2008) concludes that in a time of ongoing globalization, the income of low- and high-skilled workers will continue to diverge. Besides the impact on wages and employment, the ongoing globalization is also supposed to have reduced inflation and increased macroeconomic activity. In all cases, there are significant policy implications, in particular for monetary policy and labor market policy.

Against this background, the dissertation analyzes (*i*) the contribution of an increasing global labor supply to the "Roaring Nineties"<sup>143</sup>, i.e. its impact on wages, inflation and macroeconomic activity, and the implications for monetary policy, (*ii*) the impact of low-wage subsidies on skill formation, aggregate employment and welfare given that low-wage subsidies are supposed to be a popular tool to assure a certain income level for low-skilled and to support the employment of low-skilled in the presence of a decreasing labor demand, and (*iii*) the effectiveness of hiring and training subsidies in stimulating employment and income, and in particular the interactions between these policies.

Chapter 2 analyzes the impact of an increasing global labor supply on wages, inflation and macroeconomic activity and thereby went beyond the traditional three explanations of the "Roaring Nineties" such as (*i*) good luck, (*ii*) financial innovations and improved inventory management techniques, and (*iii*) improved macroeconomic policies, i.e., in particular, a monetary policy, which focused on price stability.

The analysis reveals that the increase in global labor supply can explain the combination of high macroeconomic activity and low inflation in recent years. The increase in the effective labor supply put downward pressure on wages and ultimately inflation. The analysis illustrates that a main transmission channel is the development of the bargaining power of the employees in combination with the initially

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<sup>143</sup>This term is often used to describe the boom at that time, see e.g. Stiglitz (2003) as well as Krueger and Solow (2002).

lower bargaining power of the employees in the emerging economies. Given that workers in advanced economies can be more easily replaced by workers in emerging economies due to increasing opportunities for trade, the bargaining power of workers in advanced economies declines and thereby also the global bargaining power. Then, also the wage and ultimately inflation decline. By implication, a slowing of labor supply growth in the future combined with an increasing bargaining power of workers in the emerging economies would reduce the dampening impact on wages and finally on inflation. Hence, monetary policy would get a more inflationary bias and thereby lead monetary authorities to adopt a more restrictive monetary stance.

In this study, the analysis is based on labor as the only input factor of production. The implementation of capital and thereby the analysis of the investment behavior – as an additional feature – is supposed to be a challenging and interesting aspect for future research.<sup>144</sup>

Whereas the analysis in Chapter 2 focuses on the implications for monetary policy, the analyses in Chapters 3 and 4 focus on the implications for labor market policy.

Chapter 3 addresses low-wages subsidies as a popular policy reaction to face the decreasing labor demand for low-skilled. It is often argued that low-wage subsidies improve the employment situation of the low-skilled labor force as they contribute to the reduction in the producer wages, which has a positive impact on the hiring decision. However, the crucial dimension of the labor market performance is aggregate employment. In this context and in contrast to the common literature, also the impact of low-wage subsidies on skilled employment is taken into account in the analysis. In particular, three channels whereby low-wage subsidies affect aggregate employment are examined: *(i)* the positive direct employment effect, *(ii)* the negative skill-acquisition effect, and *(iii)* the negative government budget effect. In order to address the specific question of this chapter, the labor force – in contrast to the second chapter – is differentiated according to its different skill levels, which are defined by the level of educational attainment. It is assumed that each skill level corresponds to a certain productivity level.

The model is calibrated for Germany. The numerical analysis reveals that low-wage subsidies significantly reduce skilled employment. Hence, the positive effect of low-wage subsidies on low-skilled employment does not cause an increase in aggregate employment to the same extent; rather the net effect is small. Furthermore, the shift from skilled to low-skilled employment reduces aggregate welfare. However,

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<sup>144</sup>See e.g. Molnar et al. (2008) for a recent study on globalization and employment with a focus on foreign direct investment.

the size of the impact on employment depends on several aspects. Whereas the size of the direct employment effect is in particular influenced by the hiring elasticity, the size of the skill-acquisition effect depends on the elasticity of the hiring rate, the degree of risk aversion and the elasticity of the training rate. With respect to future research, it may be promising to use a higher level of disaggregation with more skill levels.

Given the ongoing globalization and its adverse impact on the demand for low-skilled labor in advanced economies, often more than one policy instrument is implemented to counteract the negative impact. In this context, Chapter 4 analyzes a special type of labor market policy implications: the relevance of interactions between two kind of policies. The chapter investigates whether there are complementarities between employment policies and training policies with respect to employment and income. The definition of complementarity is straightforward: two policies are complementary, when the effect of each policy on, e.g. aggregate income is greater when it is implemented in conjunction with the other policy than in isolation. Substitutability is defined as a negative complementarity. Ignoring possible interactions could distort the evaluation of the policies.

As an example for employment and training policies, hiring subsidies and training subsidies are considered. The analysis is based on the Markov model of the previous chapter. However, some modifications of the model are necessary because other policies are analyzed. The simulation results reveal that there are significant interactions between hiring and training subsidies. However, complementarities between the two policies are quite weak or even absent (with respect to income). When comparing the results for different institutional and policy features of the economy, significant differences can be observed. In particular, the existence of complementarities with respect to aggregate income depends on the financial constraints of the government. In the absence of the government budget constraint, there are complementarities.

Independent of the results for the specific policies, which are regarded in this chapter, the analysis provides a methodology for examining policy interactions, which may be useful for future research well beyond the bounds of hiring and training subsidies.

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## 7 Appendix

### 7.1 Appendix to Chapter 2

#### 7.1.1 Profit Maximization of the Firm

Given the profit eq. (2.11), we first calculate the value to the firm of adding another worker at time  $t$  (recall that:  $N_{t+1}(i) = (1 - \varphi) N_t(i) + q_t V_t(i)$  and  $x_t(i) = \frac{q_t V_t(i)}{N_t(i)}$ ):

$$\begin{aligned}
\frac{\partial \Pi_t(i)}{\partial N_t(i)} &= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_t(i)} \stackrel{!}{=} 0 \\
\Leftrightarrow \frac{\partial \Pi_t(i)}{\partial N_t(i)} &= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \frac{\partial N_{t+1}(i)}{\partial N_t(i)} \\
\Leftrightarrow \frac{\partial \Pi_t(i)}{\partial N_t(i)} &= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} (1 - \varphi) \\
\Leftrightarrow \frac{\partial \Pi_t(i)}{\partial N_t(i)} &= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + (1 - \varphi) \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \quad (\text{A1.1.1})
\end{aligned}$$

Next, we calculate the first order condition with respect to the number of vacancies,  $V$ :

$$\begin{aligned}
\frac{\partial \Pi_t(i)}{\partial V_t(i)} &= -\kappa q_t x_t(i) + \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial V_t(i)} \stackrel{!}{=} 0 \\
\Leftrightarrow 0 &= -\kappa q_t x_t(i) + \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \frac{\partial N_{t+1}(i)}{\partial V_t(i)} \\
\Leftrightarrow \kappa q_t x_t(i) &= \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} q_t \\
\Leftrightarrow \kappa x_t(i) &= \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \quad (\text{A1.1.2})
\end{aligned}$$

Finally, we derive the forward looking difference equation for the hiring rate. We combine eq. (A1.1.1) and eq. (A1.1.2) as follows:

$$\begin{aligned}
\frac{\partial \Pi_t(i)}{\partial N_t(i)} &= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + (1 - \varphi) \underbrace{\delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)}}_{\kappa x_t(i)} \\
&= \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \quad \text{according to eq. (A1.1.2)} \quad (\text{A1.1.1a})
\end{aligned}$$

We substitute  $\frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)}$  in eq. (A1.1.2) by eq. (A1.1.1a) for  $t + 1$  and get the forward looking difference equation for the hiring rate:

$$\kappa x_t(i) = \delta E_t \Lambda_{t,t+1} [A - W_{t+1}(i) + \frac{\kappa}{2} x_{t+1}^2(i) + (1 - \varphi) \kappa x_{t+1}(i)]$$

### 7.1.2 Utility Maximization of the Household

Using eq. (2.15) subject to eq. (2.16), in which all nominal variables are normalized by the price level  $P$ , we get the Lagrange function for the household,  $\mathcal{L}_H$ :

$$\mathcal{L}_H = E_t \sum_{j=0}^{\infty} \delta^j \ln(c_{t+j}) - \varrho_{t+j} \left[ \begin{array}{l} P_{t+j} c_{t+j} + \frac{1}{1+i_{t+j}} z_{t+j}^n + P_{t+j} t_{t+j} \\ -P_{t+j} W_{t+j} n_{t+j} - P_{t+j} B_{t+j} u_{t+j} \\ - z_{t+j-1}^n - P_{t+j} \Pi_{t+j} \end{array} \right]$$

The first order condition with respect to consumption is:

$$\frac{\partial \mathcal{L}_H}{\partial c_t} = E_t \delta^j \left( \frac{1}{c_{t+j}} - \varrho_{t+j} P_{t+j} \right) \stackrel{!}{=} 0$$

For  $j = 0$ , we get:

$$\frac{1}{c_t} = P_t \varrho_t \tag{A1.2.1}$$

The first order condition with respect to bond holding is:

$$\frac{\partial \mathcal{L}_H}{\partial z_{t+j}^n} = E_t \delta^j \left( -\varrho_{t+j} \frac{1}{1+i_{t+j}} \right) + E_t \delta^{j+1} \left( -\varrho_{t+j+1} \right) (-1) \stackrel{!}{=} 0$$

For  $j = 0$ , we get:

$$\varrho_t \frac{1}{1+i_t} = \delta E_t \varrho_{t+1} \tag{A1.2.2}$$

By combining these two first order conditions, the Euler equation can be derived. We rewrite eq. (A1.2.2) by substituting  $\varrho_t$  by  $\frac{1}{c_t} \frac{1}{P_t}$  and  $\varrho_{t+1}$  by  $\frac{1}{c_{t+1}} \frac{1}{P_{t+1}}$  according to eq. (A1.2.1), respectively:

$$\frac{1}{c_t} \frac{1}{P_t} \frac{1}{1+i_t} = \delta E_t \frac{1}{c_{t+1}} \frac{1}{P_{t+1}}$$

By rearranging, we get the consumption Euler equation (recall that  $\frac{P_{t+1}}{P_t} = 1 + \pi_{t+1}$ ):

$$1 = (1+i_t) \delta E_t \left[ \frac{c_t}{c_{t+1}} \frac{1}{1+\pi_{t+1}} \right]$$

### 7.1.3 Wage Determination

**Sum of the Expected Future Wages for an Employee** The discounted sum of expected real future wages,  $W_t^E(i)$ , to be received by an employee  $i$  over the life

of the relationship at a firm renegotiating in period  $t$  is calculated as follows:

$$\begin{aligned}
W_t^E(i) &= E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} W_{t+j}(i) \\
&= W_t \\
&\quad + [(1 - \varphi) \delta] E_t \Lambda_{t,t+1} W_{t+1}(i) \\
&\quad + [(1 - \varphi) \delta]^2 E_t \Lambda_{t,t+2} W_{t+2}(i) \\
&\quad + [(1 - \varphi) \delta]^3 E_t \Lambda_{t,t+3} W_{t+3}(i) \\
&\quad + \dots
\end{aligned} \tag{A1.3.1}$$

At a firm renegotiating in period  $t$ , the current and future expected real wages are given by:

$$W_t(i) = W_t^*$$

$$E_t W_{t+1}(i) = E_t \frac{1}{P_{t+1}} (\lambda_w (1 + \pi^*) \underbrace{W_t^n}_{= W_t P_t = W_t^{*,n}} + (1 - \lambda_w) W_{t+1}^{*,n})$$

$$\begin{aligned}
E_t W_{t+2}(i) &= E_t \frac{1}{P_{t+2}} (\lambda_w (1 + \pi^*) \underbrace{W_{t+1}^n}_{= E_t W_{t+1} P_{t+1}} + (1 - \lambda_w) W_{t+2}^{*,n}) \\
&= E_t \frac{1}{P_{t+2}} (\lambda_w (1 + \pi^*) [\lambda_w (1 + \pi^*) W_t^{*,n} + (1 - \lambda_w) W_{t+1}^{*,n}] + (1 - \lambda_w) W_{t+2}^{*,n}) \\
&= E_t \frac{1}{P_{t+2}} (\lambda_w^2 (1 + \pi^*)^2 W_t^{*,n} + \lambda_w (1 - \lambda_w) (1 + \pi^*) W_{t+1}^{*,n} + (1 - \lambda_w) W_{t+2}^{*,n})
\end{aligned}$$

$$\begin{aligned}
E_t W_{t+3}(i) &= E_t \frac{1}{P_{t+3}} (\lambda_w (1 + \pi^*) \underbrace{W_{t+2}^n}_{= E_t W_{t+2} P_{t+2}} + (1 - \lambda_w) W_{t+3}^{*,n}) \\
&= E_t \frac{1}{P_{t+3}} (\lambda_w (1 + \pi^*) [\lambda_w^2 (1 + \pi^*)^2 W_t^{*,n} + \lambda_w (1 - \lambda_w) (1 + \pi^*) W_{t+1}^{*,n} + (1 - \lambda_w) W_{t+2}^{*,n}] \\
&\quad + (1 - \lambda_w) W_{t+3}^{*,n}) \\
&= E_t \frac{1}{P_{t+3}} (\lambda_w^3 (1 + \pi^*)^3 W_t^{*,n} + \lambda_w^2 (1 - \lambda_w) (1 + \pi^*)^2 W_{t+1}^{*,n} + \lambda_w (1 - \lambda_w) (1 + \pi^*) W_{t+2}^{*,n} \\
&\quad + (1 - \lambda_w) W_{t+3}^{*,n})
\end{aligned}$$

...

By substituting  $E_t W_{t+j}(i)$  (for  $j = 1, 2, \dots$ ) in eq. (A1.3.1) by the corresponding equation above, we get:

$$\begin{aligned}
W_t^E(i) &= W_t^* \\
&+ (1 - \varphi) \delta E_t \Lambda_{t,t+1} \frac{1}{P_{t+1}} (\lambda_w(1 + \pi^*) W_t^{*,n} + (1 - \lambda_w) W_{t+1}^{*,n}) \\
&+ [(1 - \varphi) \delta]^2 E_t \Lambda_{t,t+2} \frac{1}{P_{t+2}} (\lambda_w^2(1 + \pi^*)^2 W_t^{*,n} + \lambda_w(1 - \lambda_w)(1 + \pi^*) W_{t+1}^{*,n} \\
&\quad + (1 - \lambda_w) W_{t+2}^{*,n}) \\
&+ [(1 - \varphi) \delta]^3 E_t \Lambda_{t,t+3} \frac{1}{P_{t+3}} (\lambda_w^3(1 + \pi^*)^3 W_t^{*,n} + \lambda_w^2(1 - \lambda_w)(1 + \pi^*)^2 W_{t+1}^{*,n} \\
&\quad + \lambda_w(1 - \lambda_w)(1 + \pi^*) W_{t+2}^{*,n} + (1 - \lambda_w) W_{t+3}^{*,n}) \\
&+ \dots
\end{aligned}$$

By rearranging, we get:

$$\begin{aligned}
W_t^E(i) &= W_t^* \\
&+ (1 - \varphi) \delta E_t \Lambda_{t,t+1} [\lambda_w(1 + \pi^*) \frac{P_t}{P_{t+1}} W_t^* + (1 - \lambda_w) W_{t+1}^*] \\
&+ [(1 - \varphi) \delta]^2 E_t \Lambda_{t,t+2} [\lambda_w^2(1 + \pi^*)^2 \frac{P_t}{P_{t+2}} W_t^* + \lambda_w(1 - \lambda_w)(1 + \pi^*) \frac{P_{t+1}}{P_{t+2}} W_{t+1}^* \\
&\quad + (1 - \lambda_w) W_{t+2}^*] \\
&+ [(1 - \varphi) \delta]^3 E_t \Lambda_{t,t+3} [\lambda_w^3(1 + \pi^*)^3 \frac{P_t}{P_{t+3}} W_t^* + \lambda_w^2(1 - \lambda_w)(1 + \pi^*)^2 \frac{P_{t+1}}{P_{t+3}} W_{t+1}^* \\
&\quad + \lambda_w(1 - \lambda_w)(1 + \pi^*) \frac{P_{t+2}}{P_{t+3}} W_{t+2}^* + (1 - \lambda_w) W_{t+3}^*] \\
&+ \dots
\end{aligned}$$

By collecting terms, we get:

$$\begin{aligned}
W_t^E(i) = & E_t[ 1 + (1 - \varphi) \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+1} \frac{P_t}{P_{t+1}} \\
& + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^2 \Lambda_{t,t+2} \frac{P_t}{P_{t+2}} \\
& + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^3 \Lambda_{t,t+3} \frac{P_t}{P_{t+3}} \\
& + \dots ] W_t^* \\
& + (1 - \lambda_w) (1 - \varphi) \delta E_t[\Lambda_{t,t+1} + (1 - \varphi) \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+2} \frac{P_{t+1}}{P_{t+2}} \\
& + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^2 \Lambda_{t,t+3} \frac{P_{t+1}}{P_{t+3}} \\
& + \dots ] W_{t+1}^* \\
& + (1 - \lambda_w) [(1 - \varphi) \delta]^2 E_t[\Lambda_{t,t+2} + (1 - \varphi) \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+3} \frac{P_{t+2}}{P_{t+3}} \\
& + \dots ] W_{t+2}^* \\
& + (1 - \lambda_w) [(1 - \varphi) \delta]^3 E_t[\Lambda_{t,t+3} + \dots ] W_{t+3}^* \\
& + \dots
\end{aligned}$$

We rewrite and get:

$$\begin{aligned}
W_t^E(i) = & E_t[1 + (1 - \varphi) \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+1} \frac{P_t}{P_{t+1}} \\
& + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^2 \Lambda_{t,t+2} \frac{P_t}{P_{t+2}} + \dots ] W_t^* \\
& + (1 - \lambda_w) (1 - \varphi) \delta E_t \Lambda_{t,t+1} [1 + (1 - \varphi) \delta \lambda_w (1 + \pi^*) \Lambda_{t+1,t+2} \frac{P_{t+1}}{P_{t+2}} \\
& + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^2 \Lambda_{t+1,t+3} \frac{P_{t+1}}{P_{t+3}} + \dots ] W_{t+1}^* \\
& + (1 - \lambda_w) [(1 - \varphi) \delta]^2 E_t \Lambda_{t,t+2} [1 + (1 - \varphi) \delta \lambda_w (1 + \pi^*) \Lambda_{t+2,t+3} \frac{P_{t+2}}{P_{t+3}} + \dots ] W_{t+2}^* \\
& + (1 - \lambda_w) [(1 - \varphi) \delta]^3 E_t \Lambda_{t,t+3} [1 + \dots ] W_{t+3}^* \\
& + \dots
\end{aligned}$$

With

$$\Delta_t = E_t \sum_{h=0}^{\infty} [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^h \Lambda_{t,t+h} \frac{P_t}{P_{t+h}} \quad (\text{A1.3.2})$$

we get:

$$\begin{aligned}
W_t^E(i) &= \Delta_t W_t^* \\
&+ (1 - \lambda_w) (1 - \varphi) \delta E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^* \\
&+ (1 - \lambda_w) [(1 - \varphi) \delta]^2 E_t \Lambda_{t,t+2} \Delta_{t+2} W_{t+2}^* \\
&+ (1 - \lambda_w) [(1 - \varphi) \delta]^3 E_t \Lambda_{t,t+3} \Delta_{t+3} W_{t+3}^* \\
&+ \dots
\end{aligned}$$

By rearranging, we get:

$$W_t^E(i) = \Delta_t W_t^* + (1 - \lambda_w) E_t \sum_{j=1}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} \Delta_{t+j} W_{t+j}^* \quad (\text{A1.3.3})$$

**Sum of Expected Future Wages for a Firm** The discounted sum of expected future real wage payments,  $W_t^F(i)$ , by a firm  $i$  renegotiating in period  $t$  over both the existing contract and subsequent contracts is calculated as follows:

$$\begin{aligned}
W_t^F(i) &= E_t \sum_{j=0}^{\infty} \frac{N_{t+j}(i)}{N_t(i)} \delta^j \Lambda_{t,t+j} W_{t+j}(i) \\
&= W_t \\
&+ E_t \frac{N_{t+1}(i)}{N_t(i)} \delta \Lambda_{t,t+1} W_{t+1}(i) \\
&+ E_t \frac{N_{t+2}(i)}{N_t(i)} \delta^2 \Lambda_{t,t+2} W_{t+2}(i) \\
&+ E_t \frac{N_{t+3}(i)}{N_t(i)} \delta^3 \Lambda_{t,t+3} W_{t+3}(i) \\
&+ \dots
\end{aligned} \quad (\text{A1.3.4})$$



Again, at a firm renegotiating in period  $t$ , the current and future expected real wages are given by:

$$W_t(i) = W_t^*$$

$$E_t W_{t+1}(i) = E_t \frac{1}{P_{t+1}} (\lambda_w (1 + \pi^*) W_t^{*,n} + (1 - \lambda_w) W_{t+1}^{*,n})$$

$$E_t W_{t+2}(i) = E_t \frac{1}{P_{t+2}} (\lambda_w^2 (1 + \pi^*)^2 W_t^{*,n} + \lambda_w (1 - \lambda_w) (1 + \pi^*) W_{t+1}^{*,n} + (1 - \lambda_w) W_{t+2}^{*,n})$$

$$E_t W_{t+3}(i) = E_t \frac{1}{P_{t+3}} (\lambda_w^3 (1 + \pi^*)^3 W_t^{*,n} + \lambda_w^2 (1 - \lambda_w) (1 + \pi^*)^2 W_{t+1}^{*,n} + \lambda_w (1 - \lambda_w) (1 + \pi^*) W_{t+2}^{*,n} + (1 - \lambda_w) W_{t+3}^{*,n})$$

.....

