Training or Search?
Evidence and an Equilibrium Model *

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Abstract

Training programs are a major tool of labor market policies in OECD countries. I use a unique panel data set on the labor market experience of individual German workers between 2000 and 2002 to estimate a dynamic model of search and training, which allows me to quantify the impact of training programs and unemployment benefits on employment, unemployment, output, and the government expenditures.

The model extends Ljungqvist and Sargent (JPE, 1998) by incorporating a training decision and a broader menu of unemployment benefits. Government-sponsored training programs feature a key trade-off with respect to unemployment insurance programs: they offer more generous unemployment benefits but require more time and effort from workers to generate higher skills. As a result, unemployed workers with different human capital and benefits make different decisions about training, search, and job acceptance.

I use the model to quantitatively study the recent reforms implemented in Germany and run more counterfactual experiments. I simulate the transition path under back-to-back unexpected reforms in 2003-2006 and find the dynamics of the model's unemployment rates are close to the data. In a counterfactual experiment in which I model an economy with a German-like training system and a US-like unemployment benefit structure (roughly, benefits are lower), I find that employment and output rise substantially.

JEL classification: E24; J08; J24; J45

Keywords: Training programs; Job search; Human capital; Employment; Unemployment; Unemployment insurance

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1 Introduction

Training for unemployed workers is extensively used in the Organization for Economic Cooperation and Development (OECD) countries. As shown in Table 1, its expenditure accounts for about 20 percent to 50 percent of the total expenditure on active labor-market policies among the 10 OECD countries that most expensively used active labor-market policies in 2002.[1] By improving workers' human capital, training programs intend to help bring unemployed workers back into work. While microeconomic studies focus on the effects of training on individual employment probabilities and wage earnings (e.g., Heckman, LaLonde and Smith (1999) for a comprehensive review on evaluation of different training programs[2]), the effects of these large-scale government-sponsored programs on the aggregate unemployment rate, employment rate, and output are still not well understood. Furthermore, one important institutional feature in several OECD countries[3] is that training programs and unemployment insurance programs, which are usually considered the two most important active and passive labor-market polices,[4] are not separated but highly interactive with each other. For instance, in Germany, training participation used to bring extra benefits to unemployed workers by extending their maximum benefit entitlement duration or increasing the level of their benefits received in training programs.[5] While several recent reforms in the German labor market gradually cut this link and tightened the unemployment benefit structure for unemployed workers, the effects of these reforms on workers' training participation and the economy's unemployment, employment, and output have not been studied. Therefore, in this paper I develop and estimate a structural framework to analyze and quantify these macroeconomic effects.

I extend Ljungqvist and Sargent's model (JPE, 1998) in which workers' human capital varies stochastically (but exogenously) with labor-market experience to introduce training decisions and add a menu of more realistic unemployment benefits. Government-provided training programs feature a key trade-off with respect to unemployment insurance programs: they offer more generous replacement rates but require more time and effort to improve workers' skills. Thus, unemployed workers with different human capital levels and benefit entitlements make different training, search, and job acceptance decisions. The variety of choices provides us with a useful strategy for identifying key structural parameters of the model through the observed distribution of workers among labor-market states (working, searching, training), labor-market transitions across these states, and wage earnings conditional on different labor-market experience.

I apply the Simulated Method of Moments to estimate the model, using a recently released

[1] Active labor market policies are designed to help increase the probability that the unemployed find jobs or increase the underemployed' productivity and earnings, such as training programs, subsidized employment, youth measures, and measures for the disabled.

[2] Examples of more recent studies on the effects of training programs on unemployed workers' employment probability and wage earnings in several OECD countries include Sianesi (2004), Lechner, Miquel, and Wunsch (2005*a*, 2005*b*), Biewen, Fitzenberger, Osikominu and Waller (2006), Fitzenberger, Osikominu and Völter (2006), Fitzenberger, and Völter (2007), Lechner and Melly (2007).

[3] For example, in Germany and Sweden.

[4] Table 1 shows the expenditure and participation inflows for these two biggest labor market policies for selected OECD countries.

[5] Details on German training and unemployment insurance programs are described in the next section.

Table 1: Training Programs for Unemployed Workers in OECD Countries (2002)

	EXPENDITURE					PARTICIPATION	
COUNTRY	Training (GDP %)	UB (GDP %)	Total LMP (GDP %)	Training (ALMP %)	Training+UB (LMP%)	Training (LF %)	UB (LF %)
Denmark	0.67	1.37	4.6	48.2	44.1	5.8	19.6
Belgium	0.19	1.94	3.6	16.7	58.4	3.4	-
Netherlands	0.52	1.72	3.6	29.5	62.9	1.4	5.2
Germany	0.32	2.10	3.3	27.1	73.1	1.2	-
Finland	0.27	1.53	3.1	27.6	58.6	2.5	-
France	0.21	1.39	2.9	16.7	54.8	1.7	7.1
Sweden	0.28	1.04	2.5	20.1	53.9	2.5	-
Spain	0.12	1.55	2.4	15.6	69.0	2.2	1.6
Switzerland	0.12	0.77	1.3	23.1	68.5	1.7	11.2
United States	0.03	0.55	0.7	20.0	81.7	0.9	-

LMP - Labor Market Policies; ALMP - Active Labor Market Policies;
UB - Unemployment Insurance Benefits; LF - Labor Force
Note: Data for Denmark is from 2000; France and United States' data are from 2001.
Source: OECD Employment Outlook (2004)

German administrative data set, the Integrated Employment Biographies Sample (IEBS), which is a unique data set containing detailed information on workers' employment histories, wages and benefits, training-participation records, and job-search information. To circumvent the computational difficulty of the optimization problem with nonsmooth objective function and local optima, I apply a recent approach by Chernozhukov and Hong (2005), which is based on the Markov Chain Monte Carlo (MCMC) method.

The model is used to study the actual reforms in Germany and to run a series of counterfactuals. Both the long-run effects (steady states) of three actual reforms and the transitions between and following them are explored. Some selected findings follow.

First, I find a reform like the one implemented in Germany in 2005 (which reduced the extra benefits *only* for unemployed workers in training programs) decreases training enrollment by 69 percent in the long run. More workers search for a job, instead of training, and the proportion of low-skilled unemployed workers increases. As a result, the unemployment rate rises by almost one percentage point, while the employment rate decreases by 0.2 percentage point, and output falls by 1.7 percentage points. In contrast, a reform like the one implemented in 2006 (which reduced the maximum benefit duration for *all* unemployed workers) doubles training enrollment in the long run. The unemployment rate falls by 1.3 percentage points, the employment rate rises by 0.3 percentage point, and output increases by 2.4 percentage points. Thus, these two reforms enacted in Germany within a year were in marked contrast with each other.

Second, when the transition path under back-to-back unexpected reforms in 2003-2006 is simulated, the dynamics of the model's unemployment rates between and after these reforms

(2003-2008) are very close to the actual path for Germany's unemployment as shown in the data, suggesting that large-scale labor-market policy reforms can have important effects on aggregate outcomes.

Third, in a counterfactual experiment in which an economy with a German training system and US-like unemployment benefit structure is modeled, the unemployment rate falls by over 7 percentage points, the employment rate increases by 5 percentage points, and output increases by 9.9 percentage points. Hence, an injection of elements of the US system into the German system has large effects on the performance of the German labor market.

The paper is organized as follows. The remaining part of this section briefly reviews the related literature and the contribution of this paper to the literature. Section 2 provides a overview of the German training programs and unemployment insurance programs. Section 3 describes the data used in the estimation and lists some important facts observed in the data which motivate the model setup. Section 4 lays out the model and defines the equilibrium. Section 5 is a discussion about the calibration and estimation of the model. The estimation results are shown in Section 6. In Section 7 there are a series of quantitative policy analysis using the estimated model. In Section 8 the conclusion is presented as well as future research that will be undertaken. Section 9 contains the appendix.