By substituting  $E_t W_{t+j}(i)$  (for  $j = 1, 2, \dots$ ) in eq. (A1.3.4) by the corresponding equation above, we get:

$$\begin{aligned} W_t^F(i) &= W_t^* \\ &+ E_t \frac{N_{t+1}(i)}{N_t(i)} \delta \Lambda_{t,t+1} \frac{1}{P_{t+1}} (\lambda_w (1 + \pi^*) W_t^{*,n} + (1 - \lambda_w) W_{t+1}^{*,n}) \\ &+ E_t \frac{N_{t+2}(i)}{N_t(i)} \delta^2 \Lambda_{t,t+2} \frac{1}{P_{t+2}} (\lambda_w^2 (1 + \pi^*)^2 W_t^{*,n} + \lambda_w (1 - \lambda_w) (1 + \pi^*) W_{t+1}^{*,n} + (1 - \lambda_w) W_{t+2}^{*,n}) \\ &+ E_t \frac{N_{t+3}(i)}{N_t(i)} \delta^3 \Lambda_{t,t+3} \frac{1}{P_{t+3}} (\lambda_w^3 (1 + \pi^*)^3 W_t^{*,n} + \lambda_w^2 (1 - \lambda_w) (1 + \pi^*)^2 W_{t+1}^{*,n} \\ &\quad + \lambda_w (1 - \lambda_w) (1 + \pi^*) W_{t+2}^{*,n} + (1 - \lambda_w) W_{t+3}^{*,n}) \\ &+ \dots \end{aligned}$$

By rearranging, we get:

$$\begin{aligned}
W_t^F(i) &= W_t^* \\
&+ E_t \frac{N_{t+1}(i)}{N_t(i)} \delta \Lambda_{t,t+1} [\lambda_w (1 + \pi^*) \frac{P_t}{P_{t+1}} W_t^* + (1 - \lambda_w) W_{t+1}^*] \\
&+ E_t \frac{N_{t+2}(i)}{N_t(i)} \delta^2 \Lambda_{t,t+2} [\lambda_w^2 (1 + \pi^*)^2 \frac{P_t}{P_{t+2}} W_t^* + \lambda_w (1 - \lambda_w)(1 + \pi^*) \frac{P_{t+1}}{P_{t+2}} W_{t+1}^* \\
&\quad + (1 - \lambda_w) W_{t+2}^* ] \\
&+ E_t \frac{N_{t+3}(i)}{N_t(i)} \delta^3 \Lambda_{t,t+3} [\lambda_w^3 (1 + \pi^*)^3 \frac{P_t}{P_{t+3}} W_t^* + \lambda_w^2 (1 - \lambda_w)(1 + \pi^*)^2 \frac{P_{t+1}}{P_{t+3}} W_{t+1}^* \\
&\quad + \lambda_w (1 - \lambda_w)(1 + \pi^*) \frac{P_{t+2}}{P_{t+3}} W_{t+2}^* + (1 - \lambda_w) W_{t+3}^*] \\
&+ \dots
\end{aligned}$$

By collecting terms, we get:

$$\begin{aligned}
W_t^F(i) &= E_t [1 + \frac{N_{t+1}(i)}{N_t(i)} \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+1} \frac{P_t}{P_{t+1}} + \frac{N_{t+2}(i)}{N_t(i)} [\delta \lambda_w (1 + \pi^*)]^2 \Lambda_{t,t+2} \frac{P_t}{P_{t+2}} + \dots] W_t^* \\
&+ (1 - \lambda_w) E_t \delta \left[ \frac{N_{t+1}(i)}{N_t(i)} \Lambda_{t,t+1} + \frac{N_{t+2}(i)}{N_t(i)} \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+2} \frac{P_{t+1}}{P_{t+2}} + \dots \right] W_{t+1}^* \\
&+ (1 - \lambda_w) E_t \delta^2 \left[ \frac{N_{t+2}(i)}{N_t(i)} \Lambda_{t,t+2} + \frac{N_{t+3}(i)}{N_t(i)} \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+3} \frac{P_{t+2}}{P_{t+3}} + \dots \right] W_{t+2}^* \\
&+ \dots
\end{aligned}$$

Again, we rearrange and get:

$$\begin{aligned}
W_t^F(i) &= E_t [1 + \frac{N_{t+1}(i)}{N_t(i)} \delta \lambda_w (1 + \pi^*) \Lambda_{t,t+1} \frac{P_t}{P_{t+1}} + \frac{N_{t+2}(i)}{N_t(i)} [\delta \lambda_w (1 + \pi^*)]^2 \Lambda_{t,t+2} \frac{P_t}{P_{t+2}} + \dots] W_t^* \\
&+ (1 - \lambda_w) \delta E_t \frac{N_{t+1}(i)}{N_t(i)} \Lambda_{t,t+1} [1 + \frac{N_{t+2}(i)}{N_{t+1}(i)} \delta \lambda_w (1 + \pi^*) \Lambda_{t+1,t+2} \frac{P_{t+1}}{P_{t+2}} + \dots] W_{t+1}^* \\
&+ (1 - \lambda_w) \delta^2 E_t \frac{N_{t+2}(i)}{N_t(i)} \Lambda_{t,t+2} [1 + \frac{N_{t+3}(i)}{N_{t+2}(i)} \delta \lambda_w (1 + \pi^*) \Lambda_{t+2,t+3} \frac{P_{t+2}}{P_{t+3}} + \dots] W_{t+2}^* \\
&+ \dots
\end{aligned}$$

With

$$\Psi_t(i) = E_t \sum_{h=0}^{\infty} \frac{N_{t+h}(i)}{N_t(i)} [\delta \lambda_w (1 + \pi^*)]^h \Lambda_{t,t+h} \frac{P_t}{P_{t+h}} \quad (\text{A1.3.5})$$

we get:

$$\begin{aligned}
W_t^F(i) &= \Psi_t(i) W_t^* \\
&+ (1 - \lambda_w) \delta E_t \frac{N_{t+1}(i)}{N_t(i)} \Lambda_{t,t+1} \Psi_{t+1}(i) W_{t+1}^* \\
&+ (1 - \lambda_w) \delta^2 E_t \frac{N_{t+2}(i)}{N_t(i)} \Lambda_{t,t+2} \Psi_{t+2}(i) W_{t+2}^* \\
&+ \dots
\end{aligned}$$

By rearranging, we get:

$$W_t^F(i) = \Psi_t(i) W_t^* + (1 - \lambda_w) E_t \sum_{j=1}^{\infty} \delta^j \frac{N_{t+j}(i)}{N_t(i)} \Lambda_{t,t+j} \Psi_{t+j}(i) W_{t+j}^* \quad (\text{A1.3.6.})$$

**Surplus of the Worker** The surplus of a worker at a firm renegotiating in period  $t$  is given by eq. (2.20):

$$\begin{aligned}
S_t^E(i) &= W_t(i) - B_t + \delta E_t \Lambda_{t,t+1} [(1 - \varphi) S_{t+1}^E(i) - s_t S_{t+1}^E] \\
&= W_t(i) - B_t + (1 - \varphi) \delta E_t \Lambda_{t,t+1} S_{t+1}^E(i) - s_t \delta E_t \Lambda_{t,t+1} S_{t+1}^E \\
&= W_t(i) - B_t - s_t \delta E_t \Lambda_{t,t+1} S_{t+1}^E \\
&\quad + (1 - \varphi) \delta E_t \Lambda_{t,t+1} [W_{t+1}(i) - B_{t+1} + (1 - \varphi) \delta \Lambda_{t+1,t+2} S_{t+2}^E(i) \\
&\quad \quad \quad - s_{t+1} \delta \Lambda_{t+1,t+2} S_{t+2}^E] \\
&= \underbrace{E_t \sum_{j=0}^{\infty} ((1 - \varphi) \delta)^j \Lambda_{t,t+j} W_{t+j}(i)}_{= W_t^E(i) \text{ according to eq. (A1.3.1)}} \\
&\quad + E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} [-B_{t+j} - s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E]
\end{aligned}$$

By substituting  $W_t^E(i)$  by eq. (A1.3.3), we get:

$$\begin{aligned}
S_t^E(i) &= [\Delta_t W_t^* + (1 - \lambda_w) E_t \sum_{j=1}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} \Delta_{t+j} W_{t+j}^*] \\
&\quad - E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} [B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E] \\
&= \Delta_t W_t^* - E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} [B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E] \\
&\quad + (1 - \lambda_w) E_t \sum_{j=1}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} \Delta_{t+j} W_{t+j}^* \\
&= \Delta_t W_t^* - E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} [B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E] \\
&\quad + E_t \sum_{j=0}^{\infty} (1 - \lambda_w) [(1 - \varphi) \delta]^{j+1} \Lambda_{t,t+j+1} \Delta_{t+j+1} W_{t+j+1}^* \\
&= \Delta_t W_t^* - E_t \sum_{j=0}^{\infty} [ [(1 - \varphi) \delta]^j \Lambda_{t,t+j} [B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E] \\
&\quad - (1 - \lambda_w) [(1 - \varphi) \delta]^{j+1} \Lambda_{t,t+j+1} \Delta_{t+j+1} W_{t+j+1}^* ]
\end{aligned}$$

Finally, the surplus of the worker is:

$$\begin{aligned}
S_t^E(i) &= \Delta_t W_t^* \tag{A1.3.7} \\
&\quad - E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} \left[ \begin{array}{c} B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E \\ - (1 - \lambda_w) (1 - \varphi) \delta \Lambda_{t+j,t+j+1} \Delta_{t+j+1} W_{t+j+1}^* \end{array} \right]
\end{aligned}$$

**Surplus of the Firm** The surplus of a firm (i.e. the value of an additional worker,

$S_t^F(i) = \frac{\partial \Pi_t(i)}{\partial N_t(i)}$ ) renegotiating in period  $t$  is given by eq. (2.21):

$$\begin{aligned}
S_t^F(i) &= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + \delta E_t \Lambda_{t,t+1} \underbrace{\frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \frac{\partial N_{t+1}(i)}{\partial N_t(i)}}_{=(1-\varphi)} \\
&= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + (1 - \varphi) \delta E_t \Lambda_{t,t+1} S_{t+1}^F(i) \\
&= E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} [A + \frac{\kappa}{2} x_{t+j}^2(i)] - \underbrace{E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta]^j \Lambda_{t,t+j} W_{t+j}(i)}_{= W_t^E(i) \text{ according to eq. (A1.3.1)}}
\end{aligned}$$

By substituting  $W_t^E(i)$  by eq. (A1.3.3), we get:

$$\begin{aligned}
S_t^F(i) &= E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} \left[ A + \frac{\kappa}{2} x_{t+j}^2(i) \right] \\
&\quad - [\Delta_t W_t^* + (1-\lambda_w) E_t \sum_{j=1}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} \Delta_{t+j} W_{t+j}^*] \\
&= -\Delta_t W_t^* + E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} \left[ A + \frac{\kappa}{2} x_{t+j}^2(i) \right] \\
&\quad - (1-\lambda_w)(1-\varphi) \delta E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j+1} \Delta_{t+j+1} W_{t+j+1}^* \\
&= -\Delta_t W_t^* \\
&\quad + E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} \left[ \begin{array}{c} A + \frac{\kappa}{2} x_{t+j}^2(i) \\ -(1-\lambda_w)(1-\varphi) \delta \Lambda_{t+j,t+j+1} \Delta_{t+j+1} W_{t+j+1}^* \end{array} \right] \\
&\hspace{20em} \text{(A1.3.8)}
\end{aligned}$$

An alternative expression for  $S_t^F(i)$  can be derived by combining the eq. (2.12) and (2.13).

First, we rewrite eq. (2.13) as follows:

$$\begin{aligned}
\kappa x_t(i) &= \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} \\
\Leftrightarrow \kappa x_t^2(i) &= \delta E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} x_t(i) \\
\Leftrightarrow 0 &= -\kappa x_t^2(i) + E_t \Lambda_{t,t+1} \frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} x_t(i)
\end{aligned}$$

Second, we include this expression into eq. (2.12). Recall that  $\frac{\partial \Pi_{t+1}(i)}{\partial N_{t+1}(i)} = S_{t+1}^F(i)$  and  $\frac{\partial N_{t+1}(i)}{\partial N_t(i)} = (1-\varphi)$ .

$$\begin{aligned}
S_t^F(i) &= A - W_t(i) + \frac{\kappa}{2} x_t^2(i) + \delta E_t \Lambda_{t,t+1} S_{t+1}^F(i) (1-\varphi) - \kappa x_t^2(i) + E_t \Lambda_{t,t+1} S_{t+1}^F(i) x_t(i) \\
&= A - W_t(i) - \frac{\kappa}{2} x_t^2(i) + E_t \delta (1-\varphi + x_t(i)) \Lambda_{t,t+1} S_{t+1}^F(i) \\
&= A - W_t(i) - \frac{\kappa}{2} x_t^2(i) + E_t \delta \frac{N_{t+1}(i)}{N_t(i)} \Lambda_{t,t+1} S_{t+1}^F(i) \\
&= E_t \sum_{j=0}^{\infty} \delta^j \frac{N_{t+j}(i)}{N_t(i)} \Lambda_{t,t+j} \left[ A - \frac{\kappa}{2} x_{t+j}^2(i) \right] - \underbrace{E_t \sum_{j=0}^{\infty} \delta^j \frac{N_{t+j}(i)}{N_t(i)} \Lambda_{t,t+j} W_{t+j}(i)}_{= W_t^F(i) \text{ according to eq. (A1.3.4)}}
\end{aligned}$$

By substituting  $W_t^F(i)$  according to eq. (A1.3.6.), we get:

$$S_t^F(i) = E_t \sum_{j=0}^{\infty} \delta^j \frac{N_{t+j}(i)}{N_t(i)} \Lambda_{t,t+j} [A - \frac{\kappa}{2} x_{t+j}^2(i)] \quad (\text{A1.3.9})$$

$$- [\Psi_t(i) W_t^* + (1 - \lambda_w) E_t \sum_{j=1}^{\infty} \delta^j \frac{N_{t+j}(i)}{N_t(i)} \Lambda_{t,t+j} \Psi_{t+j}(i) W_{t+j}^*]$$

**Solution of the Nash Bargaining** The contract wage  $W_t^*$  is chosen to solve the following problem:

$$\max_{W_t^*} \Omega = [S_t^E(i)]^{\mu_t} [S_t^F(i)]^{1-\mu_t}$$

The solution is calculated as follows:

$$\frac{\partial \Omega}{\partial W_t^*} = \mu_t [S_t^E(i)]^{\mu_t-1} \frac{\partial S_t^E(i)}{\partial W_t^*} [S_t^F(i)]^{1-\mu_t} + [S_t^E(i)]^{\mu_t} (1 - \mu_t) ([S_t^F(i)]^{-\mu_t}) \frac{\partial S_t^F(i)}{\partial W_t^*} \stackrel{!}{=} 0$$

$$\Leftrightarrow 0 = \mu_t [S_t^E(i)]^{-1} \frac{\partial S_t^E(i)}{\partial W_t^*} S_t^F(i) + (1 - \mu_t) \frac{\partial S_t^F(i)}{\partial W_t^*}$$

According to eq. (A1.3.7),  $\frac{\partial S_t^E(i)}{\partial W_t^*} = \Delta_t$ , and according to eq. (A1.3.9),  $\frac{\partial S_t^F(i)}{\partial W_t^*} = -\Psi_t(i)$ . Hence, we write:

$$\begin{aligned} & \mu_t [S_t^E(i)]^{-1} \Delta_t S_t^F(i) + (1 - \mu_t) (-\Psi_t(i)) = 0 \\ \Leftrightarrow & \mu_t \Delta_t S_t^F(i) = (1 - \mu_t) \Psi_t(i) S_t^E(i) \\ \Leftrightarrow & \mu_t S_t^F(i) = (1 - \mu_t) \frac{\Psi_t(i)}{\Delta_t} S_t^E(i) \\ \Leftrightarrow & \mu_t S_t^F(i) = \frac{\mu_t + (1 - \mu_t) \Psi_t(i) / \Delta_t - \mu_t}{\mu_t + (1 - \mu_t) \Psi_t(i) / \Delta_t} S_t^E(i) [\mu_t + (1 - \mu_t) \Psi_t(i) / \Delta_t] \\ \Leftrightarrow & \frac{\mu_t}{\mu_t + (1 - \mu_t) \Psi_t(i) / \Delta_t} S_t^F(i) = (1 - \frac{\mu_t}{\mu_t + (1 - \mu_t) \Psi_t(i) / \Delta_t}) S_t^E(i) \end{aligned}$$