1.1 Related Literature and Contribution

This paper is related and contributes to the existing literature in the following dimensions.

First, the theoretical part of the model is built on the search model with human capital developed by Ljungqvist and Sargent (1998). They established a search model in which workers are heterogeneous in human capital levels and unemployment compensation entitlements. Workers suffer stochastic human capital loss at layoff times. Low-skilled unemployed workers entitled to generous unemployment compensation have less incentive to search. Their model is able to explain why the difference in the unemployment rates between European countries and the U.S. was small in the 1970s but large in the 1990s. They did this by exploiting the fact that European countries have much higher unemployment compensation benefits than the U.S. and the increase of "turbulence" (the probability workers lose human capital at layoff times) in the 1990s.[6] Their model highlights the importance of generous unemployment compensation and the changes of skills on workers' job-search decisions, and provides a natural platform to introduce the labor-market polices related to workers' human capital, such as training programs.[7]

I extend their model by including training decisions and adding a menu of more realistic unemployment benefits, thus provide a unified framework to study both training programs (i.e., the active type of labor-market policy) and unemployment insurance policies (i.e., the passive type of labor-market policy). The model can be used to evaluate the labor-market policy portfolio instead of only one single policy, which is quite important considering these labor-market policies are interacting with each other. By taking a structural approach, I am able to study both the long-run (steady states) and short-run (transitional periods) macroeconomic effects of a series of recent labor-market reforms (on unemployment benefit

[6] For detail explanations on the turbulence theory, see Ljungqvist and Sargent (1998, 2007, 2008).

[7] As Ljungqvist and Sargent (2007) shows, this framework can also be extended to a general equilibrium setup by including the production side and a matching feature.

structure and training policies) in Germany.[8] In addition, the model can provide important policy suggestions by running a serials of counterfactual policy experiments.

The model is also estimated by using a recently released German administrative data set. The key feature of this framework is an unobservable variable, human capital, which drives workers' different decisions at different labor-market states. Thus the most important parameters are those governing human capital transitions. By linking the unobservable human capital to the observed workers' decisions and wage earnings conditional on different labor market experience, the estimation uncovers these parameters by matching model generated moments with the data statistics. To my knowledge, this is the first work to use the micro data to estimate such a search framework with human capital.

Second, this paper is also related to the literature which applies the dynamic contract approach to the study of optimal unemployment insurance and training policies. There is a a large body of research that studies the design of the optimal unemployment insurance problem under different assumptions, which were mainly motivated by Shavell and Weiss' seminar work (1979).[9] More recently, Pavoni (2004) studied the optimal unemployment insurance in the context of the existence of human capital depreciation. Pavoni and Violante (2007) further extended this framework to analyze the optimal sequence of different labor-market policies for unemployed workers, which include training programs. While these papers provided insightful discussions of the optimal policy design, they are not able to study and quantify the effects of more realistic reforms due to their simplification assumptions made in the principle-agent setup. This paper complements this branch of literature by providing positive policy analysis of unemployment insurance and training programs in a unified framework.

Third, this paper is also related to the vast of literature on evaluating the training programs. Heckman, LaLonde and Smith (1999) provided a comprehensive review of the evaluation on different types of training programs. Recently, because of the appearance of several administrative data sets, several recent studies including Sianesi (2004), Lechner et al. (2005, 2007) and Fitzenberger et al. (2006, 2007) studied the long-run effects of training programs in several OECD countries using the newly developed evaluation tools. Although the econometric approaches and targeted programs may be different, all of these studies focus on the effects of training on *individual* employment probabilities and wage earnings. Thus the effects of large-scale, government-sponsored training programs on the *aggregate* unemployment rate and output have not been well studied. To fill this gap, this paper develops and estimates a structural search model to analyze and quantify these macroeconomic effects.

Thus, this paper contributes to the existing literature in several ways. First, this paper extends the existing literature on labor-market policies by developing a structural framework to introduce training programs. Second, micro data have been used to to estimate this framework. Third, the macroeconomic effects of training programs on the economy are studied, which complements the two related branches of literature which focus on the design of unemployment insurance and training policies and individual employment and wage-earning effects of the training programs.

[8]The framework is flexible and can also be applied to study the related problem in other OECD countries with large training programs.

[9]For example, Hopenhayn and Nicolini (1997) extended Shavell and Weiss (1979) by introducing the possibility of contingent wage taxes after re-employment. For a review of the literature, see, e.g., Karni (1999) and Fredriksson and Holmlund (2003).

2 Training Programs and Unemployment Insurance in Germany

Before going to the model, I would like to first describe the training programs and unemployment insurance programs in Germany. I chose Germany as the focus of my research because (1) it is a typical country with large government-sponsored training programs and a generous unemployment insurance system which fits the interest of this paper, (2) the German labor-market experienced a series of reforms recently that can be used as real applications of this model and (3) a high quality administrative data set from Germany was recently released that enabled me to estimate the structural model for quantitative analysis.

Note that the policies keep changing in Germany. The descriptions in Section 2.1, 2.2 and 2.3 are based on the period 2000-2002, which is the data period I used to estimate my benchmark economy. I will describe in Section 2.4 the recent policy reforms in Germany which I will study in the section of policy analysis.

2.1 Training Programs for Unemployed Workers in Germany

Training programs for unemployed workers is the largest active labor-market policy in Germany. The main purpose of these programs is to enhance unemployed workers' human capital and bring them back to work. Government pays all the training costs.

Generally speaking, all job seekers who have registered personally at the local labor office (this involves a counseling interview with a caseworker) are eligible for training participation.[10] The training takes place in classrooms and/or practical firms. The length varies from several weeks to three years depending on the particular training programs in which the worker participates. Unemployed workers may (1) learn specific skills (such as computer skills), (2) maintain, update, adjust, and extend professional skills, or (3) improve job-search skills.

2.2 Unemployment Benefits in Germany

Germany is well known for providing generous unemployment benefits to unemployed workers. As shown in Table 1, Germany's total expenditure on unemployment benefits (as a ratio of GDP) ranks first among the OECD countries. There are two types of unemployment benefits for unemployed workers: Unemployment Insurance Benefit (UI) and Unemployment Assistance Benefit (UA). The level of UI is higher than that of UA. Both benefits are linked to a worker's previous wage earnings on the job. The former is about 60 percent of a worker's net previous wage earnings, and the latter about 53 percent. When workers become unemployed, they first receive UI. The maximum entitlement duration of UI is finite and is about 19 months on average.[11] When UI expires, an unemployed worker continues to receive UA, which does not expire but will decrease by 3 percent every year.[12]

[10] After 2000, the only requirement is this *necessity* requirement. But in order to receive unemployment benefits while in a training program, unemployed workers still need to satisfy the *working* requirement which, loosely speaking, is the requirement of one year of employment in the last three years.

[11] In Germany, the maximum entitlement duration of UI depends on age. Older people have a longer maximum entitlement duration.

[12] In reality, UA is means tested.

Unemployed workers entitled to UI and UA also have certain obligations. For instance, in order to continue receiving unemployment benefits, they cannot turn down a job offer that has a wage higher than a certain amount.[13]

When an unemployed worker is not eligible for UI or UA, he can receive Social Assistance (SA) from the welfare system. This assistance is based on a flat level (which is about 40 percent of the average wage-earning level) and has no maximum duration.