Finally, the solution of the Nash bargaining is given by:

$$\chi_t(i) S_t^F(i) = [1 - \chi_t(i)] S_t^E(i) \quad \text{with } \chi_t(i) = \frac{\mu_t}{\mu_t + (1 - \mu_t) \Psi_t(i) / \Delta_t} \quad (\text{A1.3.10})$$

**Contract Wage** Next, given eq. (A1.3.10), we substitute  $S_t^F(i)$  by the expression in eq. (A1.3.8) and  $S_t^E(i)$  by the expression in eq. (A1.3.7). After some rearrange-

ments, we get:

$$\begin{aligned} \Delta_t W_t^* &= E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} \chi_{t+j}(i) \left[ A + \frac{\kappa}{2} x_{t+j}^2(i) \right. \\ &\quad \left. - (1-\varphi)(1-\lambda_w) \delta \Lambda_{t+j,t+j+1} \Delta_{t+j+1} W_{t+j+1}^* \right] \\ &+ E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} [1 - \chi_{t+j}(i)] [B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E \\ &\quad - (1-\varphi)(1-\lambda_w) \delta \Lambda_{t+j,t+j+1} \Delta_{t+j+1} W_{t+j+1}^*] \end{aligned}$$

$\Leftrightarrow$

$$\begin{aligned} \Delta_t W_t^* &= E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} \chi_t(i) \left[ A + \frac{\kappa}{2} x_{t+j}^2(i) \right] \\ &+ E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} ( [1 - \chi_t(i)] [B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E \\ &\quad - (1-\varphi)(1-\lambda_w) \delta \Lambda_{t+j,t+j+1} \Delta_{t+j+1} W_{t+j+1}^*] ) \end{aligned}$$

$\Leftrightarrow$

$$\begin{aligned} \Delta_t W_t^* &= E_t \sum_{j=0}^{\infty} [(1-\varphi) \delta]^j \Lambda_{t,t+j} ( \chi_t(i) \left[ A + \frac{\kappa}{2} x_{t+j}^2(i) \right] \\ &\quad + [1 - \chi_t(i)] [B_{t+j} + s_{t+j} \delta \Lambda_{t+j,t+j+1} S_{t+j+1}^E \\ &\quad - (1-\varphi)(1-\lambda_w) \delta \Lambda_{t+j,t+j+1} \Delta_{t+j+1} W_{t+j+1}^*] ) \end{aligned}$$

The equation above can be written in a recursive form:

$$\begin{aligned} \Delta_t W_t^* &= \chi_t(i) \left[ A + \frac{\kappa}{2} x_t^2(i) \right] \\ &+ [1 - \chi_t(i)] [B_t + s_t \delta E_t \Lambda_{t,t+1} S_{t+1}^E] \\ &- (1-\varphi)(1-\lambda_w) \delta E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^* \\ &+ (1-\varphi) \delta E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^* \end{aligned}$$

$\Leftrightarrow$

$$\begin{aligned} \Delta_t W_t^* &= \chi_t(i) \left[ A + \frac{\kappa}{2} x_t^2(i) \right] \\ &+ [1 - \chi_t(i)] [B_t + s_t \delta E_t \Lambda_{t,t+1} S_{t+1}^E] \\ &+ (1-\varphi) \lambda_w \delta E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^* \end{aligned}$$

By simplification, we obtain:

$$\begin{aligned}\Delta_t W_t^* &= W_t^T(i) + (1 - \varphi) \delta \lambda_w E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^* \\ \Leftrightarrow W_t^* &= \frac{1}{\Delta_t} [W_t^T(i) + (1 - \varphi) \delta \lambda_w E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^*]\end{aligned}\quad (\text{A1.3.11})$$

where  $W^T$  denotes the target wage:

$$\begin{aligned}W_t^T(i) &= \chi_t(i) \left[ A + \frac{\kappa}{2} x_t^2(i) \right] + [1 - \chi_t(i)] [B_t + s_t \delta E_t \Lambda_{t,t+1} S_{t+1}^E] \\ \Leftrightarrow W_t^T(i) &= \chi_t(i) \left[ A + \frac{\kappa}{2} x_t^2(i) \right] + [1 - \chi_t(i)] B_t + [1 - \chi_t(i)] s_t \delta E_t \Lambda_{t,t+1} S_{t+1}^E(i)\end{aligned}\quad (\text{A1.3.12})$$

Finally, we derive the equilibrium expression of the contract wage given by eq. (A1.3.11). In the steady state,  $\Lambda_{t,t+1} = 1$ . As all other variables are stationary, we skip the time index:

$$\begin{aligned}W^* &= \frac{1}{\Delta} (W^T + (1 - \varphi) \delta \lambda_w \Delta W^*) \\ \Leftrightarrow W^* &= \frac{1}{\Delta} W^T + (1 - \varphi) \delta \lambda_w W^*\end{aligned}$$

According to eq. (A1.4.5),  $\Delta = \frac{1}{1 - (1 - \varphi) \delta \lambda_w} \Leftrightarrow 1 - (1 - \varphi) \delta \lambda_w = \frac{1}{\Delta} \Leftrightarrow (1 - \varphi) \delta \lambda_w = 1 - \frac{1}{\Delta}$ . So, we can write:

$$\begin{aligned}W^* &= \frac{1}{\Delta} W^T + \left(1 - \frac{1}{\Delta}\right) W^* \\ \Leftrightarrow W^* &= W^T\end{aligned}$$

**Target Wage** The target wage,  $W_t^T(i)$ , given by eq. (A1.3.12), can be written more precisely. By taking into account eq. (2.24), we can write:

$$W_t^T = \chi_t(i) \left[ A + \frac{\kappa}{2} x_t^2(i) \right] + [1 - \chi_t(i)] B_t + [1 - \chi_t(i)] s_t \delta E_t \Lambda_{t,t+1} \underbrace{\frac{\chi_{t+1}(i)}{1 - \chi_{t+1}(i)} S_{t+1}^F(i)}_{= S_{t+1}^E(i)}$$

Taking into account that  $\frac{\partial \Pi_t(i)}{\partial N_t(i)} = S_t^F(i)$  according to eq. (2.12) and (2.21), we can rewrite eq. (2.13) as follows:

$$\kappa x_t(i) = \delta E_t \Lambda_{t,t+1} S_{t+1}^F(i)$$



Given this,  $W_t^T(i)$  can be written as follows:

$$W_t^T(i) = \chi_t(i) \left[ A + \frac{\kappa}{2} x_t^2(i) \right] + [1 - \chi_t(i)] B_t + [1 - \chi_t(i)] s_t \kappa x_t(i) E_t \frac{\chi_{t+1}(i)}{1 - \chi_{t+1}(i)} \quad (\text{A1.3.13})$$

In the steady state,  $\Lambda_{t,t+1} = 1$  and  $\chi_t = \chi_{t+1}$ . As all variables are stationary, the time index is skipped:

$$W^T = \chi \left[ A + \frac{\kappa}{2} x^2 \right] + [1 - \chi] B + s \kappa x \chi \quad (\text{A1.3.14})$$

**Wage Index** Finally, the wage index,  $W$ , is calculated as follows:

$$\begin{aligned} W_t &= (1 - \lambda_w) W_t^* + \lambda_w \frac{1}{P_t} (1 + \pi^*) P_{t-1} W_{t-1} \\ \Leftrightarrow W_t &= (1 - \lambda_w) W_t^* + \lambda_w \frac{1 + \pi^*}{1 + \pi_t} W_{t-1} \end{aligned}$$

In the steady state,  $\pi^* = \pi_t = \pi$  and  $W_t = W_{t-1} = W$ . So we can write:

$$\begin{aligned} W &= (1 - \lambda_w) W^* + \lambda_w W \\ \Leftrightarrow W &= W^* \end{aligned} \quad (\text{A1.3.15})$$

#### 7.1.4 Iteration of the Cumulative Discount Factors

**Cumulative Discount Factor of the Worker,  $\Delta_t$**  The cumulative discount factor of the worker  $\Delta_t$ , given by eq. (2.22), can be written as follows:

$$\begin{aligned} \Delta_t &= E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^j \frac{P_t}{P_{t+j}} \Lambda_{t,t+j} \\ \Leftrightarrow \Delta_t &= 1 + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)] E_t \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} \\ &\quad + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^2 E_t \frac{P_t}{P_{t+2}} \Lambda_{t,t+2} + \dots \\ \Leftrightarrow \Delta_t &= 1 + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)] E_t \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} \\ &\quad + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^2 E_t \frac{P_t}{P_{t+1}} \frac{P_{t+1}}{P_{t+2}} \Lambda_{t,t+1} \Lambda_{t+1,t+2} + \dots \\ \Leftrightarrow \Delta_t &= 1 + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)] E_t \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} (1 + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^1 \frac{P_{t+1}}{P_{t+2}} \Lambda_{t+1,t+2} + \dots) \end{aligned} \quad (\text{A1.4.1})$$

Moreover:

$$\begin{aligned}
E_t \Delta_{t+1} &= E_t \sum_{j=0}^{\infty} [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^j \frac{P_{t+1}}{P_{t+1+j}} \Lambda_{t+1, t+1+j} \\
\Leftrightarrow E_t \Delta_{t+1} &= 1 + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)] E_t \frac{P_{t+1}}{P_{t+2}} \Lambda_{t+1, t+2} + \dots \quad (\text{A.1.4.2})
\end{aligned}$$

Next, we substitute  $(1 + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)]^1 \frac{P_{t+1}}{P_{t+2}} \Lambda_{t+1, t+2} + \dots)$  in eq. (A1.4.1) by  $E_t \Delta_{t+1}$  according to eq. (A.1.4.2) and get:

$$\begin{aligned}
\Delta_t &= 1 + [(1 - \varphi) \delta \lambda_w (1 + \pi^*)] E_t \frac{P_t}{P_{t+1}} \Lambda_{t, t+1} \Delta_{t+1} \\
\Leftrightarrow \Delta_t &= 1 + (1 - \varphi) \delta \lambda_w E_t \frac{1 + \pi^*}{1 + \pi_{t+1}} \Lambda_{t, t+1} \Delta_{t+1} \quad (\text{A1.4.3})
\end{aligned}$$

Finally, we derive the equilibrium expression. With respect to the equilibrium, we can write:

$$\Lambda_{t+i, t+i+1} = \frac{u'(c_{t+i+1})}{u'(c_{t+i})} = 1 \quad \text{as } c_{t+i+1} = c_{t+i} \quad (\text{A1.4.4})$$

where  $c$  is per capita consumption.

Then, the steady state expression is calculated by rearranging eq. (A1.4.3). As all variables are stationary, the time index is skipped:

$$\begin{aligned}
\Delta &= 1 + (1 - \varphi) \delta \lambda_w \frac{1 + \pi^*}{1 + \pi} \Delta \\
\Leftrightarrow \Delta &= 1 + (1 - \varphi) \delta \lambda_w \Delta \\
\Leftrightarrow \Delta &= \frac{1}{1 - (1 - \varphi) \delta \lambda_w} \quad (\text{A1.4.5})
\end{aligned}$$

**Cumulative Discount Factor of the Firm,  $\Psi_t$**  The cumulative discount factor of the firm,  $\Psi_t(i)$ , given by eq. (2.23) can be written as follows:

$$\begin{aligned}
\Psi_t(i) &= E_t \sum_{j=0}^{\infty} \frac{N_{t+j}(i)}{N_t(i)} [\delta \lambda_w (1 + \pi^*)]^j \frac{P_t}{P_{t+j}} \Lambda_{t,t+j} \\
\Leftrightarrow \Psi_t(i) &= 1 + E_t \frac{N_{t+1}(i)}{N_t(i)} [\lambda_w \delta (1 + \pi^*)] \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} \\
&\quad + E_t \frac{N_{t+2}(i)}{N_t(i)} [\lambda_w \delta (1 + \pi^*)]^2 \frac{P_t}{P_{t+2}} \Lambda_{t,t+2} + \dots \\
\Leftrightarrow \Psi_t(i) &= 1 + E_t \frac{N_{t+1}(i)}{N_t(i)} [\lambda_w \delta (1 + \pi^*)] \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} \\
&\quad + E_t \frac{N_{t+2}(i)}{N_{t+1}(i)} \frac{N_{t+1}(i)}{N_t(i)} [\lambda_w \delta (1 + \pi^*)]^2 \frac{P_t}{P_{t+1}} \frac{P_{t+1}}{P_{t+2}} \Lambda_{t,t+1} \Lambda_{t+1,t+2} + \dots \\
\Leftrightarrow \Psi_t(i) &= 1 + E_t \frac{N_{t+1}(i)}{N_t(i)} [\lambda_w \delta (1 + \pi^*)] \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} [1 \\
&\quad + \frac{N_{t+2}(i)}{N_{t+1}(i)} [\lambda_w \delta (1 + \pi^*)] \frac{P_{t+1}}{P_{t+2}} \Lambda_{t+1,t+2} + \dots]
\end{aligned} \tag{A1.4.6}$$

Moreover:

$$\begin{aligned}
\Psi_{t+1}(i) &= E_t \sum_{j=0}^{\infty} \frac{N_{t+1+j}(i)}{N_{t+1}(i)} [\lambda_w \delta (1 + \pi^*)]^j \frac{P_{t+1}}{P_{t+1+j}} \Lambda_{t+1,t+1+j} \\
\Leftrightarrow \Psi_{t+1}(i) &= 1 + E_t \frac{N_{t+2}(i)}{N_{t+1}(i)} [\lambda_w \delta (1 + \pi^*)] \frac{P_{t+1}}{P_{t+2}} \Lambda_{t+1,t+2} + \dots
\end{aligned} \tag{A1.4.7}$$

Then, we substitute  $[1 + \frac{N_{t+2}(i)}{N_{t+1}(i)} [\lambda_w \delta (1 + \pi^*)] \frac{P_{t+1}}{P_{t+2}} \Lambda_{t+1,t+2} + \dots]$  in eq. (A1.4.6) by  $\Psi_{t+1}(i)$  according to eq. (A1.4.7) and get:

$$\begin{aligned}
\Psi_t(i) &= 1 + E_t \frac{N_{t+1}(i)}{N_t(i)} [\lambda_w \delta (1 + \pi^*)] \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} \Psi_{t+1}(i) \\
\Leftrightarrow \Psi_t(i) &= 1 + [(1 - \varphi) + x_t(i)] [\lambda_w \delta (1 + \pi^*)] E_t \frac{P_t}{P_{t+1}} \Lambda_{t,t+1} \Psi_{t+1}(i) \\
\Leftrightarrow \Psi_t(i) &= 1 + [(1 - \varphi) + x_t(i)] \lambda_w \delta E_t \frac{1 + \pi^*}{1 + \pi_{t+1}} \Lambda_{t,t+1} \Psi_{t+1}(i)
\end{aligned} \tag{A1.4.8}$$

Finally, the equilibrium expression is derived. In eq. (A1.4.8), all variables are stationary, so the time index is skipped:

$$\begin{aligned}
\Psi &= 1 + [(1 - \varphi) + x] \lambda_w \delta \frac{1 + \pi^*}{1 + \pi} \Psi \\
\Leftrightarrow \Psi &= 1 + [(1 - \varphi) + x] \lambda_w \delta \Psi \\
\Leftrightarrow \Psi &= \frac{1}{1 - ((1 - \varphi) + x) \lambda_w \delta}
\end{aligned} \tag{A1.4.9}$$

### 7.1.5 Government Budget Constraint

The government budget constraint is given by:

$$P_t B_t U_t + Z_{t-1}^n = \frac{1}{1+i_t} Z_t^n + P_t T_t$$

where  $T_t$  are net taxes (= total taxes – government expenditures other than unemployment benefits). In per capita terms, we get:

$$\begin{aligned} P_t B_t \frac{U_t}{L_{t-1}} + \frac{Z_{t-1}^n}{L_{t-1}} &= \frac{1}{1+i_t} \frac{Z_t^n}{L_{t-1}} + P_t \frac{T_t}{L_{t-1}} \\ \Leftrightarrow B_t \frac{U_t}{L_t} \frac{L_t}{L_{t-1}} + \frac{Z_{t-1}^n}{L_{t-1}} \frac{1}{P_t} &= \frac{1}{1+i_t} \frac{Z_t^n}{L_t} \frac{L_t}{L_{t-1}} \frac{1}{P_t} + \frac{T_t}{L_t} \frac{L_t}{L_{t-1}} \\ \Leftrightarrow B_t u_t (1+g^L) + \frac{z_{t-1}^n}{P_t} &= \frac{1}{1+i_t} \frac{z_t^n}{P_t} (1+g^L) + t_t (1+g^L) \\ \Leftrightarrow B_t u_t (1+g^L) &= \frac{1}{1+i_t} z_t (1+g^L) + t_t (1+g^L) \end{aligned} \quad (\text{A1.5.1})$$

### 7.1.6 Economic System

**Transition Period** The following system of equations is used for the analysis of the transitory impact of a labor supply impulse.