2.3 Training Participation and Unemployment Benefit

An important feature of the German training policy is that unemployed workers in training programs can receive extra benefits compared with standard unemployment benefits.[14] The benefit unemployed workers receive is called Income Maintenance (IM). An unemployed worker who receives IM in training programs can hold his UI entitlement for up to two years. Since the amount of IM is equal to that of UI (if the worker is entitled to UI), this is equivalent (roughly) to say the worker can extend the UI entitlement in training programs. Second, for an unemployed worker entitled to UA, the average IM received is greater than the UA, which means he receives higher UA benefits in training programs. Both bring extra incentive for unemployed workers to participate in training programs.

2.4 Three Recent Reforms

The above descriptions (in Section 2.2 and 2.3) apply to the policies in the period 2000-2002. Ever since 2003, Germany has undertaken a series of reforms that gradually changed these benefit policies. For example, after the reform in 2003, the UI entitlement duration for an unemployed worker was reduced by half of the duration of training programs. An unemployed worker entitled to UA no longer received any extra benefit.[15] And since 2005, receipt of IM no longer extends the UI entitlement qualification period, which means that unemployed workers receive the same level and same length of unemployment benefits in training programs. In 2006, the German government reduced the maximum UI entitlement duration for all unemployed workers, so the maximum length of UI entitlement in training programs was also reduced.

It is still not clear how these reforms affected unemployed workers and the economy in general. From the micro level, this series of changes may change unemployed workers' training participation and job-search strategies. From the macro level, these reforms may affect the unemployment rate, the employment rate, and output. These effects have partially motivated this paper on setting up a framework to study these interesting recent policy reforms.

[13]During the first three months, the unemployed can reject jobs offering less than 80 percent of prior earnings, and thereafter less than 70 percent until the sixth month of unemployment. After six months, all job seekers must accept jobs providing net earnings equal to or higher than unemployment insurance benefits. For reference, see Ebbinghaus and Eichhorst (2006).

[14]In several other OECD countries such as Sweden, training participation also affects unemployed workers' receipt of unemployment benefits.

[15]Remember that before 2003, in some programs unemployed workers entitled with UA receive the benefit which has the same amount of UI, which is higher than the UA amount.

3 Data

The data set used in this paper, **Integrated Employment Biographies Sample (IEBS)**, is a recently released German administrative data set which contains all required information for the use of my estimation. This data set combines spells of the following four different data sets of the Federal Employment Agency (BA), and thus contains both unemployment and employment, unemployment insurance, and training information.[16]

- The IAB employment history (BeH), which contains 12,594,862 spells between 1990 and 2003
- The IAB benefit recipient history (LeH), which contains 2,388,627 spells between 1990 and 2004
- The participants-in-measures data (MTG), which contains 238,232 spells between 2000 and 2004
- Data on job search originating from the applicants pool database (BewA), which contains 1,828,266 spells between 2000 and 2004

IEBS was constructed by selecting people born on one of eight designated days of the year from the sample frame, making this data set a representative 2.2 percent sample of the target population.

3.1 Sample Selection

I selected the observations for males that fell between January 1, 2000, and December 31, 2002.[17] I dropped those observations on people older than 60 on January 1, 2000. This reduces the possibility of retirement before the end of the selected data set.[18] The final sample contained 460,131 individuals with a total of 15,536,946 spells.

3.2 Convert Spell Data into Panel Data

The IEBS comes in spells. For each spell, the data contain the employment status, daily wages if employed, and records on a daily basis of received unemployment benefits, job search, and participation in active labor-market programs.

To fit the model, I converted the data set into a longitudinal form. I set the length of the model period to be one month. Thus, the selected data covers 36 model periods. I chose the status on the first day of each model period as the status throughout this model period. (For classification and explanations of labor market states (employment, search, training), please see Appendix section.)

[16]With financial support of the Federal Ministry of Education and Research, the FEA has, in 2004, established a Research Data Centre (FDZ) to facilitate access to and promote labor market research based on its data (Kohlmann, 2005).

[17]IEBS contains the data from January 1, 2000, and December 31, 2003. I chose the period between January 1, 2000, and December 31, 2002 because during this period the studied policies remained stable.

[18]Since the data set targets the workers who have labor-market experience, I did not put a low-end cap on worker's age.

3.3 Observed Facts

In this part I list several important facts observed in the data. These observed facts will motivate the setup of my model in the next section. *Throughout this paper, except for the calculation of the unemployment rate, I call the workers in training programs unemployed workers and the period in training programs the unemployment period.*

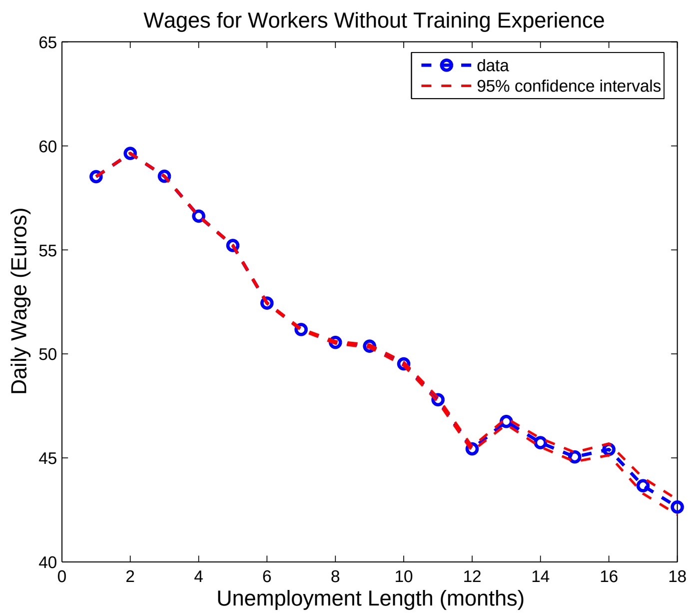


Figure 1: This figure plots the accepted wages for unemployed workers without training experience. x axis shows the length of the unemployment spell unemployed workers have before they become employed. y axis shows the average daily wages. The blue circles are the data. Red dashed lines are the corresponding 95% confidence intervals.

Fact 1. The average level of the accepted wages *decreases* with the unemployment length for unemployed workers without training experience. Figure 1 plots the average accepted wages for unemployed workers without training experience. x axis shows the length of the unemployment spell unemployed workers experience before they become employed. y axis shows the average daily wages. This figure says that unemployed workers' accepted wages decrease with the unemployment length. There are at least two possible explanations for it. First, heterogeneity can lead to this change. For example, suppose there are two types of unemployed workers, high-skilled unemployed workers and low-skilled unemployed workers. If high-skilled workers can earn more (on the job) and leave unemployment faster than low-skilled workers, the proportion of the low-skilled workers in the unemployment pool will increase with the length of unemployment spell. This leads to the decrease of the accepted wages. Second, without heterogeneity, the depreciation of the workers' skills can also lead to this. Suppose workers are homogenous at the time they become unemployed and workers' skill depreciates during the unemployment period. Then, given the same assumption that high-skilled workers can earn more (on the job) and leave unemployment faster than low-skilled workers, the accepted wages will decrease with the length of the unemployment spell.

Fact 2. As shown in Table 2, accepted wages *increase* with the unemployment length for workers who have extensive training experience (e.g., spending more than 50 percent of unemployment time in training programs), and *decrease* (but slower than that for workers without any training experience) for the workers with less training experience (e.g., spending no more than 50 percent of unemployment time in training programs). This suggests that participating in training increases the workers' human capital.[19]

Fact 3. As Table 3 shows, for workers with short unemployment spells (i.e., less than or equal to 4 months), the average *previous* wage level before unemployment for the workers who do not participate in training is *higher* than that of training participants. This says that unemployed workers with lower previous wages are more likely to participate in training programs.