Employment rate:

$$n_t = \frac{1}{1+g^L} [ (1-\varphi) n_{t-1} + \sigma_M u_{t-1}^\sigma v_{t-1}^{1-\sigma} ] \quad (\text{A1.6.1})$$

Unemployment rate:

$$u_t = 1 - n_t \quad (\text{A1.6.2})$$

Probability for an unemployed person of finding a job:

$$s_t = \frac{x_t n_t}{u_t} \quad (\text{A1.6.3})$$

Probability for a firm of filling a vacancy:

$$q_t = \sigma_M \left( \frac{u_t}{v_t} \right)^\sigma \quad (\text{A1.6.4})$$

Forward looking difference equation for the hiring rate:

$$\kappa x_t = \delta E_t \Lambda_{t,t+1} [ A - W_{t+1} + \frac{\kappa}{2} x_{t+1}^2 + (1-\varphi) \kappa x_{t+1} ] \quad (\text{A1.6.5})$$

Hiring rate:

$$x_t = q_t \frac{v_t}{n_t} \quad (\text{A1.6.6})$$

Euler equation:

$$1 = (1 + i_t) \delta E_t \frac{c_t}{c_{t+1}} \frac{1}{1 + \pi_{t+1}} \quad (\text{A1.6.7})$$

Product market equilibrium:

$$c_t = A n_t - \frac{\kappa}{2} x_t^2 n_t \quad (\text{A1.6.8})$$

Component of the firm's discount rate:

$$\Lambda_{t,t+1} = \frac{c_t}{c_{t+1}} \quad (\text{A1.6.9})$$

Cumulative discount factor of the worker:

$$\Delta_t = 1 + (1 - \varphi) \delta \lambda_w E_t \frac{1 + \pi^*}{1 + \pi_{t+1}} \Lambda_{t,t+1} \Delta_{t+1} \quad (\text{A1.6.10})$$

Cumulative discount factor of the firm:

$$\Psi_t = 1 + ((1 - \varphi) + x_t) \lambda_w \delta E_t \frac{1 + \pi^*}{1 + \pi_{t+1}} \Lambda_{t,t+1} \Psi_{t+1} \quad (\text{A1.6.11})$$

Bargaining power of the worker:

$$\chi_t = \frac{\mu_t}{\mu_t + (1 - \mu_t) \Psi_t / \Delta_t} \quad (\text{A1.6.12})$$

Unemployment benefits:

$$B_t = \bar{b} W_t \quad (\text{A1.6.13})$$

Target wage:

$$W_t^T = \chi_t \left[ A + \frac{\kappa}{2} x_t^2 \right] + [1 - \chi_t] B_t + [1 - \chi_t] s_t \kappa x_t E_t \frac{\chi_{t+1}}{1 - \chi_{t+1}} \quad (\text{A1.6.14})$$

Contract wage:

$$W_t^* = \frac{1}{\Delta_t} [W_t^T + (1 - \varphi) \delta \lambda_w E_t \Lambda_{t,t+1} \Delta_{t+1} W_{t+1}^*] \quad (\text{A1.6.15})$$

Wage index:

$$W_t = (1 - \lambda_w) W_t^* + \lambda_w \frac{1 + \pi^*}{1 + \pi_t} W_{t-1} \quad (\text{A1.6.16})$$

Nominal interest rate:

$$(1 + i_t) = [1 + i_{t-1}]^{\lambda_i} \left[ (1 + i^*) \left( \frac{1 + \pi_t}{1 + \pi^*} \right)^{a_\pi} \left( \frac{A n_t}{A n} \right)^{a_y} \right]^{1 - \lambda_i} \quad (\text{A1.6.17})$$

Government budget constraint:

$$B_t u_t (1 + g^L) + z_{t-1} = \frac{1}{1 + i_t} z_t (1 + g^L) + t_t (1 + g^L) \quad (\text{A1.6.18})$$

Ratio of bonds to output:

$$z_t = \bar{z} A n_t \quad (\text{A1.6.19})$$

Average bargaining power:

$$\mu_t = \frac{\mu_a - \mu_{e,t}}{(1 + g^L)^t} + \mu_{e,t} \quad (\text{A1.6.20})$$

Bargaining power in the emerging economies:

$$\mu_{e,t} = 0.5 \phi_t \quad (\text{A1.6.21})$$

Underlying autoregressive process:

$$\phi_t = \lambda_\mu \phi_{t-1} + (1 - \lambda_\mu) - (1 - 0.5)(1 - \lambda_\mu) \left(1 - \frac{g^L}{g_{new}^L}\right) \quad (\text{A1.6.22})$$

In total, we have 22 unknown variables ( $n, u, q, v, s, x, i, c, \Lambda, \Delta, \Psi, \chi, B, W^T, W^*, W, \pi, t, z, \mu, \mu_e, \phi$ ) and 22 equations.

**Steady State** In the steady state, the model is given by the following system of equations.

Employment rate:

$$n = \frac{1}{1 + g^L} [ (1 - \varphi) n + \sigma_M u^\sigma v^{1-\sigma} ] \quad (\text{A1.6.1a})$$

Unemployment rate:

$$u = 1 - n \quad (\text{A1.6.2a})$$

Probability for an unemployed person of finding a job:

$$s = \frac{x n}{u} \quad (\text{A1.6.3a})$$

Probability for a firm of filling a vacancy:

$$q = \sigma_M \left( \frac{u}{v} \right)^\sigma \quad (\text{A1.6.4a})$$

Forward looking difference equation for the hiring rate:

$$\kappa x = \delta \left[ A - W + \frac{\kappa}{2} x^2 + (1 - \varphi) \kappa x \right] \quad (\text{A1.6.5a})$$

Hiring rate:

$$x = \frac{q v}{n} \quad (\text{A1.6.6a})$$

Euler equation:

$$1 = (1 + i) \delta \quad (\text{A1.6.7a})$$

Product market equilibrium:

$$c = A n - \frac{\kappa}{2} x^2 n \quad (\text{A1.6.8a})$$

Component of the firm's discount rate:

$$\Lambda = 1 \quad (\text{A1.6.9a})$$

Cumulative discount factor of the worker:

$$\Delta = \frac{1}{1 - (1 - \varphi) \delta \lambda_w} \quad (\text{A1.6.10a})$$

Cumulative discount factor of the firm:

$$\Psi = \frac{1}{1 - ((1 - \varphi) + x) \lambda_w \delta} \quad (\text{A1.6.11a})$$

Bargaining power of the worker:

$$\chi = \frac{\mu}{\mu + (1 - \mu) \Psi / \Delta} \quad (\text{A1.6.12a})$$

Unemployment benefit:

$$B = \bar{b} W^* \quad (\text{A1.6.13a})$$

Target wage:

$$W^T = \chi \left[ A + \frac{\kappa}{2} x^2 \right] + [1 - \chi] B + s \kappa x \chi \quad (\text{A1.6.14a})$$

Contract wage:

$$W^* = W^T \quad (\text{A1.6.15a})$$

Wage index:

$$W = W^* \quad (\text{A1.6.16a})$$

Nominal interest rate:

$$(1 + i) = (1 + r^*)(1 + \pi^*) \quad (\text{A1.6.17a})$$

Government budget constraint:

$$B u (1 + g^L) + z = \frac{1}{1 + i} z (1 + g^L) + t (1 + g^L) \quad (\text{A1.6.18a})$$

Ratio of bonds to output:

$$z = \bar{z} A n \quad (\text{A1.6.19a})$$

Average bargaining power:

$$\mu = \mu_a \quad (\text{A1.6.20a})$$

Bargaining power in the emerging economies:

$$\begin{aligned} \mu_e &= 0.25 \quad \text{in the initial steady state (exogenously given)} & (\text{A1.6.21a}) \\ &= \mu_a \quad \text{in the new steady state (exogenously given)} \end{aligned}$$

Underlying autoregressive process:

$$\begin{aligned} \phi &= 0.5 \quad \text{in the initial steady state} & (\text{A1.6.22a}) \\ &= 1 \quad \text{in the new steady state} \end{aligned}$$

In total, we have 22 unknown variables ( $n, u, q, v, s, x, \delta, i, c, \Lambda, \Delta, \Psi, \chi, B, W^T, W^*, W, t, z, \mu, \mu_e, \phi$ ) and 22 equations. In the initial steady state, the job finding rate,  $s$ , is set exogenously to  $s = 0.45$ , and  $\kappa$  is treated as an unknown value. However, with respect to the new steady state,  $\kappa$  is given by the value of the initial steady state and  $s$  is treated as an endogenous variable.

### 7.1.7 Data

To calculate the effective global labor supply, we weight the labor supply of a country or region with the corresponding export-to-GDP ratio (see for this approach Harrigan and Balaban, 1999, as well as IMF, 2007a). The underlying data are provided by the World Development Indicators Database (World Bank, 2008). With



respect to the world, the effective labor supply in 2005 was 129% higher than in 1980 and 81% higher than in 1990, which corresponds to an average annual growth rate of 4.0%. Table 7.1 shows the corresponding data for the emerging economies, i.e. China, India, Eastern Europe and Central Asia, and the advanced economies (i.e. the high-income OECD countries).

Given this, we calculate the growth rate of the effective labor supply in the countries that have entered the world economy in recent decades (emerging economies) for the period 1990-2005. With respect to the model, we assume a constant labor supply in the advanced economies. Therefore, we normalize the effective labor supply in these countries to 1 in each year. Then, the normalized effective labor supply in the emerging economies (= sum of the effective labor supply in China, India as well as Eastern Europe and Central Asia divided by the effective labor supply in the advanced economies) is calculated for the years 1990 and 2005. The results imply an average annual growth rate of labor supply of above 3%. Taking into account the assumption of a constant labor supply in the advanced economies (being equal to 1), the calculation of the global growth rate yields a monthly rate of about 0.25%.

	China	India	Eastern Europe and Central Asia	Advanced economies
effective labor supply				
1980	53,901,962	16,146,866		65,006,853
1990	124,697,720	23,225,316	48,347,136	71,286,513
2005	288,707,477	87,532,460	83,025,739	105,964,519
1980-2005				
average annual growth rate in %	6.9	7.0		2.0
contribution to total growth in % points	65.4	19.9		11.4
1990-2005				
average annual growth rate in %	5.8	9.2	3.7	2.7
contribution to total growth in % points	36.2	14.2	7.6	7.6

Table 7.1: Effective Labor Supply

Sources: World Bank (2008). – Own calculations.

Eastern Europe and Central Asia (developing countries only): Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Georgia, Hungary, Kazakhstan,

Kyrgyz Republic, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovak Republic, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan.

Advanced economies: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea (Rep.), Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

### 7.1.8 Detailed Analysis of the Dynamics for the Full Model

When analyzing the reaction of the model variables to the labor supply impulse, four phases are considered. Due to the different lagged adjustment processes, the variables do not achieve their (local) extreme values in the same period. However, a detailed period-by-period analysis is beyond the scope of this chapter, as we are interested in the long-term behavior of the variables. Therefore, the division into four phases is just used as a general guideline for the analysis of the results. The phases are determined by extreme values of several variables: the first phase corresponds to the first period after the impulse, the second phase contains the periods up to period  $t \approx 10$ , the third phase up to  $t \approx 130$  and the fourth phase covers the periods after  $t \approx 130$ .

In the first phase, directly after the labor supply impulse, the employment rate decreases immediately (according to eq. (2.7)) and the unemployment rate increases. Moreover, the adjusted bargaining power,  $\chi$ , decreases immediately after the impulse. As analyzed in detail by Gertler and Trigari (2008), the horizon effect (due to  $\lambda_w > 0$ ) reduces the bargaining power of the workers as it makes them more impatient. Therefore, the adjusted bargaining power,  $\chi$ , is lower than the bargaining power,  $\mu$ . In particular, the labor supply impulse causes an immediate drop of the adjusted bargaining power,  $\chi$ . This reaction – on its own – reduces the target wage,  $W^T$ , according to eq. (2.26) and finally the aggregate wage given by the wage index,  $W$ . However, a lower aggregate wage would increase the hiring rate,  $x$ , according to eq. (2.14) and thereby the finding probability,  $s$ .<sup>145</sup> Both, the increase of the hiring rate and the increase of the job finding probability – on their own – cause an increase of the target wage in the same period according to eq. (2.26). Thus, with respect to the target wage, there are two opposing effects: first, a negative effect due to the declining bargaining power and second, a positive effect due to the increasing hiring rate and the increasing job finding probability. In the first period, the positive impact of the hiring rate and the finding probability, respectively, dominates. The

<sup>145</sup>Combining eq. (2.3) and eq. (2.10) provides:  $s = x * N/U$ .

target wage and finally the aggregate wage increases.

In this context, it is revealing to already regard the simulation results for  $\lambda_w = 0$ . For  $\lambda_w = 0$ , there is no horizon effect (i.e.  $\chi_t = \mu_t$ ). In particular, there is also no immediate drop of the adjusted bargaining power,  $\chi$ . Therefore, the initial wage increase for  $\lambda_w = 0$  is higher than for  $\lambda_w > 0$ . Consequently, the initial increase in the hiring rate,  $x$ , as well as of the job finding probability,  $s$ , are lower.

Also consumption per capita initially declines as – according to eq. (2.35) – consumption per capita is positively correlated with the employment rate. Given a declining consumption per capita (i.e.  $\frac{c_t}{c_{t+1}} > 1$ ), the Euler equation implies a reduction of the interest rate,  $i$ , below the steady state level. In order to explain the initial reaction of the inflation rate, we regard the Taylor Rule. After implementing a positive growth rate of labor supply, the output gap becomes positive. Even after the initial negative impulse, the employment rate,  $n$ , is still above the new steady state level,  $n^{new}$ . Hence, the effective output,  $y_t = A n_t$ , is higher than the potential output,  $y^* = A n^{new}$ . This argument – on its own – requires a higher interest rate,  $i$ , i.e. an interest rate level above the steady state level. Standard macroeconomic models assume that the interest rate targeted by the central bank (via the Taylor rule) equals the interest rate implied by the Euler equation.<sup>146</sup> Now, the second factor in the Taylor rule, the inflation rate, becomes relevant, as its development makes the interest rate implications of the Taylor rule and the Euler equation, respectively, consistent. An interest rate below the steady state level, as implied by the Euler equation, causes a decline in the inflation rate,  $\pi$ , according to the Taylor rule. In the presence of a positive output gap, the decline of the inflation rate has to be strong enough to be consistent with a negative interest rate.

In the second phase ( $t = 2$  up to  $t \approx 10$ ), some variables (in particular the job filling probability,  $q$ , the job finding probability,  $s$ , the interest rate,  $i$ , the inflation rate,  $\pi$ , as well as the target wage,  $W^T$ , and the contract wage,  $W^*$ ) move into the opposite direction – compared to the first phase, whereas other variables retain their direction. In contrast to the first period, the increasing unemployment rate causes an increase of the filling probability,  $q$ , and simultaneously a decline of the job finding probability,  $s$ . Now, the declining finding rate,  $s$ , contributes to the decline of the target wage,  $W^T$ , according to eq. (2.26) and finally the aggregate wage. The increase of the hiring rate,  $x$ , still has a positive impact on the wage, which is, however, lower than in the first phase and not sufficient to compensate the negative effects. Due to the further reduction of the employment rate,  $n$ , the positive output

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<sup>146</sup>See Woodford (2003). Given this equalization, the Euler equation provides a direct link between monetary policy and consumption demand.

gap becomes smaller. Moreover, consumption per capita,  $c$ , decreases further, but to a smaller extent (i.e.  $\frac{c_t}{c_{t+1}} > \frac{c_{t+1}}{c_{t+2}} > 1$ ). Thus, the Euler equation generates an interest rate that is still below steady state but higher than in the first period. Given the higher interest rate and the lower positive output gap, monetary policy following the Taylor rule generates an inflation rate that is higher than in the first period (i.e. less negative in this calibration framework).

In the third phase ( $t \approx 10$  up to  $t \approx 130$ ), several variables change their trend. In particular, the employment rate,  $n$ , increases, which can be explained as follows. Due to the decreasing global bargaining power, the contract wage,  $W^*$ , (i.e. the result of the Nash bargaining) and – to a less extreme extent – the aggregate wage given by the wage index,  $W$ , fall significantly. In this context, it is revealing to already regard the simulation results for  $\lambda_\mu = 0$  with respect to the third phase. In the case of a constant bargaining power, the employment rate does not increase and, in particular, the inflation rate does not decrease. Hence, with respect to the full model, the dynamics of the bargaining power are the main driving force. In the full model, simultaneously to the increase of the employment rate, consumption per capita increases (i.e.  $\frac{c_t}{c_{t+1}} < 1$ ) but to a declining extent. The Euler equation thus implies a decreasing interest rate. Moreover, due to the increasing employment rate,  $n$ , the output gap increases. Given the increasing output gap and the interest rate implication of the Euler equation, monetary policy following a Taylor Rule generates an inflation rate below steady state, in particular an inflation rate, which decreases further.

In the fourth phase (after  $t \approx 130$ ), the dominating process is again the development of the adjusted bargaining power. However, now, the adjusted bargaining power increases because the convergence process with respect the bargaining power in the emerging economies dominates. The contract wage,  $W^*$ , and – to a minor extent – the target wage,  $W^T$ , increase. Moreover, the employment rate,  $n$ , decreases again and converges to its new equilibrium,  $n^{new}$ . Hence, the output gap becomes smaller. Simultaneously, consumption per capita also decreases, but the decline becomes smaller in the course of time (i.e.  $1 < \frac{c_{t+1}(i)}{c_{t+2}(i)} < \frac{c_t(i)}{c_{t+1}(i)}$ ). Hence, the interest rate – starting from a level below steady state – increases according to the Euler equation (2.19) and converges to its steady state. Thus, to sum up, on the one hand, the interest rate, as implied by the Euler equation, increases from a level below steady state to the steady state. On the other hand, the output gap converges to 0. Given both factors, monetary policy following a Taylor rule implies that the inflation rate has to become less negative. Hence, starting from a level below steady state, the inflation rate increases and converges to its steady state.

### 7.1.9 Results for the Full Model

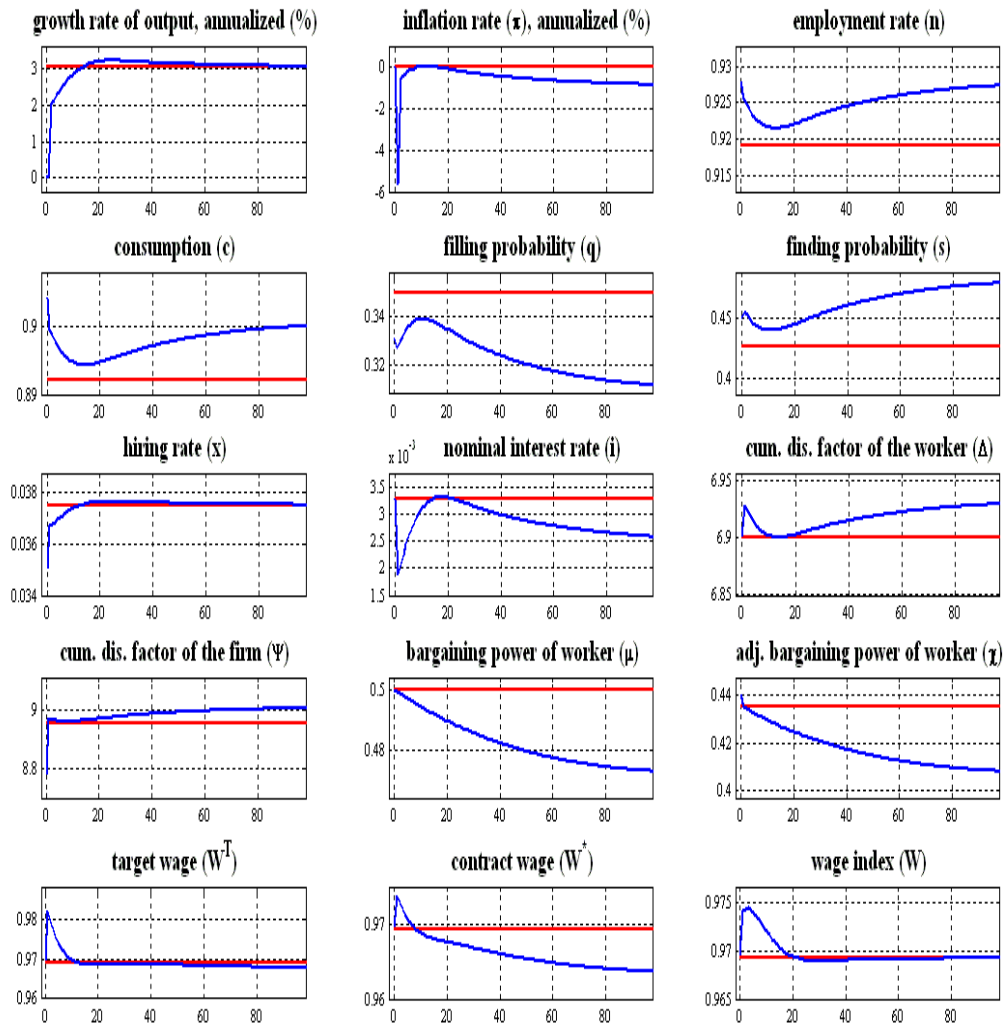


Figure 7.1: Short-term Dynamics of the Full Model

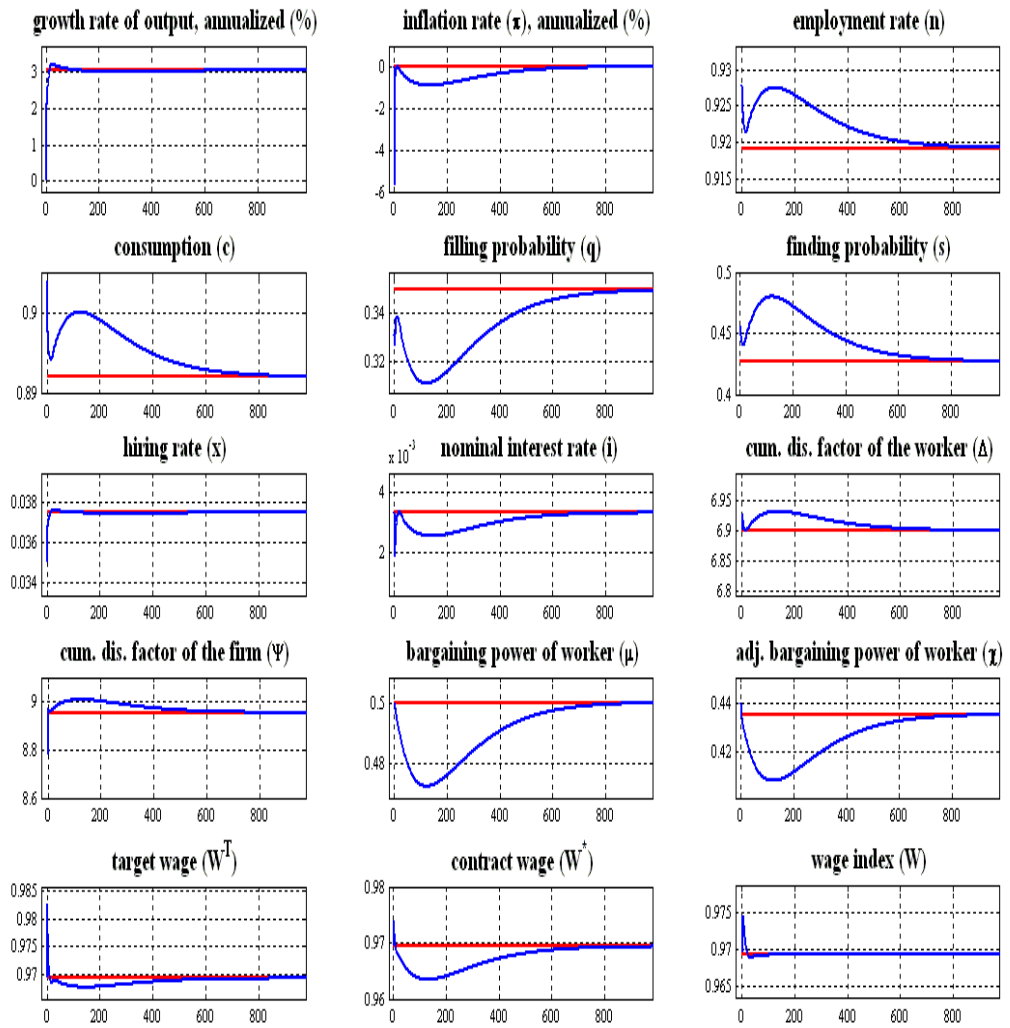


Figure 7.2: Long-term Dynamics of the Full Model

### 7.1.10 Results for the Modified Model with $\lambda_\mu = 0$

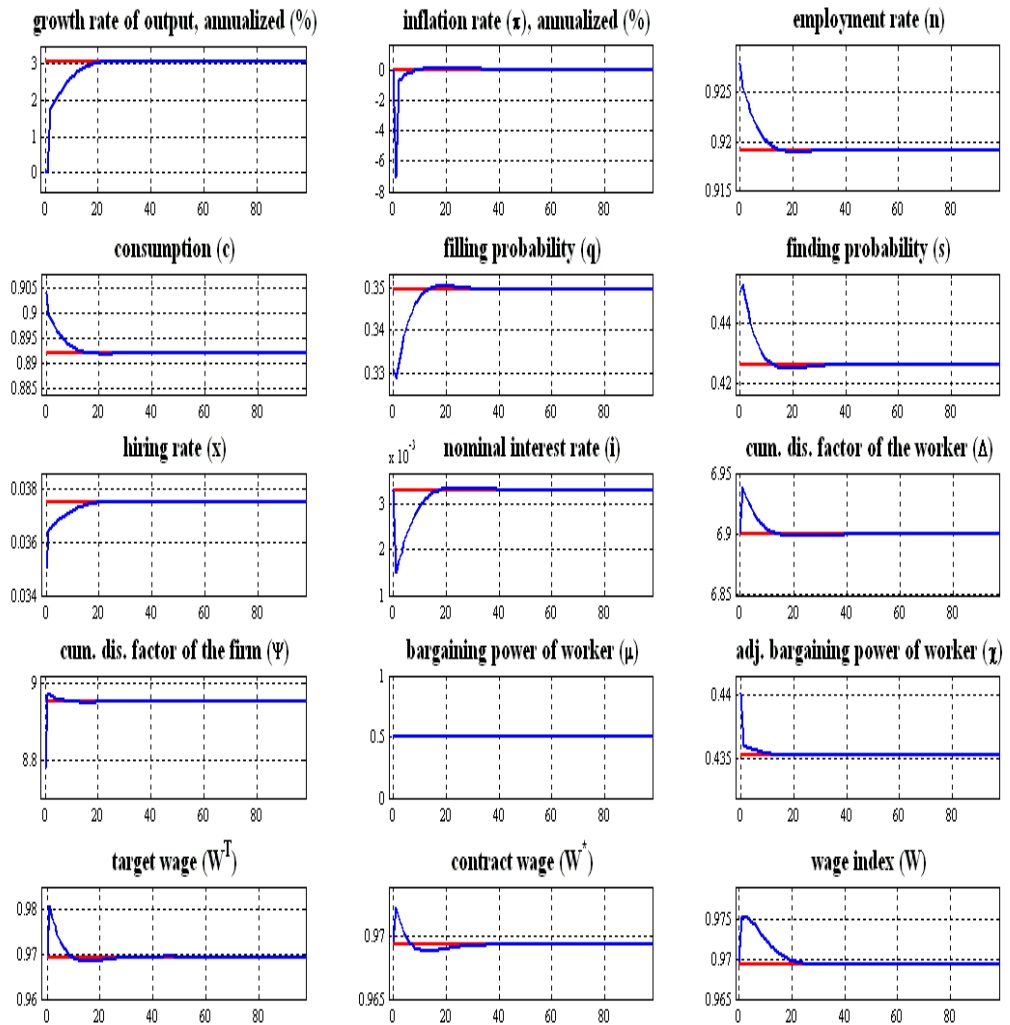


Figure 7.3: Short-term Dynamics of the Modified Model ( $\lambda_\mu = 0$ )

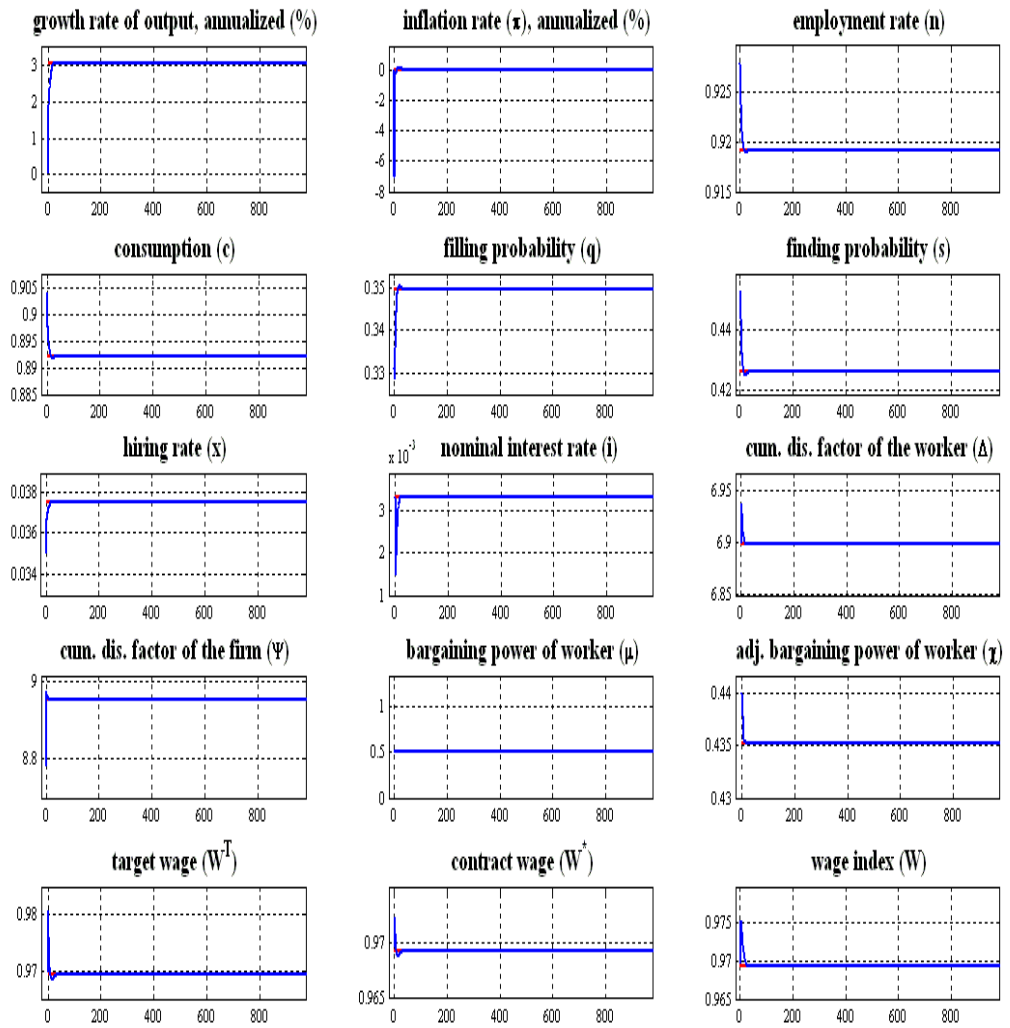


Figure 7.4: Long-term Dynamics of the Modified Model ( $\lambda_\mu = 0$ )



### 7.1.11 Results for the Modified Model with $\lambda_w = 0$

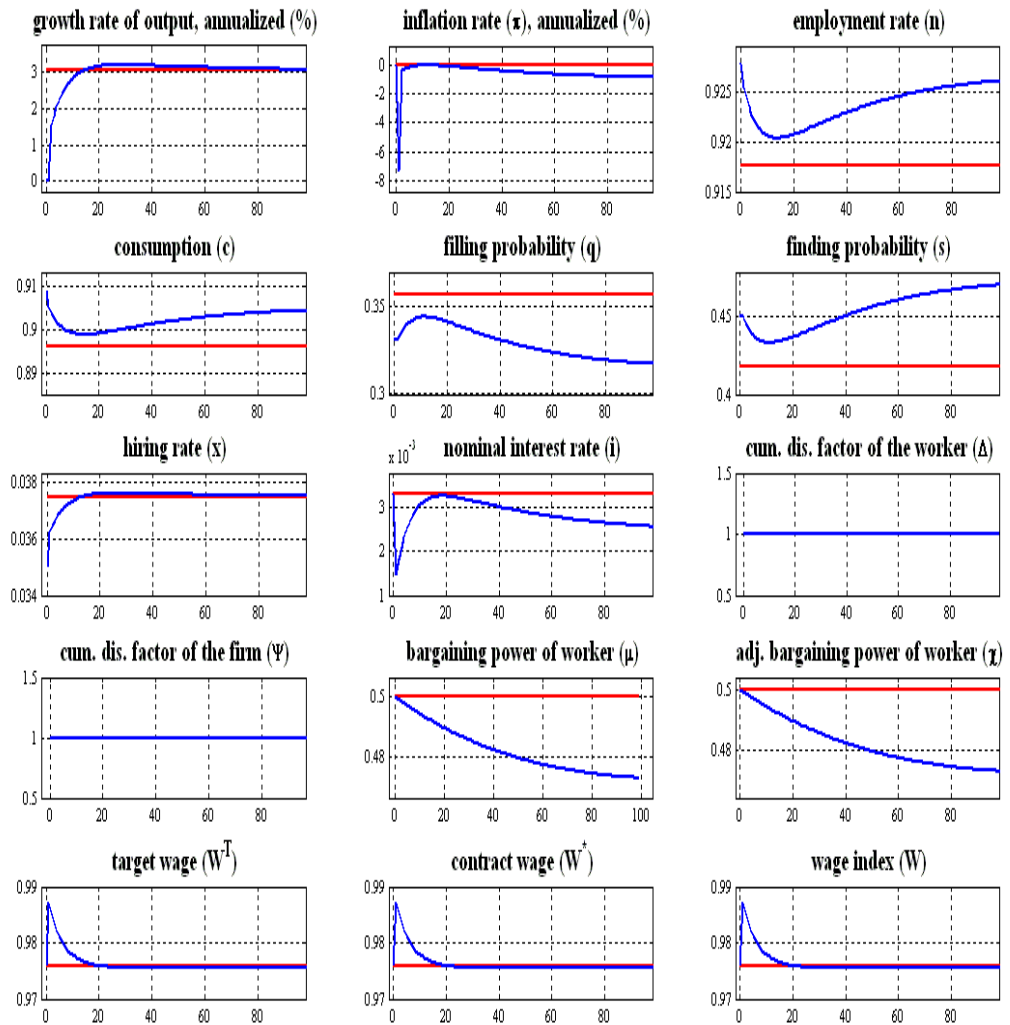


Figure 7.5: Short-term Dynamics of the Modified Model ( $\lambda_w = 0$ )

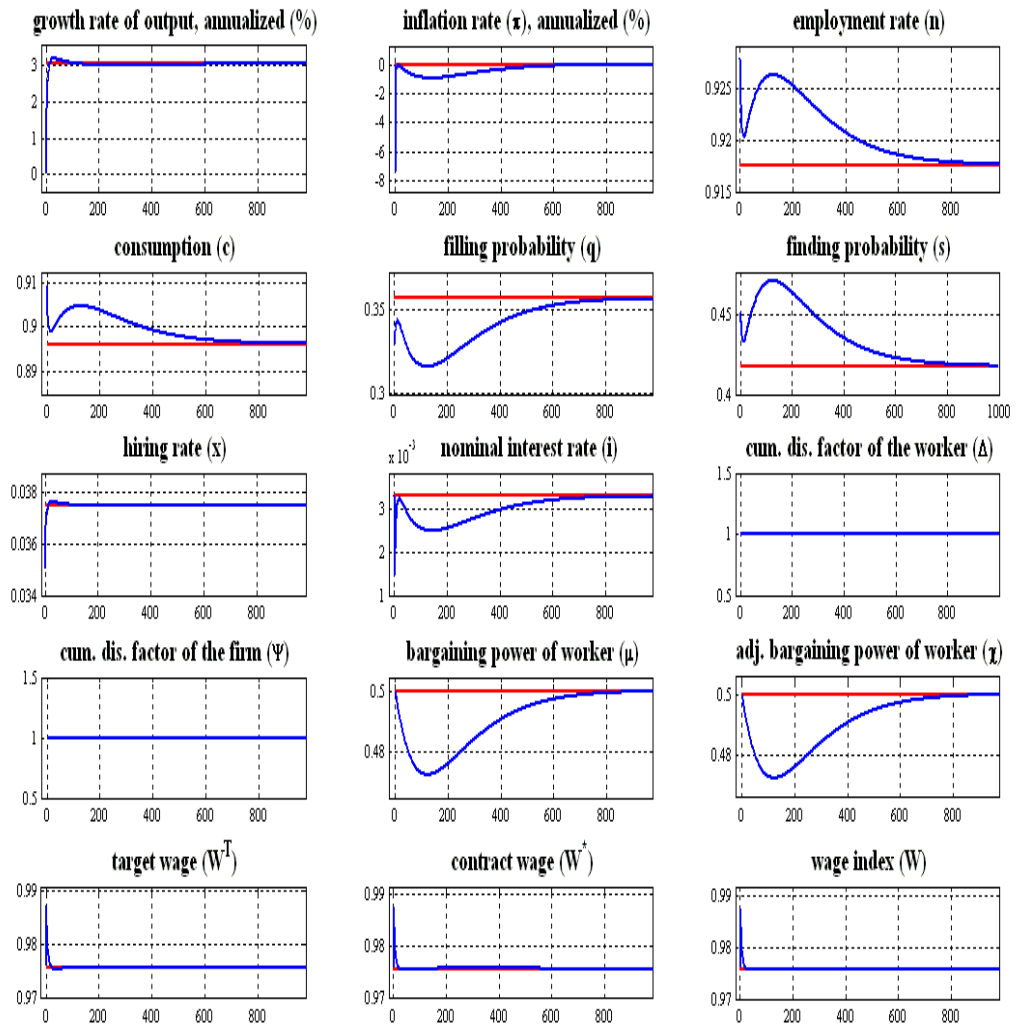


Figure 7.6: Long-term Dynamics of the Modified Model ( $\lambda_w = 0$ )

### 7.1.12 Results for the Modified Model with $\lambda_i = 0$

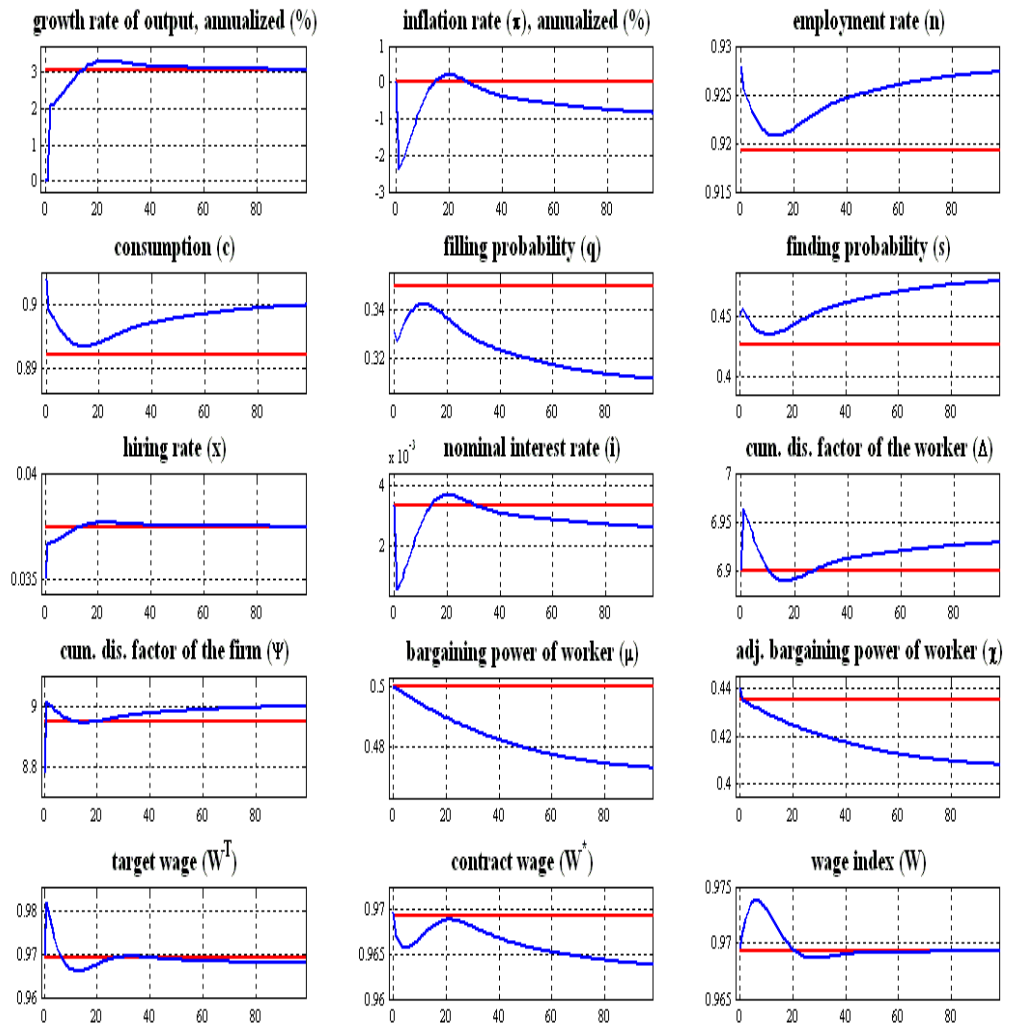


Figure 7.7: Short-term Dynamics of the Modified Model ( $\lambda_i = 0$ )