Fact 4. As shown in the Table 4, for workers with long unemployment spells (i.e., larger than or equal to 1 year), the *longer* the workers stayed in training programs, the *more* their accepted wages increased (as a percentage of previous wages). This says that the longer an unemployed worker stays in training programs, the greater the likelihood that he can improve wage earnings in the new job.[20]

Fact 5. The transition rate per model period (i.e., per month) from training programs to employment is 25 percent lower than the transition rate from search to employment. This is shown in Table 7. This means that the probability of being employed is lower during training periods than it is during the search periods.

Fact 6. The average accepted wages of the workers with unemployment benefits is about 40 percent higher than that of workers without unemployment benefits. It implies that unemployment compensation entitlement is important in determining workers' accepted wages. There are at least two possible explanations for this. One is that workers with unemployment compensation are more patient in their job-search, and thus end up with higher accepted wages. Another possible explanation is that workers without unemployment compensation are those who have searched for a job for a long time; thus, their human capital has depreciated a lot, which in turn lowers their accepted wages.

[19] This can also be seen from the change of the wages conditional on the training experience, as shown in Table 4.

[20] Since these workers have been unemployed for a long time, they are more likely low-skilled workers, who are the main targets of the training programs.

Table 2: Wage Level by Training Experience (Euros)

		Training Intensity		
		0%	$\leq 50\%$	$> 50\%$
	2 months	59.6	55.8	47.9
Unemployment	4 months	56.6	53.8	50.9
Length	12 months	45.4	51.5	58.2
	18 months	42.6	49.9	61.8

Table 3: Previous Wage by Training Experience (Euros)

		Training Intensity		
		0%	$\leq 50\%$	$> 50\%$
	2 months	58.5	53.1	46.4
Unemployment	4 months	56.8	53.8	49.9
Length	12 months	51.9	54.4	55.2
	18 months	49.7	58.0	54.1

Table 4: Percent of Wage Changes (relative to previous level)

		Training Intensity		
		0%	$\leq 50\%$	$> 50\%$
	2 months	2.0	5.1	3.1
Unemployment	4 months	-0.2	-0.1	2.0
Length	12 months	-12.4	-5.3	5.4
	18 months	-14.2	-14.0	14.3

4 The Model

I extend Ljungqvist and Sargent's search model with human capital (JPE, 1998) to introduce training decisions and add a more realistic benefit structure. In this part, first I lay out the elements in the economy and show the timing of the model. Then I describe the decision problems for each type of workers before I define the stationary equilibrium.

4.1 Environment

Three Types of Workers In This Economy: There is a continuum of workers with geometrically distributed life spans. At the beginning of every period, a worker dies with probability α. To keep the population constant, I assume that when a workers dies, he is replaced with a newborn worker who has the lowest human capital level.[21] According to whether workers are employed or not and whether they choose training or job search when they are unemployed, I divide them into three groups: employed workers, unemployed workers who search, and unemployed workers who participate in training.[22] Workers are risk neutral and maximize their lifetime utility. There is disutility of search, training and work. I normalize the disutility of work to be zero.

- **Employed Workers** An employed worker's wage earning is given by the product of two components. One is the worker's human capital, h. The other is his wage per unit of human capital, w. I assume the distribution of w, is exogenously given by $F(w)$. When a worker meets a wage offer, it means he gets a w which is drawn from the distribution $F(w)$.[23] By this specification, high-skilled workers have higher wage earnings than do low-skilled workers given the same wage offer. But a low-skilled worker who has a high wage (per unit of human capital) offer may have the same (or even higher) wage earnings as that of a high-skilled worker with a low-wage offer.

  All employed workers need to pay income tax rate $\tau_0 + \tau$. Here I assume τ is the part used by the government to finance the expenditure on the benefits and training cost, while τ_0 summarizes the remaining part, which is fixed in this model.[24]

  An employed worker with human capital h faces the probability $\lambda(h)$ that he will be laid off in the beginning of the next period.[25] When he is laid off, he is entitled to UI

[21] In the extenuation part of this paper, I will change this assumption and allow a newborn worker to inherit part of the human capital from the old.

[22] Note that in the real economy, workers in training programs may not be counted as unemployed workers. But for convenience, in this paper (except when noted by special announcement), the unemployment period includes the time workers spend in training programs. To be consistent with the literature, however, in the results part of this paper I will exclude those workers in training programs when I report the unemployment rate.

[23] Since the focus of this paper is on the supply side, I use this exogenous wage distribution to simplify the production side. It's interesting, however, to extend the model to include the production side. One possible way is to introduce the matching and bargaining feature into the model. See Ljungqvist and Sargent (2007) for an example.

[24] Throughout this paper, the tax revenue refers to the part brought by τ.

[25] I assume the probability of being laid off depends on an employed worker's human capital h because I observe that the average previous wage earnings for unemployed workers is much lower than the average wage earnings for employed workers.

benefits. I also allow for on-the-job search. But I assume the new job offer arriving rate during every employed period is exogenous, given by π^J. When a new job offer arrives, it means an employed worker receives a w, which is drawn from $F(w)$. An employed worker with a new job offer in hand decides whether to accept the new one, stay with the current one, or quit to become unemployed. When he quits, I assume he is not eligible to receive unemployment benefits.

- **Unemployed Workers Who Search** An unemployed worker either chooses search activity or participates in training programs every period. When he chooses search, he needs to choose a search effort as well. A higher search effort means a higher probability that he finds a job. A higher search effort is also associated with a higher level of disutility. Additionally, he observes whether his human capital depreciates by the end of this period.

- **Unemployed Workers Who Participate in Training** When an unemployed worker chooses to participate in training programs, he needs to choose a training effort. A higher training effort means a higher human capital accumulation rate. But like the search effort, higher training effort also brings higher disutility. I assume unemployed workers in training programs may also receive some job offer every period.[26] I use π^T to denote the job-offer arriving rate in the training programs every period.

Three Types of Benefits: Since one important exercise of this paper is to apply the model to study quantitatively the effects of the recent unemployment benefit reforms in Germany on workers' training and search decisions, I set the benefit structure in the model as close as possible to that in the real German economy. So, there are two types of unemployment benefits: the unemployment insurance benefit (UI) and the unemployment assistance benefit (UA). When unemployed workers are not entitled to unemployment benefits, they receive the social assistance benefit (SA) from the welfare system.

- **Unemployment Insurance Benefit (UI)** UI is available to all workers when they are laid off. I assume those who voluntarily quit their job are not eligible for UI.[27] The UI benefit is linked to a worker's previous wage earnings before unemployment. In the literature, the ratio of the benefit to a worker's previous wage earnings is called the replacement ratio. So I use η_{ui} to denote the replacement ratio of UI benefits. With a constant replacement ratio, workers who have higher wage earnings also receive higher UI benefits when they are unemployed. The UI benefit is the highest type of benefit unemployed workers can receive. But the duration of this benefit entitlement is finite. Instead of explicitly specifying the duration of the UI benefit entitlement, I use the expiration rate to characterize this length. I define the expiration rate as the probability that an unemployed worker will lose his UI benefit in the next period, conditional on the fact that the worker is currently entitled to it.[28] So, for example, 20 months of UI benefit entitlement means an expiration rate of 0.05 per month. One

[26] I allow this because I observed in the data evidence of direct transitions from training to employment.

[27] Since in the model an employed worker always has the option to keep his old job (when he receives a new one), he will choose quitting the job only if his human capital becomes high enough that he wants to find a better wage offer. In this case, his current wage earning is actually not low.

[28] There are two considerations when using this expiration rate. First, by using a constant expiration rate to

important feature of training programs in Germany is that unemployed workers can receive UI benefits for longer if they are enrolled in these programs. Thus, I use δ_{ui}^{T} to denote the expiration rate of the UI benefit for unemployed workers face in training programs and δ_{ui}^{S} to denote the expiration rate of the UI benefit for unemployed workers who are searching for a job.