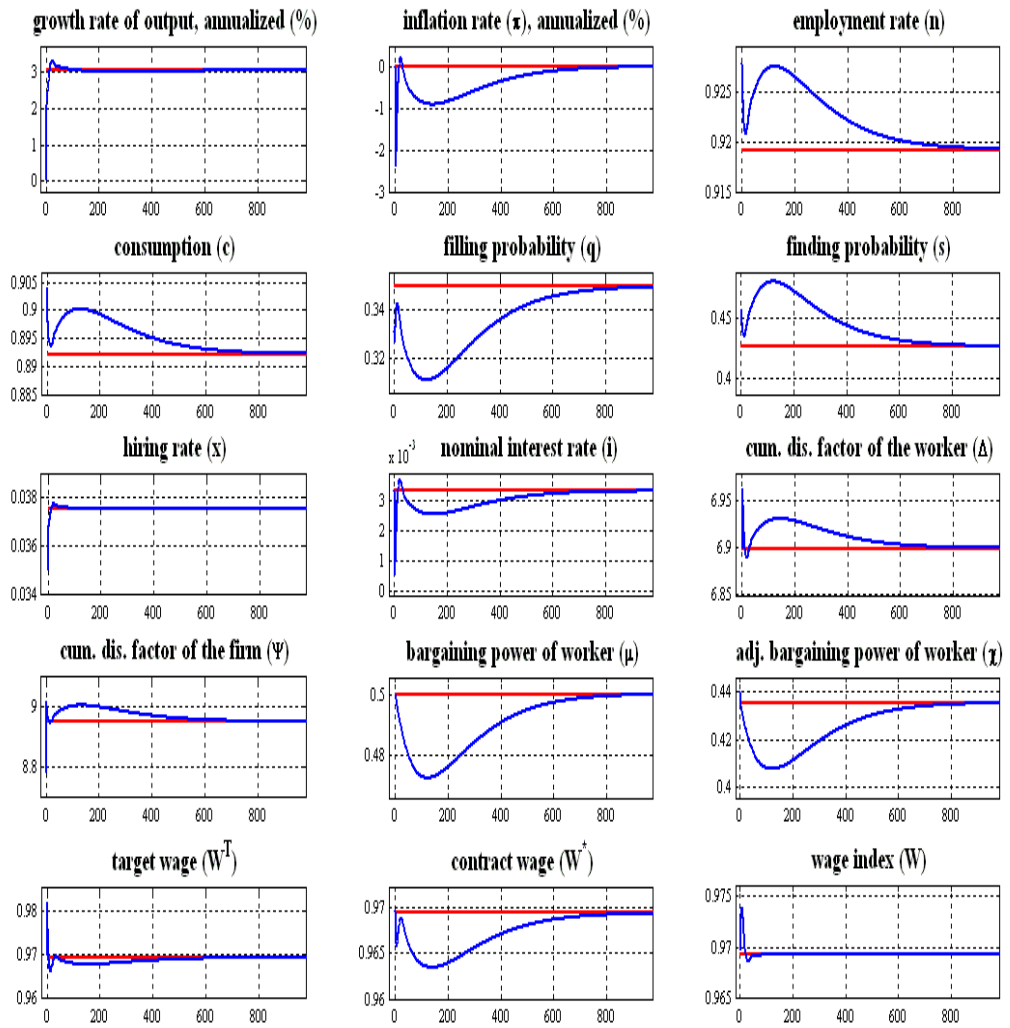


Figure 7.8: Long-term Dynamics of the Modified Model ( $\lambda_i = 0$ )

### 7.1.13 Price Adjustment Costs and Money Growth Rule

In the following, a modified version of the model is presented. In particular, there are two modifications: first, the introduction of Rotemberg price adjustment costs (Rotemberg, 1982, 1983) and monopolistic competition and, second, the introduction of money holding in the utility function of the household and the substitution of the Taylor rule by a money growth rule. Initially, the modifications of the theoretical model are illustrated. Then, the numerical analysis is presented.

**Modifications of the Theoretical Model** Compared to the initial model, the following equations change: the forward looking difference equation for the hiring rate, the equation, which determines the target wage and the government budget constraint. Moreover, the Taylor rule is replaced by a money growth rule and two equations are added: the equation determining the marginal costs and the money demand equation. The derivations are illustrated in the following.

**Profit Maximization of the Firm** In the presence of monopolistic competition and Rotemberg price adjustment costs, the profit maximization problem is solved as follows. Based on eq. (2.11) subject to eq. (2.4) and eq. (2.9), the following Lagrange function for the firm,  $\mathcal{L}_{F(i)}$ , is formed:

$$\mathcal{L}_{F(i)} = E_t \sum_{j=0}^{\infty} \delta^j \Lambda_{t,t+j} \left[ \begin{array}{l} \left[ \frac{P_{t+j}(i)}{P_{t+j}} Y_{t+j}(i) - \frac{W_{t+j}^n(i)}{P_{t+j}} N_{t+j}(i) - \frac{\kappa}{2} x_{t+j}^2(i) N_{t+j}(i) \right. \\ \left. - \frac{\psi}{2} \left( \frac{P_{t+j}(i)}{P_{t+j-1}(i)} - (1 + \pi) \right)^2 Y_{t+j} \right] \\ - \xi_{t+j} [N_{t+j}(i) - (1 - \varphi) N_{t+j-1}(i) - q_{t+j-1} V_{t+j-1}(i)] \\ \left. - \zeta_{t+j} [Y_{t+j}(i) - A N_{t+j}(i)] \right] \end{array} \right] \quad (\text{A1.13.1})$$

The first order condition with respect to employment is (recall that:  $x_t(i) = \frac{q_t V_t(i)}{N_t(i)}$ ):

$$\begin{aligned} \frac{\partial \mathcal{L}_{F(i)}}{\partial N_{t+j}(i)} &= E_t \delta^j \Lambda_{t,t+j} \left( -\frac{W_{t+j}^n(i)}{P_{t+j}} + \frac{\kappa}{2} x_{t+j}^2(i) - \xi_{t+j} + \zeta_{t+j} A \right) \\ &\quad + E_t \delta^{j+1} \Lambda_{t,t+j+1} \xi_{t+j+1} (1 - \varphi) \\ &\stackrel{!}{=} 0 \end{aligned}$$

For  $j = 0$ , we get:

$$\xi_t = \zeta_t A - \frac{W_t^n(i)}{P_t} + \frac{\kappa}{2} x_t^2(i) + E_t \delta \Lambda_{t,t+1} \xi_{t+1} (1 - \varphi) \quad (\text{A1.13.2})$$

The first order condition with respect to the number of vacancies is:

$$\frac{\partial \mathcal{L}_{F(i)}}{\partial V_t(i)} = E_t \delta^j \Lambda_{t,t+j} (-\kappa q_{t+j} x_{t+j}(i)) + E_t \delta^{j+1} \Lambda_{t,t+j+1} (-\xi_{t+j+1})(-q_{t+j}(i)) \stackrel{!}{=} 0$$

For  $j = 0$ , we get:

$$\kappa x_t(i) = \delta E_t \Lambda_{t,t+1} \xi_{t+1} \quad (\text{A1.13.3})$$

In order to calculate the first order condition with respect to the price  $P_t(i)$ ,  $Y_{t+j}(i)$  in eq. (A1.13.1) is substituted by  $Y_{t+j}(\frac{P_{t+j}(i)}{P_{t+j}})^{-\epsilon}$ :

$$\mathcal{L}_{F(i)} = E_t \sum_{j=0}^{\infty} \delta^j \Lambda_{t,t+j} \left[ \begin{array}{l} [(\frac{P_{t+j}(i)}{P_{t+j}})^{1-\epsilon} Y_{t+j} - \frac{W_{t+j}^n(i)}{P_{t+j}} N_{t+j}(i) - \frac{\kappa}{2} x_{t+j}^2(i) N_{t+j}(i) \\ - \frac{\psi}{2} (\frac{P_{t+j}(i)}{P_{t+j-1}(i)} - (1 + \pi))^2 Y_{t+j}] \\ - \xi_{t+j} [N_{t+j}(i) - (1 - \varphi) N_{t+j-1}(i) - q_{t+j-1} V_{t+j-1}(i)] \\ - \zeta_{t+j} [(\frac{P_{t+j}(i)}{P_{t+j}})^{-\epsilon} Y_{t+j} - A N_{t+j}(i)] \end{array} \right]$$

The first order condition with respect to the price is:

$$\begin{aligned} \frac{\mathcal{L}_{F(i)}}{\partial P_{t+j}(i)} &= E_t \delta^j \Lambda_{t,t+j} [(1 - \epsilon) \frac{P_{t+j}^{-\epsilon}(i)}{P_{t+j}^{1-\epsilon}} Y_{t+j} - \psi (\frac{P_{t+j}(i)}{P_{t+j-1}(i)} - (1 + \pi)) \frac{Y_{t+j}}{P_{t+j-1}(i)} \\ &\quad - \zeta_{t+j} (-\epsilon) \frac{P_{t+j}^{-\epsilon-1}(i)}{P_{t+j}^{-\epsilon}} Y_{t+j}] \\ &\quad + E_t \delta^{j+1} \Lambda_{t,t+j+1} ((-\psi) (\frac{P_{t+j+1}(i)}{P_{t+j}(i)} - (1 + \pi)) \frac{-P_{t+j+1}(i)}{P_{t+j}^2(i)} Y_{t+j+1} \stackrel{!}{=} 0 \end{aligned}$$

For  $j = 0$ , we get:

$$\begin{aligned} 0 &= (1 - \epsilon) \frac{P_t^{-\epsilon}(i)}{P_t^{1-\epsilon}} Y_t - \psi (\frac{P_t(i)}{P_{t-1}(i)} - (1 + \pi)) \frac{Y_t}{P_{t-1}(i)} - \zeta_t (-\epsilon) \frac{P_t^{-\epsilon-1}(i)}{P_t^{-\epsilon}} Y_t \\ &\quad + \delta E_t \Lambda_{t,t+1} ((-\psi) (\frac{P_{t+1}(i)}{P_t(i)} - (1 + \pi)) \frac{-P_{t+1}(i)}{P_t^2(i)} Y_{t+1} \end{aligned}$$

With  $P_t(i) = P_t$ , we get:

$$\begin{aligned}
0 &= (1 - \epsilon) \frac{Y_t}{P_t} - \psi \left( \frac{P_t}{P_{t-1}} - (1 + \pi) \right) \frac{Y_t}{P_{t-1}} + \zeta_t \epsilon \frac{Y_t}{P_t} \\
&\quad + \delta E_t \Lambda_{t,t+1} \psi \left( \frac{P_{t+1}}{P_t} - (1 + \pi) \right) \frac{P_{t+1}}{P_t^2} Y_{t+1} \\
\Leftrightarrow 0 &= (1 - \epsilon) - \psi \left( \frac{P_t}{P_{t-1}} - (1 + \pi) \right) \frac{P_t}{P_{t-1}} + \zeta_t \epsilon \\
&\quad + \delta E_t \Lambda_{t,t+1} \psi \left( \frac{P_{t+1}}{P_t} - (1 + \pi) \right) \frac{P_{t+1}}{P_t} \frac{Y_{t+1}}{Y_t} \\
\Leftrightarrow 0 &= (1 - \epsilon) - \psi((1 + \pi_t) - (1 + \pi))(1 + \pi_t) + \zeta_t \epsilon \\
&\quad + \delta E_t \Lambda_{t,t+1} \psi((1 + \pi_{t+1}) - (1 + \pi))(1 + \pi_{t+1}) \frac{Y_{t+1}}{Y_t} \\
\Leftrightarrow 0 &= (1 - \epsilon) - \psi(\pi_t - \pi)(1 + \pi_t) + \zeta_t \epsilon \\
&\quad + \delta E_t \Lambda_{t,t+1} \psi(\pi_{t+1} - \pi)(1 + \pi_{t+1}) \frac{L_{t+1}}{L_t} \frac{A}{A} \frac{n_{t+1}}{n_t} \\
&\hspace{15em} (7.1) \\
\Leftrightarrow -\zeta_t \epsilon &= -\psi(\pi_t - \pi)(1 + \pi_t) + \delta E_t \Lambda_{t,t+1} \psi(\pi_{t+1} - \pi)(1 + \pi_{t+1}) (1 + g^L) \frac{n_{t+1}}{n_t} - \epsilon + 1 \\
\Leftrightarrow \zeta_t &= \left[ \psi(\pi_t - \pi)(1 + \pi_t) - \delta E_t \Lambda_{t,t+1} \psi(\pi_{t+1} - \pi)(1 + \pi_{t+1}) (1 + g^L) \frac{n_{t+1}}{n_t} + \epsilon - 1 \right] / \epsilon \\
&\hspace{15em} (A1.13.4)
\end{aligned}$$

In the steady state ( $\pi_{t+j} = \pi$ ), the condition becomes  $\zeta_t = \frac{\epsilon-1}{\epsilon}$ , like in Krause and Lubik (2007).

Finally, the forward looking difference equation for the hiring rate can be derived. The combination of eq. (A1.13.2) and eq. (A1.13.3) yields:

$$\begin{aligned}
\xi_t &= \zeta_t A - \frac{W_t^n(i)}{P_t} + \frac{\kappa}{2} x_t^2(i) + (1 - \varphi) \underbrace{\kappa x_t(i)}_{= \delta E_t \Lambda_{t,t+1} \xi_{t+1} \text{ according to eq. (A1.13.3)}} \hspace{5em} (A1.13.2a) \\
&= \delta E_t \Lambda_{t,t+1} \xi_{t+1} \text{ according to eq. (A1.13.3)}
\end{aligned}$$

*Excursion:*

Given the previous equation, the marginal costs can be calculated as follows:

$$\begin{aligned}
\xi_t &= \zeta_t A - \frac{W_t^n(i)}{P_t} + \frac{\kappa}{2} x_t^2(i) + (1 - \varphi) \kappa x_t(i) \\
\zeta_t A &= \frac{W_t^n(i)}{P_t} + \xi_t - \frac{\kappa}{2} x_t^2(i) - (1 - \varphi) \kappa x_t(i) \\
\zeta_t &= \frac{W_t^n(i)}{A} + \frac{1}{A} \left[ \xi_t - \frac{\kappa}{2} x_t^2(i) - (1 - \varphi) \kappa x_t(i) \right]
\end{aligned}$$

The first term on the right hand side ( $\frac{W_t(i)}{A}$ ) is the real wage divided by the product of labor. The second term arises from the presence of labor market frictions (i.e. costs of adjusting employment size). For  $\kappa = 0$  (and hence – according to eq. (A1.13.3) –  $\xi_t = 0$ ), we get:  $\zeta_t = \frac{W_t(i)}{A}$ .

*End of the Excursion*

The substitution of  $\xi_{t+1}$  in eq. (A1.13.3) by the expression in eq. (A1.13.2a) for  $t + 1$  yields the modified forward looking difference equation for the hiring rate:

$$\kappa x_t(i) = \delta E_t \Lambda_{t,t+1} \underbrace{\left[ \zeta_{t+1} A - \frac{W_{t+1}^n(i)}{P_{t+1}} + \frac{\kappa}{2} x_{t+1}^2(i) + (1 - \varphi) \kappa x_{t+1}(i) \right]}_{= \xi_{t+1} \text{ according to eq. (A1.13.2a)}} \quad (\text{A1.13.5})$$

Besides the forward looking difference equation, the equation determining the target wage is modified as follows:

$$W_t^T = \chi_t \left[ \zeta_t A + \frac{\kappa}{2} x_t^2 \right] + [1 - \chi_t] B_t + [1 - \chi_t] s_t \kappa x_t E_t \frac{\chi_{t+1}}{1 - \chi_{t+1}} \quad (\text{A1.13.6})$$

**Utility Maximization of the Household** In the presence of money holding, the utility maximization problem of the household is solved as follows. Initially, money holding is introduced into the utility function as well as into the budget constraint. Then, the modified Lagrange function for the household,  $\mathcal{L}_H$ , is given by:

$$\mathcal{L}_H = E_t \sum_{j=0}^{\infty} \delta^j \left( \ln(c_{t+j}) + \frac{\varsigma_v}{1 - v} (m_{t+j})^{1-v} - \varrho_{t+j} \left[ \begin{array}{l} P_{t+j} c_{t+j} + P_{t+j} m_{t+j} + \frac{1}{1+i_{t+j}} z_{t+j}^n + P_{t+j} t_{t+j} \\ - P_{t+j} W_{t+j} n_{t+j} - P_{t+j} B_{t+j} u_{t+j} \\ - P_{t+j-1} m_{t+j-1} - z_{t+j-1}^n - P_{t+j} \Pi_{t+j} \end{array} \right] \right)$$

The first order condition with respect to consumption is:

$$\frac{\partial \mathcal{L}_H}{\partial c_t} = E_t \delta^j \left( \frac{1}{c_{t+j}} - \varrho_{t+j} P_{t+j} \right) \stackrel{!}{=} 0$$

For  $j = 0$ , we get:

$$\frac{1}{c_t} = P_t \varrho_t \quad (\text{A1.13.7})$$



The first order condition with respect to bond holding is:

$$\frac{\partial L_H}{\partial z_{t+j}^n} = E_t \delta^j (-\varrho_{t+j} \frac{1}{1+i_{t+j}}) + E_t \delta^{j+1} (-\varrho_{t+j+1})(-1) \stackrel{!}{=} 0$$