- **Unemployment Assistance Benefit (UA)** When UI expires, an unemployed worker receives a less generous unemployment benefit, UA, which decreases slightly over time. For the same consideration as described above, I use the expiration rate δ_{ua} to characterize this decreasing feature of the benefit. For example, if the UA benefit decreases by 5 percent per month, it corresponds to an expiration rate of 5 percent per month, which means there is a 5 percent chance that an unemployed worker who is entitled to this benefit will lose it in the next month.[29] To capture the fact that training brings extra benefits for unemployed workers entitled to UA, I allow that the replacement ratio of UA in training programs, η_{ua}^{T}, is higher than that in the search periods, η_{ua}^{S}. So, the difference $\eta_{ua}^{T} - \eta_{ua}^{S}$ measures the extra benefits (as a ratio of previous wage earnings) that unemployed workers can receive in training programs.

- **Social Assistance Benefit (SA)** When unemployed workers are not eligible to receive either UI or UA, they can receive social assistance (SA) from the welfare system. This assistance does not depend on workers' previous wage earnings. Thus, it is a flat rate that on average is less generous than UI and UA benefits.

Human Capital Dynamics Human capital dynamics is an important feature of this model. A worker's human capital experiences stochastic accumulation and depreciation during different states. Specifically, during employed periods, a worker's human capital accumulates according to the transition function $\mu^{e}(h, h')$; during search periods, a worker's human capital depreciates according to the transition function $\mu^{u}(h, h')$; at the layoff time, a worker's human capital depreciates according to the transition function $\mu^{l}(h, h')$;[30] and when workers attend training programs, their human capital accumulates according to the transition function $\mu^{T}(t, h, h')$, where t refers to the training effort the worker chooses.

Search Technology A worker chooses the search effort continuously in the interval $[0, 1]$. I use $\pi(s)$ to denote the probability of finding a job when a worker chooses the job-search effort s.[31] The disutility of the search effort is denoted by $v(s)$, with $v'(s) > 0, v''(s) > 0$.

denote the expected benefit duration, I do not need to keep track of how long an unemployed worker has been receiving this benefit. This saves me one state variable which is quite important to the success of estimation strategy. Second, my assumption about the linear utility of the consumption means the worker cares only about the expected value of his future benefits; thus, this simplification will not change the main results of this paper.

[29] Notice the difference between the interpretation of the UI expiration rate and the UA expiration rate. The former measures the expected duration of the benefit. The latter measures how fast it decreases.

[30] By using the laid-off human capital transition function $\mu^{l}(h, h')$, I can check the effect of turbulence theory in this economy later. For example, if transition matrix μ^{l} is an identity matrix, it implies no human capital depreciation happening at the time of layoff; if I let the transition matrix μ^{l} be lower-triangle, it means workers experience some human capital loss upon layoff. In that case, I can study how turbulent economy behaviors differ from those in a tranquil economy under different policies. For an explanation of turbulence theory, see Ljungqvist and Sargent (1998, 2007, 2008).

[31] To focus the effect of human capital on wage earnings, I assume workers' human capital doesn't affect their job-finding rate. Hence, a high-skilled worker finds it easier to find a "better" job (i.e., a job with higher

Training Technology Training accumulates the human capital. A higher training effort means a higher human capital accumulation rate. Specifically, if a worker with human capital h chooses training effort t in the training programs, his human capital becomes h' with probability $\mu^T(t, h, h')$ at the end of this period. And the disutility associated with training effort t is $d(t)$.

Government in This Economy The government imposes a proportional income tax on employed workers. As I will describe below in the section on the employed worker's problem, I break down this income tax into two parts, τ and τ_0. τ is to used to finance the expenditure on three types of benefits paid to workers, as well as the direct training cost.[32] τ_0 is fixed, swhich represents all other taxes employed workers face. The government keeps the budget constraint balanced every period.

4.2 Timing

Figure 2 shows the timing of the model. At the beginning of every period, shocks take place first, which means some workers die and some employed workers are laid off. After that workers observe how their human capital changes. Basically, workers on the job and in training programs during the last period may find that their human capital improves while workers who were searching in the last period or experienced a layoff at the beginning of this period may lose part of the human capital. Employed workers then make decisions. Given that a new job offer arrives, an employed worker decides whether to switch to the new job, stay with the current one, or quit to be unemployed. At this time, there are two types of unemployed workers, according to whether they have a job offer in hand. An unemployed worker who receives a job offer at the end of last period[33] decides whether to accept it. An unemployed worker who does not have any job offer in hand[34] decides whether to participate in training programs or search for a job.[35] In both search and training cases, the worker also needs to choose an effort.[36] Finally, workers find out whether they receive any new job offers at the end of the period.

4.3 Workers' Problems

I will describe the problem of each type of worker according to whether the worker is employed or not and to which type of benefit he is entitled if unemployed.

wage earnings) since wage earnings are given by w times h.

[32] The direct cost of training refers to the cost aside from the benefit payments to the training workers, such as the expenditure on buying facilities and the salary of the caseworker and teachers in training programs.

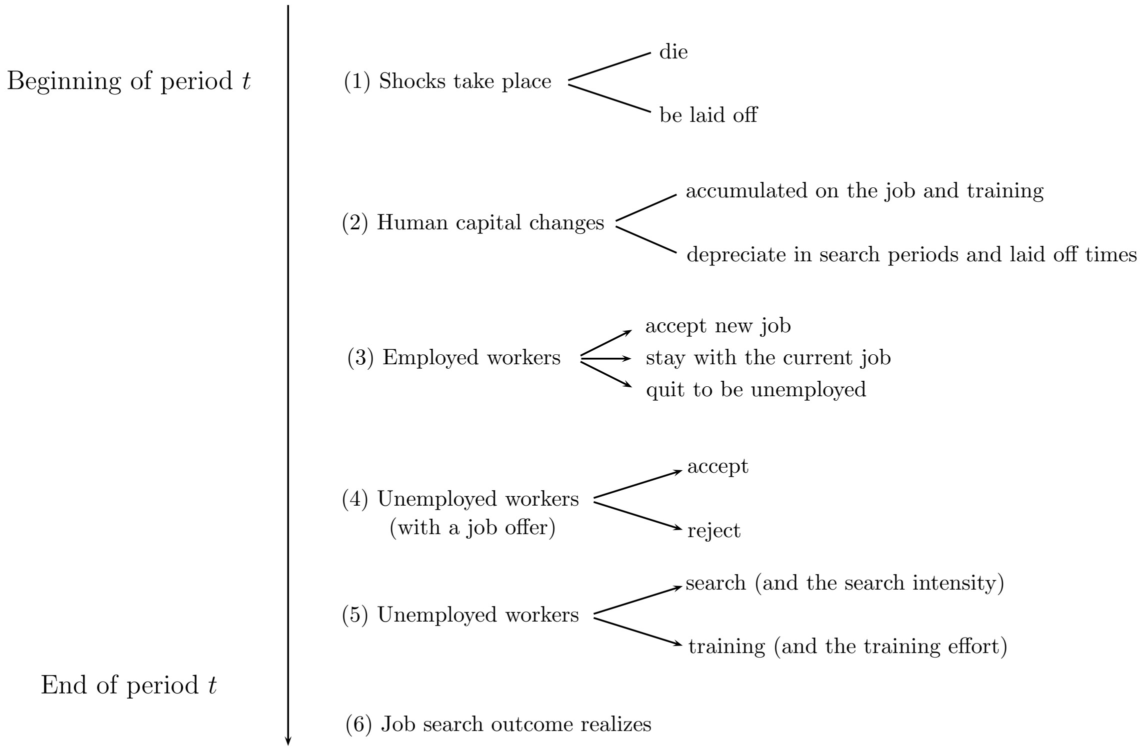
[33] Notice that although the probability of receiving a job offer depends on whether an unemployed worker chooses search or training, in both cases he may receive a job offer.

[34] These also include those unemployed workers who have just turned down their job offers and workers who were laid off or quit at the beginning of this period.

[35] I assume that an unemployed worker can choose either training or search, which may not be true in reality; the assumption that there are also new job offers arriving in training programs reflects the fact that training and search are not completely exclusive. What is important is that the job arriving rates may be different during the search and the training period, which unemployed workers must take this into account in their decisions.

[36] Search effort and training effort play different roles in the model. Search effort increases the job-offer arriving rate while training effort determines the human capital accumulation rate.

Figure 2: **Timing of the Model**



4.3.1 The Problem for an Employed Worker

An employed worker who works with wage w and has human capital h this period earns wh. Let I denote his after-tax wage earning, i.e., $I \equiv (1-\tau_0-\tau)wh$. In the next period, conditional on not being laid off or dying, his human capital may change to h'; he may also receive a new wage offer, w'. In that case, the worker needs to decide whether to accept the new wage offer, to stay in the current job, or to quit and become unemployed. If a worker quits and becomes unemployed, he is not eligible for UI and therefore receives SA. Let $V^e(w,h)$ denote the value for an employed worker with human capital h who works for this period at wage w, and let $V_{sa}(h,I)$ denote the value for an unemployed worker with human capital h who receives SA. Then the value function for an employed worker is as follows:

$$\begin{aligned} V^e(w,h) \quad = \quad & I + (1-\alpha)\beta\Big\{(1-\lambda(h))\sum_{h'}\mu^e(h,h') \\ & \cdot\big[\pi^J \int V(h',w',w)F(w') + (1-\pi^J)V(h',w,w)\big] \\ & +\lambda(h)\sum_{h'}\mu^l(h,h')V_{ui}(h',I)\Big\} \end{aligned} \tag{1}$$

where $V(h', w', w)$ denotes the value for a worker with new human capital h', new wage offer w' and current wage w.

$$V(h', w', w) \quad = \quad \max\{V^e(w, h'), V^e(w', h'), V_{sa}(h')\} \tag{2}$$

4.3.2 The Problem for an Unemployed Worker with UI

At the beginning of every period, conditional on that he doesn't die, an unemployed worker with the UI benefit chooses whether to search for a job or participate in training programs during this period. In both cases he has to specify the amount of effort he will use. The UI benefit is equal to the replacement ratio η_{ui} times his after-tax wage earning I. As discussed in the previous section, the UI expiration rate faced by unemployed workers in training programs, δ^T_{ui}, is lower than that faced by unemployed workers who search, δ^S_{ui}. In order to remain eligible for UI in the next period, unemployed workers are not allowed to turn down "suitable" job offers.[37] $\kappa\tilde{I}$ is used to measure this criterion, where $\tilde{I}$ is the last wage earnings of a now unemployed worker. That means if an unemployed worker turns down a wage offer that can bring higher wage earnings than $\kappa\tilde{I}$, he is not eligible to receive UI in the next period.

Let $V_{ui}(h, I)$, $V^S_{ui}(h, I)$, and $V^T_{ui}(h, I)$ denote the value functions for unemployed workers who are entitled to UI, unemployed workers who are entitled to UI and choose search activity, and unemployed workers who are entitled to UI and participate in training, respectively. Then the problem faced by an unemployed worker entitled to UI benefits can be described by the following Bellman equation.

$$V_{ui}(h, I) = \max_{\{\text{search, training}\}} \{V^S_{ui}(h, I), V^T_{ui}(h, I)\} \tag{3}$$

where

$$\begin{aligned} V^S_{ui}(h, I) \quad &= \quad \max_s \Big\{ -c(s) + \eta_{ui} \cdot I \\ &\quad +(1-\alpha)\beta \sum_{h'} \mu^u(h, h') \Big[[1-\pi(s)] U^S_{ui}(h', I) \\ &\quad +\pi(s) \big(\int_{wh' < \kappa\tilde{I}} \max\{V^e(h', w), U^S_{ui}(h', I)\} dF(w) \\ &\quad + \int_{wh' \geq \kappa\tilde{I}} \max\{V^e(h', w), V_{sa}(h', I)\} dF(w) \big) \Big] \Big\} &(4) \\ U^S_{ui}(h', I) \quad &\equiv \quad (1-\delta^S_{ui}) V_{ui}(h', I) + \delta^S_{ui} V_{ua}(h', I) &(5) \end{aligned}$$

[37] This is a common requirement in Germany and several other OECD countries.

and

$$\begin{aligned}
V_{ui}^T(h,I) &= \max_t \Big\{ -d(t) + \eta_{ui}\cdot I \\
&\quad +(1-\alpha)\beta\sum_{h'}\mu^T(t,h,h')\Big[[1-\pi^T]U_{ui}^T(h',I) \\
&\quad +\pi^T\big(\int_{wh'<\kappa\tilde{I}}\max\{V^e(h',w),U_{ui}^T(h',I)\}dF(w) \qquad (6)\\
&\quad +\int_{wh'\geq\kappa\tilde{I}}\max\{V^e(h',w),V_{sa}(h',I)\}dF(w)\big)\Big]\Big\} \\
U_{ui}^T(h',I) &\equiv (1-\delta_{ui}^T)V_{ui}(h',I)+\delta_{ui}^T V_{ua}(h',I) \qquad (7)
\end{aligned}$$

4.3.3 The Problem for an Unemployed Worker with UA

When UI benefits expire, an unemployed worker receives UA benefits. At the beginning of every period, the decision faced by an unemployed worker with UA is similar to that of an unemployed worker with UI. The worker has to choose whether to search for a job or participate in training programs during this period; in both cases the worker needs to choose an effort level. Similarly, let $V_{ua}(h,I)$, $V_{ua}^S(h,I)$, and $V_{ua}^T(h,I)$ denote the value functions for unemployed workers who are entitled to UA, unemployed workers who are entitled to UA and choose search activity, and unemployed workers who are entitled to UA and participate in training, respectively. The problem faced by an unemployed worker who is entitled to UA benefits is described by the following Bellman equation.

$$V_{ua}(h,I) = \max_{\{\text{search, training}\}}\{V_{ua}^S(h,I),V_{ua}^T(h,I)\} \qquad (8)$$

where

$$\begin{aligned}
V_{ua}^S(h,I) &= \max_s \Big\{ -c(s) + \eta_{ua}^S\cdot I \\
&\quad +(1-\alpha)\beta\sum_{h'}\mu^u(h,h')\Big[[1-\pi(s)]U_{ua}(h',I) \\
&\quad +\pi(s)\big(\int_{wh'<\kappa\tilde{I}}\max\{V^e(h',w),U_{ua}(h',I)\}dF(w) \\
&\quad +\int_{wh'\geq\kappa\tilde{I}}\max\{V^e(h',w),V_{sa}(h',I)\}dF(w)\big)\Big]\Big\} \qquad (9)\\
U_{ua}(h',I) &\equiv (1-\delta_{ua})V_{ua}(h',I)+\delta_{ua}V_{sa}(h',I) \qquad (10)
\end{aligned}$$

and

$$\begin{aligned}
V_{ua}^T(h,I) &= \max_t \Big\{ -d(t) + \eta_{ua}^T\cdot I \\
&\quad +(1-\alpha)\beta\sum_{h'}\mu^T(t,h,h')\Big[[1-\pi^T]U_{ua}(h',I) \\
&\quad +\pi^T\big(\int_{wh'<\kappa\tilde{I}}\max\{V^e(h',w),U_{ua}(h',I)\}dF(w) \\
&\quad +\int_{wh'\geq\kappa\tilde{I}}\max\{V^e(h',w),V_{sa}(h',I)\}dF(w)\big)\Big]\Big\} \qquad (11)
\end{aligned}$$

Notice that participation in training programs has different implications for whether one receives UI and UA. For unemployed workers entitled to UI, training extends the expected length of their benefit entitlement.[38] For unemployed workers entitled to UA, training increases the level of their benefits.