For  $j = 0$ , we get:

$$\varrho_t \frac{1}{1+i_t} = \delta E_t \varrho_{t+1} \quad (\text{A1.13.8})$$

By combining the two first order conditions, the Euler equation can be derived. We rewrite eq. (A1.13.8) by substituting  $\varrho_t$  by  $\frac{1}{c_t} \frac{1}{P_t}$  and  $\varrho_{t+1}$  by  $\frac{1}{c_{t+1}} \frac{1}{P_{t+1}}$  according to eq. (A1.13.7), respectively:

$$\frac{1}{c_t} \frac{1}{P_t} \frac{1}{1+i_t} = \delta E_t \frac{1}{c_{t+1}} \frac{1}{P_{t+1}}$$

By rearranging, we get the consumption Euler equation (Recall that  $\frac{P_{t+1}}{P_t} = 1 + \pi_{t+1}$ ):

$$1 = (1+i_t) \delta E_t \left[ \frac{c_t}{c_{t+1}} \frac{1}{1+\pi_{t+1}} \right] \quad (\text{A1.13.9})$$

The first order condition with respect to money holding is:

$$\frac{\partial L_H}{\partial m_{t+j}} = E_t \delta^j (\varsigma_v [m_{t+j}]^{-\nu} - \varrho_{t+j} P_{t+j}) + E_t \delta^{j+1} (-\varrho_{t+j+1})(-P_{t+j}) \stackrel{!}{=} 0$$

For  $j = 0$ , we get:

$$0 = \varsigma_v [m_t]^{-\nu} - \varrho_t P_t + E_t \delta \varrho_{t+1} P_t \quad (\text{A1.13.10})$$

By using eq. (A1.13.8), we can write:

$$0 = \varsigma_v [m_t]^{-\nu} - \varrho_t P_t + \varrho_t \frac{1}{1+i_t} P_t$$

We substitute  $\varrho_t$  by  $\frac{1}{c_t} \frac{1}{P_t}$  according to eq. (A1.13.7) and get:

$$\begin{aligned}
0 &= \varsigma_v [m_t]^{-v} - \frac{1}{c_t} \frac{1}{P_t} P_t + \frac{1}{c_t} \frac{1}{P_t} \frac{1}{1+i_t} P_t \\
\Leftrightarrow 0 &= \varsigma_v [m_t]^{-v} - \frac{1}{c_t} + \frac{1}{c_t} \frac{1}{1+i_t} \\
\Leftrightarrow \varsigma_v [m_t]^{-v} &= \frac{1}{c_t} \left(1 - \frac{1}{1+i_t}\right) \\
\Leftrightarrow \varsigma_v [m_t]^{-v} &= \frac{1}{c_t} \left(\frac{i_t}{1+i_t}\right) \\
\Leftrightarrow \frac{1}{\varsigma_v} [m_t]^v &= c_t \frac{1+i_t}{i_t} \\
\Leftrightarrow m_t &= \left[\varsigma_v c_t \frac{1+i_t}{i_t}\right]^{1/v}
\end{aligned} \tag{A1.13.11}$$

**Money Growth Rule** The Taylor rule is replaced by a money growth rule. In particular, total nominal money balance,  $M_t^n$ , is assumed to grow with the rate  $g^L$ , i.e. with the same growth rate as labor supply,  $L$ , and total output,  $Y$ :

$$\begin{aligned}
M_t^n &= M_{t-1}^n (1 + g^L) \\
\Leftrightarrow P_t M_t &= P_{t-1} M_{t-1} (1 + g^L) \\
\Leftrightarrow M_t &= \frac{P_{t-1}}{P_t} M_{t-1} (1 + g^L) \\
\Leftrightarrow M_t &= \frac{1}{1 + \pi_t} M_{t-1} (1 + g^L)
\end{aligned}$$

and in per capita terms:

$$\Leftrightarrow m_t = \frac{1}{1 + \pi_t} m_{t-1} \tag{A1.13.12}$$

**Government Budget Constraint** The modified government budget constraint is:

$$P_t B_t U_t + M_{t-1}^n + Z_{t-1}^n = M_t^n + \frac{1}{1+i_t} Z_t^n + P_t T_t \tag{A1.13.13}$$

and in per capita terms:

$$\begin{aligned}
& P_t B_t \frac{U_t}{L_{t-1}} + \frac{M_{t-1}^n}{L_{t-1}} + \frac{Z_{t-1}^n}{L_{t-1}} = \frac{M_t^n}{L_{t-1}} + \frac{1}{1+i_t} \frac{Z_t^n}{L_{t-1}} + P_t \frac{T_t}{L_{t-1}} \\
\Leftrightarrow & B_t \frac{U_t}{L_t} \frac{L_t}{L_{t-1}} + \frac{M_{t-1}^n}{L_{t-1}} \frac{1}{P_t} + \frac{Z_{t-1}^n}{L_{t-1}} \frac{1}{P_t} = \frac{M_t^n}{L_t} \frac{L_t}{L_{t-1}} \frac{1}{P_t} + \frac{1}{1+i_t} \frac{Z_t^n}{L_t} \frac{L_t}{L_{t-1}} \frac{1}{P_t} + \frac{T_t}{L_t} \frac{L_t}{L_{t-1}} \\
\Leftrightarrow & B_t u_t (1+g^L) + \frac{m_{t-1}^n}{P_t} + \frac{z_{t-1}^n}{P_t} = \frac{m_t^n}{P_t} (1+g^L) + \frac{1}{1+i_t} \frac{z_t^n}{P_t} (1+g^L) + t_t (1+g^L) \\
\Leftrightarrow & B_t u_t (1+g^L) + m_{t-1} + z_{t-1} = m_t (1+g^L) + \frac{1}{1+i_t} z_t (1+g^L) + t_t (1+g^L)
\end{aligned} \tag{A1.13.13a}$$

## Numerical Evaluation

**Calibration** Before presenting the results of the simulations, the additional parameter values have to be calibrated. With respect to the price adjustment costs, the parameter  $\psi$  is set at 104.85; the degree of monopolistic competition  $\epsilon$  is set at 10; these parameter values correspond to the values in Faia et al. (2009). Furthermore, with respect to utility of money holding, we choose  $\nu = 1$  (see, e.g. Merkl and Snower, 2007) and  $\varsigma_\nu = 0.001$ .

**Results of the Simulation** The following graphs illustrate the long-term and the short-term dynamics.

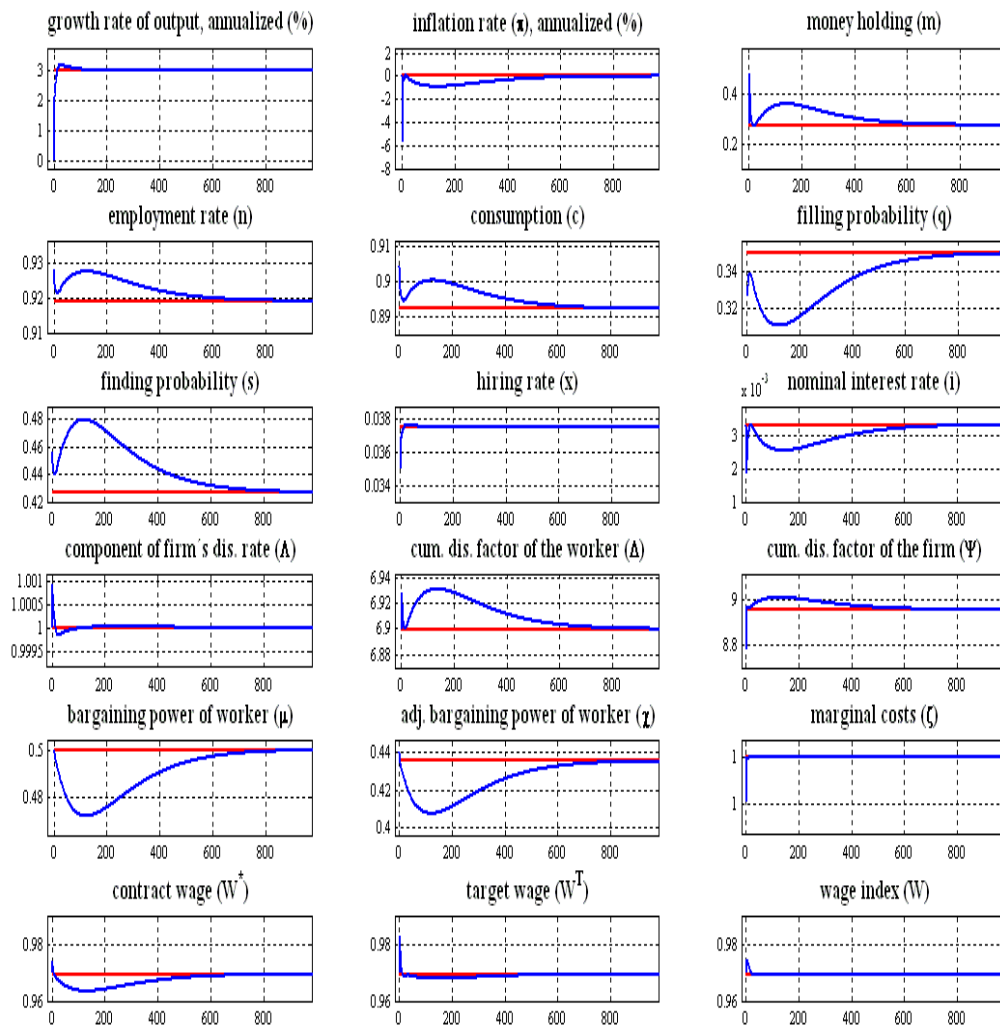


Figure 7.9: Model with Price Adjustment Costs and Money Growth Rule: Long-term Dynamics

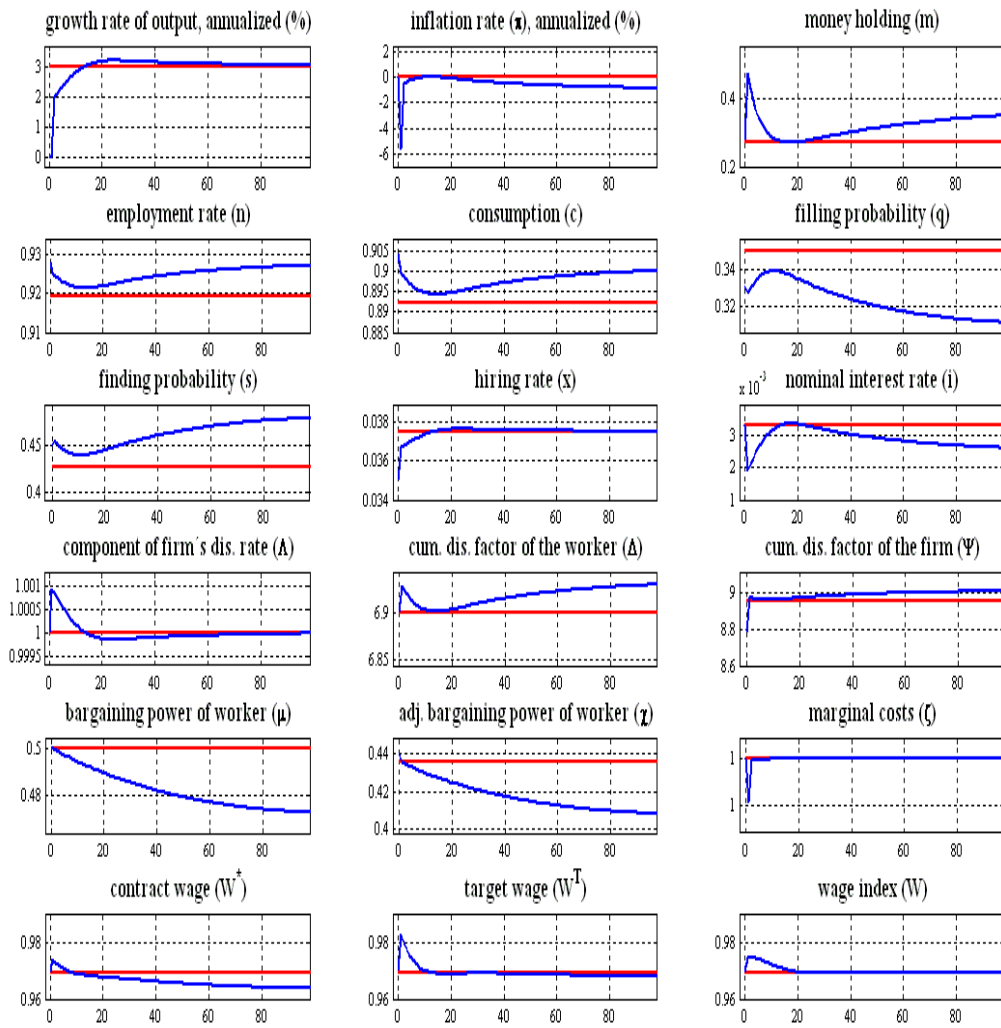


Figure 7.10: Model with Price Adjustment Costs and Money Growth Rule: Short-term Dynamics

## 7.2 Appendix to Chapter 3

### 7.2.1 Hiring Rate in the Low-Skilled Sector

The expected present value of the firm's profit in period  $t$ ,  $\pi_{l,t}$ , is calculated as follows:

$$\begin{aligned}
\pi_{l,t} &= (a_l - w_l) + \delta[(1 - \varphi_l - \rho - \tau_N) E_t \pi_{l,t+1} - \varphi_l \varsigma_l] \\
\Leftrightarrow \pi_{l,t} &= (a_l - w_l) - \delta \varphi_l \varsigma_l + \delta(1 - \varphi_l - \rho - \tau_N) E_t \pi_{l,t+1} \\
\Leftrightarrow \pi_{l,t} &= (a_l - w_l) - \delta \varphi_l \varsigma_l + \delta(1 - \varphi_l - \rho - \tau_N)[(a_l - w_l) + \delta[(1 - \varphi_l - \rho - \tau_N) E_t \pi_{l,t+2} - \varphi_l \varsigma_l]] \\
\Leftrightarrow \pi_{l,t} &= (a_l - w_l) - \delta \varphi_l \varsigma_l + \delta(1 - \varphi_l - \rho - \tau_N)(a_l - w_l) + \delta^2(1 - \varphi_l - \rho - \tau_N)^2 E_t \pi_{l,t+2} \\
&\quad - \delta^2 (1 - \varphi_l - \rho - \tau_N) \varphi_l \varsigma_l \\
&\Leftrightarrow \dots
\end{aligned}$$

The expression can be summarized as follows:

$$\begin{aligned}
\pi_{l,t} &= (a_l - w_l) \sum_{j=0}^{\infty} \delta^j (1 - \varphi_l - \rho - \tau_N)^j - \delta \varphi_l \varsigma_l \sum_{j=0}^{\infty} \delta^j (1 - \varphi_l - \rho - \tau_N)^j \\
\Leftrightarrow \pi_{l,t} &= \frac{(a_l - w_l) - \delta \varphi_l \varsigma_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} \tag{A2.1.1}
\end{aligned}$$

When calculating the hiring rate, the stochastic component,  $-\epsilon_{\eta_l,t}$ , representing an operating cost or a productivity shock, has to be taken into account, as it is revealed before the employment decisions are made. For a given hiring cost per worker,  $\chi_l$ , an unemployed is hired, whenever  $\pi_{l,t} - \epsilon_{\eta_l,t} > \chi_l$ . By substituting  $\pi_{l,t}$  according to equation (A2.1.1), and solving for the random component,  $-\epsilon_{\eta_l,t}$ , the following equation is obtained:

$$\epsilon_{\eta_l,t} < \frac{a_l - w_l - \delta \varphi_l \varsigma_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} - \chi_l$$

The probability of being hired is given by the following equation:

$$\eta_l = \Gamma_{\eta_l} \left( \frac{a_l - w_l - \delta \varphi_l \varsigma_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} - \chi_l \right) \tag{A2.1.2}$$

Taking into account that  $\chi_l = c_\eta w_l$  and  $\varsigma_l = c_\varphi w_l$ , the hiring rate is given by:  $\eta_l = \Gamma_{\eta_l} \left( \frac{a_l - w_l - \delta \varphi_l c_\varphi w_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} - c_\eta w_l \right)$ . Finally, the expression of the hiring rate is linearized according to a first-order Taylor series expansion with respect to the initial steady

state:

$$\begin{aligned}
\eta_{l,new} = & \eta_{l,0} + \Gamma'_{\eta_{l,0}} \left[ -\frac{1 + c_\varphi \delta \varphi_l + c_\eta (1 + \delta (-1 + \rho + \tau_N + \varphi_l))}{1 + \delta (-1 + \rho + \tau_N + \varphi_l)} \right]_0 * (w_{l,new} - w_{l,0}) \\
& + \Gamma'_{\eta_{l,0}} \left[ \frac{1}{1 + \delta (-1 + \rho + \tau_N + \varphi_l)} \right]_0 * (a_{l,new} - a_{l,0}) \\
& + \Gamma'_{\eta_{l,0}} \left[ -\frac{\delta (a_l + w_l (-1 + c_\varphi (1 + \delta (-1 + \rho + \tau_N))))}{(1 + \delta (-1 + \rho + \tau_N + \varphi_l))^2} \right]_0 * (\varphi_{l,new} - \varphi_{l,0}) \\
& + \Gamma'_{\eta_{l,0}} \left[ \frac{\delta (-a_l + w_l + c_\varphi w_l \delta \varphi_l)}{(1 + \delta (-1 + \rho + \tau_N + \varphi_l))^2} \right]_0 * (\tau_{N,new} - \tau_{N,0})
\end{aligned} \tag{A2.1.2a}$$

### 7.2.2 Firing Rate in the Low-Skilled Sector

For a given firing cost per worker,  $\varsigma_l$ , the employee is fired, when  $\pi_{l,t} - \epsilon_{\varphi_l,t} < -\varsigma_l$ . Substituting  $\pi_{l,t}$  according to equation (A2.1.1), and solving for the random component,  $\epsilon_{\varphi_l,t}$ , the following equation is obtained:

$$\epsilon_{\varphi_l,t} > \varsigma_l + \frac{a_l - w_l - \delta \varphi_l \varsigma_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)}$$

The probability of being fired is given by the following equation:

$$\varphi_l = 1 - \Gamma_{\varphi_l} \left( \frac{a_l - w_l - \delta \varphi_l \varsigma_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} + \varsigma_l \right) \tag{A2.2.1}$$

Taking into account that  $\varsigma_l = c_\varphi w_l$ , the firing rate is given by:

$$\begin{aligned}
\varphi_l &= 1 - \Gamma'_{\varphi_l} \left( \frac{a_l - w_l - \delta \varphi_l c_\varphi w_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} + c_\varphi w_l \right) \\
\Leftrightarrow \varphi_l &= 1 - \Gamma'_{\varphi_l} \left( \frac{a_l - w_l - \delta \varphi_l c_\varphi w_l + (1 - \delta (1 - \varphi_l - \rho - \tau_N)) c_\varphi w_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} \right) \\
\Leftrightarrow \varphi_l &= 1 - \Gamma'_{\varphi_l} \left( \frac{a_l - w_l + (1 - \delta (1 - \rho - \tau_N)) c_\varphi w_l}{1 - \delta (1 - \varphi_l - \rho - \tau_N)} \right)
\end{aligned} \tag{A2.2.2}$$

Again, the expression is linearized according to a first-order Taylor series expansion with respect to the initial steady state:

$$\begin{aligned}
\varphi_{l,new} = \varphi_{l,0} &- \Gamma'_{\varphi_{l,0}} \left[ \frac{-1 + c_{\varphi} (1 + \delta (-1 + \rho + \tau_N))}{1 + \delta (-1 + \rho + \tau_N + \varphi_l)} \right]_0 && * (w_{l,new} - w_{l,0}) \\
&- \Gamma'_{\varphi_{l,0}} \left[ \frac{1}{1 + \delta (-1 + \rho + \tau_N + \varphi_l)} \right]_0 && * (a_{l,new} - a_{l,0}) \\
&- \Gamma'_{\varphi_{l,0}} \left[ \frac{-\delta (a_l + w_l (-1 + c_{\varphi} (1 + \delta (-1 + \rho + \tau_N))))}{(1 + \delta (-1 + \rho + \tau_N + \varphi_l))^2} \right]_0 && * (\varphi_{l,new} - \varphi_{l,0}) \\
&- \Gamma'_{\varphi_{l,0}} \left[ \frac{\delta (-a_l + w_l + c_{\varphi} w_l \delta \varphi_l)}{(1 + \delta (-1 + \rho + \tau_N + \varphi_l))^2} \right]_0 && * (\tau_{N,new} - \tau_{N,0})
\end{aligned} \tag{A2.2.2a}$$

### 7.2.3 The Labor Market States

To quantify the labor market states for the initial steady state, the "Labor Force Statistics by educational attainment by sex and age - indicators" and the "Labor Force Statistics by educational attainment by sex and age - composition" are used. They are delivered by the OECD (1999–2005) for the years 1997 – 2003. As underlying labor force, the working age population, i.e. the group of people between 15 and 64 years, is chosen.