4.3.4 The Problem for an Unemployed Worker with SA

When unemployed workers are not eligible for either UI or UA, they receive SA. In this case, the worker's training participation decision and job acceptance decision do not affect the receipt of the entitled benefit in the next period. Let $V_{sa}(h, I)$, $V^S_{sa}(h, I)$, and $V^T_{sa}(h, I)$ denote the value functions for unemployed workers entitled to SA, unemployed workers who search and are entitled to SA, unemployed workers who participate in training and are entitled to SA, respectively. The problem faced by an unemployed worker entitled to SA is described by the following Bellman equation.

$$V_{sa}(h) = \max\{V^S_{sa}(h),\ V^T_{sa}(h)\} \tag{12}$$

where

$$\begin{aligned} V^S_{sa}(h) \quad = \quad & \max_s \Big\{ -c(s) + SA \\ & +(1-\alpha)\beta \sum_{h'} \mu^u(h, h') \Big[[1-\pi(s)] V_{sa}(h') \\ & +\pi(s) \int \max\{V^e(h', w), V_{sa}(h')\} dF(w) \Big] \Big\} \end{aligned} \tag{13}$$

and

$$\begin{aligned} V^T_{sa}(h) \quad = \quad & \max_t \Big\{ -d(t) + SA \\ & +(1-\alpha)\beta \sum_{h'} \mu^T(t, h, h') \Big[[1-\pi^T] V_{sa}(h') \\ & +\pi^T \int \max\{V^e(h', w), V_{sa}(h')\} dF(w) \Big] \Big\} \end{aligned} \tag{14}$$

4.3.5 Government Budget Constraint

The government uses tax revenue to finance the training costs and the expenditures on different benefits paid to unemployed workers. Every period the following budget constraint holds.

$$\begin{aligned} & \int (\phi + \eta_{ui} I) d\Lambda^T_{ui}(h, I) + \int (\phi + \eta^T_{ua} I) d\Lambda^T_{ua}(h, I) \\ + & \int \eta_{ui} I d\Lambda^S_{ui}(h, I) + \int \eta^S_{ua} I d\Lambda^S_{ua}(h, I) + \int SA d\Lambda_{sa}(h) \quad = \quad \int \tau w h d\Lambda^e(w, h) \end{aligned} \tag{15}$$

ϕ is the average direct training cost per training worker. $\Lambda^i_b(I, h)$ is the invariant distribution of the worker entitled to unemployment benefit b ($b = UI, UA$) and choosing activity i ($i = S, T$); $\Lambda_{sa}(h)$ is the invariant distribution of the worker entitled to SA.

[38] This is reflected by the lower expiration rate in training programs than during the search period.

4.4 Equilibrium

A ***Recursive Stationary Equilibrium*** consists of a set of government policies $\{\tau, \tau_0, \kappa, \eta_b^i, \delta_b^i, SA\}$ (where $b = UI, UA$; $i = S, T$), workers' decision rules on search, training and job offer acceptance (at different labor market status), and time-invariant distribution, such that:

- Given the government's policies, workers' decision rules solve workers' problems defined by equations (1) – (14).
- The associated time-invariant distribution is consistent with workers' optimal decisions.
- The government's budget constraint (15) holds for every period.

5 Calibration and Estimation

To solve the model quantitatively, I need to specify the human capital transition function, wage offer distribution, search and training disutility function and the function of the job finding rate in the search period.

Human Capital Transition Probabilities. Human capital may depreciate at layoff times and in search periods, and accumulate during employment periods and in training programs. I assume there are only two levels of human capital: a high level, $h^H = 2$, and a low level, $h^L = 1$. The human capital transition functions in each labor market state are described as follows.

During an employment period, a low-skilled worker has the probability μ^e of updating his skill level to the high level.[39] A high-skilled worker does not lose his human capital during the employment period. Therefore the human capital transition is given by the following transition matrix.

$$\begin{pmatrix} 1-\mu^e & \mu^e \\ 0 & 1 \end{pmatrix}$$

In a training period, the probability of upgrading the human capital for a low-skilled worker depends on his effort. I assume there are only two training efforts a worker can choose, a high level and a low level.[40] The probabilities that human capital changes from the low level to the high level at the low training effort and the high training effort are μ^{tl} and μ^{th}, respectively. A high-skilled worker doesn't lose his human capital in the training period. Thus the human capital transition matrices associated with the low training effort and the high training effort are given as follows:

$$\begin{pmatrix} 1-\mu^{tl} & \mu^{tl} \\ 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} 1-\mu^{th} & \mu^{th} \\ 0 & 1 \end{pmatrix}$$

[39] In this paper workers' skill and workers' human capital refer to the same thing.

[40] The main consideration of only using two training effort levels is to not introduce a human capital production function, which describes how training effort affects human capital accumulation, since I haven't found a good candidate in the literature for such a human capital production function.

In every search period, a high-skilled worker's human capital depreciates with the probability μ^u. A low-skilled worker's human capital does not depreciate. So the human capital transition matrix in the search period is as follows:

$$\begin{pmatrix} 1 & 0 \\ \mu^u & 1-\mu^u \end{pmatrix}$$

When an employed worker is laid off, with probability μ^l a high-skilled worker loses part of his human capital and becomes a low-skilled worker. A low-skilled worker's human capital doesn't change at layoff time. The human capital transition matrix is as follows:

$$\begin{pmatrix} 1 & 0 \\ \mu^l & 1-\mu^l \end{pmatrix}$$

So in total I use 5 parameters to summarize these different human capital transitions.

Wage Offer Distribution The wage (per human capital level) associated with a job offer follows a normal distribution $N(\mu_w, \sigma_w)$, which is truncated between 0 and 1.5.[41]

Disutility Function for Job Search The function form of the job search disutility is taken from Ljungqvist and Sargent (2007). The disutility associated with a search effort level, s, is given by the function $c(s) = A\frac{1-(1-s)^\gamma}{\gamma}$.

Disutility for Training Efforts Since there are two different training effort levels, the associated disutilities are $d(t^L)$ and $d(t^H)$, where t^L and t^H refer to the low and high training effort levels, respectively.

Function for Job-Finding Rate in the Search Period An unemployed worker's job-finding rate in the search period depends on his search effort. The function on this job finding rate is $\pi(s) = Bs^\xi$, which is a more general version of the function form used in Ljungqvist and Sargent (2007).[42]

5.1 Calibration of the Parameters

I divide the model parameters into two groups. In the first group, the values of the parameters are chosen directly to match their counterparts in the data or the corresponding labor-market policies. In the second group, the parameters cannot be calibrated separately and thus I estimate them jointly.

The first group of parameters include the probability a worker dies every period, α, the discount rate, β, the replacement ratio of UI, η_{ui}, and the expiration rates of UI in the search period and the training period, $\delta_{ui}^S, \delta_{ui}^T$, the replacement ratios of UA in the search period and the training period, η_{ua}^S, η_{ua}^T, and the expiration rate of UA, δ_{ua}, social assistance level, SA,

[41] The density is adjusted correspondingly to ensure that it is a proper density function after the truncation.