In a first step, the averages for the variables "Employment/population ratio", "Unemployment rate", "Share of the labour force" and "Share of unemployment" are calculated. Moreover, the annual employment rates are calculated. In a second step, the annual values for employment and unemployment for four categories of educational attainment ("below upper secondary", "upper secondary, general", "upper secondary, vocational" and "at least post secondary") are calculated. The results are shown in Table 7.2.

	employment	unemployment	sum
below upper secondary	14.3	2.4	16.7
upper secondary, general	2.8	0.3	3.1
upper secondary, vocational	46.3	4.6	50.9
at least post secondary	27.7	1.6	29.3
sum	91.1	8.9	100

Table 7.2: Values for the Initial Labor Market States

However, according to these data, the group of employed people with "below upper secondary" education also contains the apprentices. Indeed, for the purpose of the analysis, it has to be distinguished explicitly between those who are regularly working and the apprentices. Based on data from the Statistisches Bundesamt (2006,



2008), the fraction of apprentices in the total labor force (4%) is calculated. Given this, the level of apprentices can be quantified and the level of employed people with "below upper secondary" education can be adjusted, correspondingly. The results are shown in Table 7.3.

In the analysis, people with "below upper secondary" education are classified as low-skilled, people with "upper secondary vocational" education are classified as "medium-skilled", people with "at least post secondary" education are classified as "high-skilled". The latter group as well as people with "upper secondary general" education are not part of the labor force being relevant for the analysis of the transition rates.

	employment ( $N_i$ )	unemployment ( $U_i$ )
low-skilled labor ( $i = l$ )	10.3	2.4
medium-skilled labor ( $i = m$ )	46.3	4.6
training ( $T$ )	4.0	—

Table 7.3: Values for the Initial Labor Market States and the Initial State of Vocational Training

Given these data, the number of people leaving,  $S$ , the firing rate of the medium-skilled employees,  $\varphi_m$ , the number of people in the first period of training  $T_1$  and the death rate,  $\rho$ , can be calculated simultaneously. This is done by using the equations (1), (2) and (6) of the corresponding Markov matrix of the transition probabilities, and the fact that the number of people being in vocational training is given by  $T = T_1 \sum_{c=1}^p (1 - \rho - \theta)^{c-1}$ . Finally, all relevant values ( $N_m$ ,  $U_m$ ,  $N_l$ ,  $U_l$ ,  $T$ ,  $S$  and  $T_1$ ) are normalized so that the sum of the relevant population is 1.

## 7.3 Appendix to Chapter 4

### 7.3.1 Incentive for the Firm to engage in General Vocational Training

When answering the question why firms have – in contrast to the initial theory (e.g. Becker, 1964) – an interest to pay for general training, two aspects are noteworthy, the presence of firing costs and the compression of the wage structure.

(i) High firing costs can create an incentive to invest in general training. As an employer can decide not to take over an apprentice at the end of the training phase, but faces considerable costs when firing a regular employee, the firm may be willing to invest in vocational training. Such a training may provide an employment test, employers are willing to pay for (Harhoff and Kane, 1993).

(ii) Another reason for the willingness of the firm to pay for general training can be given by a compressed wage structure. This aspect is analyzed in detail by Acemoglu and Pischke (1999). As there is a reason to believe that this is an essential aspect in Germany, the theoretical background – based on Acemoglu and Pischke (1999) – is shown in the following.

Assume that the amount of training is a continuous variable,  $\Theta$ . The product of the worker,  $a(\Theta)$ , as well as the wage,  $w(\Theta)$ , are functions of the amount of training. The worker gets a wage, which corresponds to the outside option  $o(\Theta)$ . Given that there are no frictions, there is  $w(\Theta) = o(\Theta) = a(\Theta)$ . The profit of the employer is  $\pi = a(\Theta) - w(\Theta) = 0$ . The employer has no incentive to invest in general training: a higher amount of general human capital raises the productivity but – to the same extent – also the wage, thus the profit is not affected; in this example the profit is even zero.

Next, it is assumed that there is a compressed wage structure. In particular, it is assumed that there are some kind of mobility costs  $\Delta(\Theta)$  with  $\Delta'(\Theta) > 0$ . Hence, the outside option of the worker is  $o(\Theta) = a(\Theta) - \Delta(\Theta)$ . Again, the worker gets a wage corresponding to the outside option:  $w(\Theta) = o(\Theta) = a(\Theta) - \Delta(\Theta)$ . As  $\Delta'(\Theta) > 0$ , the wage structure is compressed, which is illustrated by the fact that  $\frac{\partial w(\Theta)}{\partial \Theta} < \frac{\partial a(\Theta)}{\partial \Theta}$ . Now, the profit of the firm is given by  $\pi = a(\Theta) - w(\Theta) = \Delta(\Theta) = \pi(\Theta)$ . As the profit increases with  $\Theta$ , the firm has an interest to invest in general training.

Next, the wage is assumed to be the result of a Nash bargain. Moreover, in a first step, it is assumed that there are no firing costs, i.e.  $c_\varphi = 0$ . In the presence of unemployment benefits, the wage – being the result of a Nash bargain – is calculated as follows:

$$w(\Theta) = \frac{\mu}{1 - \beta + \beta\mu} a(\Theta)$$

where  $\beta$  is the replacement rate and  $\mu$  is the bargaining power of the employee.

Thus, the profit of the firm,  $\pi(\Theta)$ , can be calculated as follows:

$$\pi(\Theta) = a(\Theta) - w(\Theta) = a(\Theta)\left(1 - \frac{\mu}{1 - \beta + \beta\mu}\right)$$

Thus, for  $\frac{\partial\pi(\Theta)}{\partial\Theta} > 0$ , an increase in the amount of training,  $\Theta$ , has a positive impact on the profit of the firm. This implies that  $1 - \frac{\mu}{1 - \beta + \beta\mu} > 0$ , which is fulfilled for  $\mu < 1$  and  $\beta < 1$ . The first condition,  $\mu < 1$ , implies that the firm must be able to capture a fraction of the profit in the bargaining process. The second condition again stresses what has already been mentioned. Here,  $\beta < 1$  is the replacement rate, but in a more general interpretation it can also be seen as the ratio of the outside option relative to the wage. The lower  $\beta$ , the higher is the compression of the wage structure. Taking also firing costs into account (i.e.  $c_\varphi > 0$ ), the condition to be fulfilled is  $\frac{\mu}{1 - \beta + \beta\mu - \mu c_\varphi} < 1$ . For the calibration, with  $\mu = 0.20$ ,  $c_\varphi = 0.6$  and  $\beta_m = 0.6825$ , the condition is satisfied.

Finally, a short numerical exercise is delivered, showing that firms in the model framework have an incentive to invest in general training. During the training phase, the firm realizes a loss:  $(a_v - w_v - k_v) \sum_{c=1}^3 \delta^{c-1} (1 - \rho - \theta)^{c-1} = -17,7023$  EUR. With a probability  $\eta_{T,N}^1 (1 - \rho - \theta)^3 = 0.33$ , the successful apprentice will stay in the firm, which has conducted the vocational training. Then, the former apprentice will generate a profit of 175,381 EUR (according to eq. (4.9)), which has to be discounted by the factor  $\delta^p = 0.89$ . The overall surplus is 34,471 EUR. Thus, the firm has an incentive to engage in general vocational training.

### 7.3.2 A Simple Model with a Government Budget Constraint

In contrast to the benchmark model, the following one is a 2-period model. Together with some additional properties ( $\theta = 0$ ,  $\rho = 0$ ), the simplification allows for an analytical solution even in the presence of the government budget constraint. The worker's possible labor market states are illustrated in Figure 7.11: training  $T$ , medium-skilled employment  $N_m$ , medium-skilled unemployment  $U_m$ , low-skilled employment in period 1 and 2,  $N_l^1$  and  $N_l^2$ , respectively, and finally low-skilled unemployment in period 1 and 2,  $U_l^1$  and  $U_l^2$ , respectively. At the end of the second period, all people die. The number of deaths is assumed to be equal to the number of people leaving school ( $S = N_m + U_m + N_l^2 + U_l^2$ ). Hence, the labor force is a constant. A person leaving school is hired with probability  $\eta_{S,T}$  as apprentice and with probability  $(1 - \eta_{S,T})\eta_l$  as low-skilled employee. The residual fraction remains unemployed. A trained person becomes a medium-skilled employee in the second period with probability  $\eta_{T,N}$ . For the sake of simplicity, low-skilled people are as-

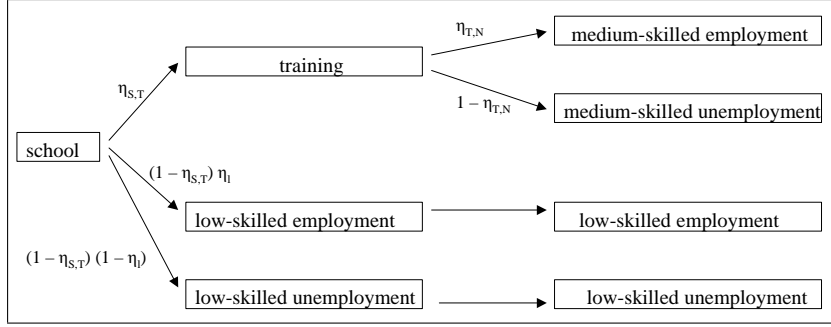


Figure 7.11: The Dynamic Structure of the Simple Model

sumed to not change their labor market state in the second period. Given all this, the following expressions for the steady state are obtained:

$$N_l^1 = (1 - \eta_{S,T}) \eta_l (N_m + U_m + N_l^2 + U_l^2) \quad (\text{A3.2.1})$$

$$U_l^1 = (1 - \eta_{S,T})(1 - \eta_l) (N_m + U_m + N_l^2 + U_l^2) \quad (\text{A3.2.2})$$

$$N_m = \eta_{T,N} T \quad (\text{A3.2.3})$$

$$U_m = (1 - \eta_{T,N}) T \quad (\text{A3.2.4})$$

$$N_l^2 = N_l^1 \quad (\text{A3.2.5})$$

$$U_l^2 = U_l^1 \quad (\text{A3.2.6})$$

Moreover, the total labor force is normalized to 1:

$$1 = T + N_m + U_m + N_l^1 + U_l^1 + N_l^2 + U_l^2 \quad (\text{A3.2.7})$$

Given these equations, the steady state expressions for each labor market state as a function of the transition rates, can be calculated:  $N_m = 0.5 \eta_{S,T} \eta_{T,N}$ ,  $U_m = 0.5 \eta_{S,T} (1 - \eta_{T,N})$ ,  $T = \frac{\eta_{S,T}}{2}$ ,  $N_l^1 = N_l^2 = 0.5 (1 - \eta_{S,T}) \eta_l$  and finally  $U_l^1 = U_l^2 = 0.5 (1 - \eta_{S,T})(1 - \eta_l)$ .

With respect to the random cost  $\epsilon$ , a uniform distribution with a lower limit of 0 is assumed. For the sake of simplicity, hiring and firing costs are ignored. The hiring rate  $\eta_{T,N}$  and the training rate  $\eta_{S,T}$ , which are affected by the subsidies can be derived by adjusting the expression in eq. (4.17) and eq. (4.21), respectively, with respect to the number of periods; moreover  $k_v = 0$ . The hiring rate is given by:

$$\eta_{T,N} = \frac{a_m - w_m + \sigma^{\eta_{T,N_m}}}{\epsilon_{\eta_{T,N_m}}^+} \quad (\text{A3.2.8})$$

and the training rate is given by:

$$\eta_{S,T} = \frac{a_v - w_v + \sigma^{\eta_{S,T}} + \delta \eta_{T,N} (a_m - w_m + \sigma^{\eta_{T,Nm}})}{\epsilon_{\eta_{S,T}}^+} \quad (\text{A3.2.9})$$

where  $w_m = a_m \mu$ , which is given by eq. (4.14) for  $\gamma = 0$ ,  $\beta_m = 0$  and  $c_\varphi = 0$ . Given these expression, the labor markets states can be written as functions of the subsidies.

In order to determine aggregate income, each labor market state has to be linked with the corresponding income. As – by assumption –  $\beta_m = \beta_l = 0$ , the values associated with unemployment are 0. In the case of training the income corresponds to the wage  $w_v$ . In the absence of taxes, aggregate income is calculated as follows:

$$\Phi = T w_v + N_m w_m + (N_l^1 + N_l^2) w_l \quad (\text{A3.2.10})$$

By substituting the variables presenting the labor market states in eq. (A3.2.10) by their steady state expressions and by substituting the hiring rate  $\eta_{T,N}$  and the training rate  $\eta_{S,T}$  by the corresponding equations derived above, an expression of aggregate income,  $\Phi$ , as a function of the two subsidies, is obtained. Then, the cross derivative of aggregate income with respect to the two subsidies can be calculated:

$$\frac{\partial^2 \Phi}{\partial \sigma^{\eta_{T,Nm}} \partial \sigma^{\eta_{S,T}}} = \frac{a_m \mu}{2 \epsilon_{\eta_{T,Nm}}^+ \epsilon_{\eta_{S,T}}^+} \quad (\text{A3.2.11})$$

The cross derivative is unambiguously positive. Hence, the two subsidies are complementary with respect to aggregate income.

Next, taxes are introduced. In the presence of the taxes, aggregate income is calculated as follows:

$$\Phi = T w_v + N_m w_m (1 - t) + (N_l^1 + N_l^2) w_l (1 - t) \quad (\text{A3.2.12})$$

Moreover, the government budget constraint is given by:

$$t (N_m w_m + (N_l^1 + N_l^2) w_l) = T \sigma^{\eta_{S,T}} + N_m \sigma^{\eta_{T,Nm}} \quad (\text{A3.2.13})$$

Hence, the tax rate,  $t$ , is given by:

$$t = (T \sigma^{\eta_{S,T}} + N_m \sigma^{\eta_{T,Nm}}) / (N_m w_m + (N_l^1 + N_l^2) w_l) \quad (\text{A3.2.13a})$$

The variables presenting the labor market states in eq. (A3.2.12) and in eq. (A3.2.13a),

respectively, are substituted by the corresponding steady state expression. Then,  $t$  in eq. (A3.2.12) is substituted by the modified expression in eq. (A3.2.13a). Again, the result is an expression for the aggregate income,  $\Phi$ , being a function of the two subsidies. The cross derivative of aggregate income with respect to the two subsidies is calculated:

$$\begin{aligned} \frac{\partial^2 \Phi}{\partial \sigma^{\eta_{S,T}} \partial \sigma^{\eta_{T,N_m}}} &= \frac{a_m (2\mu - 1 - 2\delta(1 - \mu)) - 2(1 + \delta)\sigma^{\eta_{T,N_m}}}{2\epsilon_{\eta_{T,N_m}}^+ \epsilon_{\eta_{S,T}}^+} \quad (\text{A3.2.14}) \\ &= \frac{a_m \mu}{2\epsilon_{\eta_{T,N_m}}^+ \epsilon_{\eta_{S,T}}^+} + \frac{a_m (2\delta + 1)(\mu - 1) - 2(1 + \delta)\sigma^{\eta_{T,N_m}}}{2\epsilon_{\eta_{T,N_m}}^+ \epsilon_{\eta_{S,T}}^+} \end{aligned}$$

This equation shows the contrast to the cross derivative in the absence of the government budget constraint, which is given by the last term on the right-hand side. The additional term is unambiguously negative. For a plausible parameter value ( $\mu \leq 0.75$  if  $\delta = 1$ ) the total term is definitively negative. Hence, in the presence of the government budget constraint, there are no complementarities with respect to income.

### 7.3.3 The Derivation of the Cross Derivative

To derive the cross derivative of the income,  $\Phi$ , with respect to the subsidies, eq. (4.22) has to be rewritten. This is done in four steps. First,  $T$  as well as  $N_i$  and  $U_i$  for  $i = l, m, h$ , are substituted in eq. (4.22) by the corresponding steady state expressions. They can be derived by solving eq. (4.3) for  $Z_t = MT_t * Z_t$  and taking into account that  $T = T_1 \sum_{c=1}^p (1 - \rho - \theta)^{c-1}$ . Second, the training rate,  $\eta_{S,T}$ , is substituted according to eq. (4.21) and the hiring rates  $\eta_{T,N_m}^1$  and  $\eta_{T,N_m}^2$  are substituted according to eq. (4.17) for  $\eta_{T,N_m} = \eta_{T,N_m}^1$  and eq. (4.18). Third, the wages,  $w_i$ , are substituted according to eq. (4.14) for  $i = l, m, h$ . Finally, there is (i)  $t_i = 0$  for  $i = l, m, h$ , (ii)  $\theta = 0$ , (iii)  $p = 1$  and (iv)  $\gamma = 0$ . Hence, the result is an expression for aggregate income,  $\Phi$ , being an explicit function of the subsidies,  $\sigma^{\eta_{S,T}}$  and  $\sigma^{\eta_{T,N_m}}$ , as well as of the limits of the uniform distributions.



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- 10/2007: Verein für Socialpolitik (VfS),  
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- 04/2006: Deutsche Bundesbank,  
*Dynare Workshop*
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Ich erkläre hiermit an Eides Statt, dass ich meine Doktorarbeit „The Globalization of Labor Markets and its Policy Implications“ selbstständig angefertigt habe und dass ich alle von anderen Autoren wörtlich übernommenen Stellen, wie auch die sich an die Gedanken anderer Autoren eng anlehenden Ausführungen meiner Arbeit, besonders gekennzeichnet und die Quellen zitiert habe.

Berlin, 11. August 2009

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