[42] Ljungqvist and Sargent (2007) used $\pi(s) = s^\xi$ in their quantitative analysis.

Table 5: Calibrated Values of Model Parameters

Paramter	*Notation*	*Value*	*Source and Moments to Match*
probability workers die every period	α	0.0021	43 years of working life
discount factor	β	0.9967	annual risk-free interest rate of 4.02%[a]
suitable earning level ($e(I) = \kappa \cdot I$)	κ	0.7	OECD (2003)
UI replacement ratio	η_{ui}	0.60	OECD (2003)
UA replacement ratio (search period)	η_{ua}^{s}	0.53	OECD (2003)
UA replacement ratio (training period)	η_{ua}^{Tr}	0.575	OECD (2003)
UI expiration rate every search period	δ_{ui}^{s}	0.052	maximum UI entitlement duration of 19.3 months in search periods (Wunsch, 2005)
UI expiration rate every training period	δ_{ui}^{Tr}	0.023	maximum UI entitlement duration of 43 months in training periods (Wunsch, 2005)
UA expiration rate every period	δ^{ua}	0.0025	decreases by 3% per year OECD (2003)
monthly training cost per participant[b]	ϕ	0.59	IZA Research Report (2005)
income tax rate (the fixed part)	τ_0	0.35	the total tax rate ($\tau + \tau_0$) is about 40%

[a]This is the average value of the term structure of interest rates on listed Federal securities residual maturity of 1 years between 2000 and 2002. (Data source: Bundesbank, Germany, 2008).

[b]This is the direct training cost besides the unemployment compensation paid to the participants.

the parameter on the suitable wage earnings level, κ, the direct training cost per participant, ϕ, the income tax rate for employed workers (the fixed part), τ_0.

Table 5 reports the values of these parameters and the moments they calibrate to. α is chosen to be 0.0021 so the average working life of a worker in the model is 43 years.[43] The discount rate, β, is chosen to match the average risk-free rate during $2000-2002$ in Germany. Other policy parameters are directly translated from the German labor-market policies. The average training cost, ϕ, is chosen to match the average training cost per participant as a ratio of the average wages over the same period.

5.2 Estimation

The second group includes the following 17 parameters.

- the human capital transition probabilities $\{\mu^e, \mu^u, \mu^{tl}, \mu^{th}, \mu^l\}$
- the probabilities workers are laid off (for both low-skilled and high-skilled workers) $\lambda(L), \lambda(H)$
- job-offer arriving rate in training programs π^T
- job-offer arriving rate on the job π^J
- parameters on the job-offer arriving rate in search period, B, ξ
- parameters on search disutility function, A, γ

[43]In the data I chose workers whose ages are below 63 at year 2003. I assume the average ages when workers enter the labor market is 20. So the average working life is about 43 years.

- parameters on training disutility, $d(t^L)$, $d(t^H)$
- parameters on wage offer distribution, μ, σ

Since they cannot be calibrated separately, I apply Simulated Method of Moments to estimate them jointly. The moments I use in the estimation process include wage earnings moments conditional on workers' labor market experience (i.e., unemployment length, training experience, benefit entitlements), statistics on wage earning distribution, transitions among different market states, distribution of workers over different labor-market states and benefit entitlements. In total, the 17 parameter values are chosen to match 36 selected moments in the estimation procedure.

To explain which moments I chose and why these moments are informative to identify the model parameters, let me first explain how the parameters are linked to the model moments. Figure 3 presents a graphic view of the model structure and how each parameter affects the worker's decision, the transitions (across different labor-market states) and distributions in the model. According to the different labor-market status, the economy can be thought of as an economy with three real "islands": employment island (E), search island (S), training island (T) and one intermediate island, nonemployment island (U).[44] Every period we can "see" workers are moving among different islands. The model parameters which I labeled on the graph are the different forces which drive workers to move.[45] For example, the layoff probabilities $\lambda(L), \lambda(H)$ affect the transition rate from E island to U island.[46] A larger layoff probability leads to a higher transition rate from employment island to nonemployment island every period. If the parameters on $\pi(s)$ imply the job search technology is now more effective, the transition from S to E and also from U to S (or from E to S) will increase. Similarly an increase in the job finding rate in the training programs, π^T, increases the transition from T to E, and an increase of human capital accumulation rates, μ^{tl} and μ^{th}, will increase both the transition from T to S and T to E. If the human capital depreciation rate (i.e., μ^u) increases, the transition from S to T will also increase.

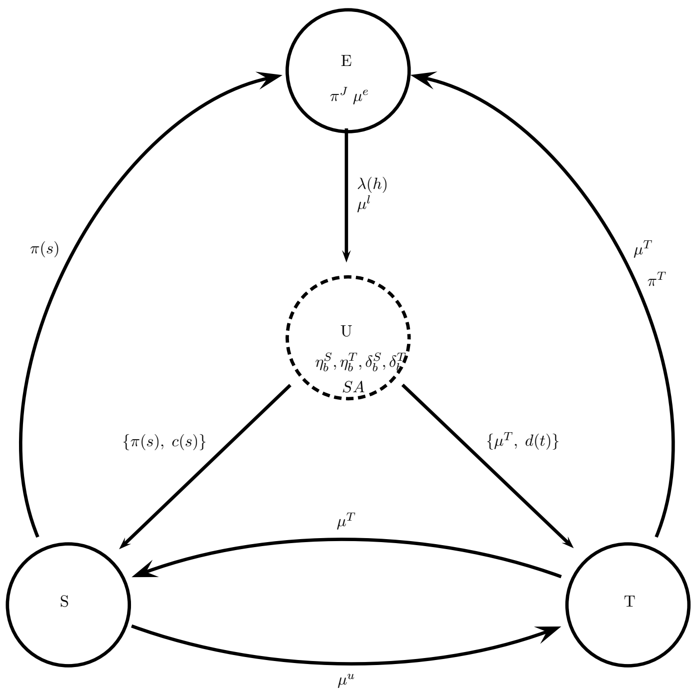
The transition rates from U to S and T are affected by two factors. One is the distribution of low-skilled workers and high-skilled workers in U island, since low-skilled workers are more likely to participate in training and high-skilled workers prefer job-search. This distribution is driven by the difference between the layoff probability that of low-skilled workers, $\lambda(L)$, and that of high-skilled workers', $\lambda(H)$, and the probability high-skilled worker's human capital depreciates at the layoff time, μ^l. For example, if $\lambda(L)$ or μ^l increases, which increases the proportion of low-skilled workers in U island, it increases the transition from U to T island. The second factor is the search and training technology. For instance, given the distribution of low-skilled workers and high-skilled workers and benefit entitlements, if the search technology is more effective, more workers will choose search. Similarly, if training technology is more effective, more workers will choose training. And all these transitions and individual decisions

[44] The reason I call the nonemployment island (U) an intermediate island is that workers only temporarily stay there and go to other islands. For example, when an employed worker is laid off, the worker first comes to U island before he makes the decision whether to go to S island or T island in this period.

[45] These actually include exogenous moves and endogenous moves. For example, when an employed worker receives an exogenous layoff shock, he is *exogenously* sent from E island to U island. But when he decides whether to go to S island or T island, this is actually an *endogenous* move, which is decided by the worker himself.

[46] The transition rate from E to U is the sum of the transition rates from E to S and from E to T.

Figure 3: A Graphic View of Model Structure and Key Parameters



E – Employment; U – Out of Work; S – Search; T – Training will lead to the equilibrium distribution of workers in each island. So, one important strategy I exploit here is to use these observed transitions and distributions to help identify part of the unobserved parameter values.

Besides transitions and distribution moments, the second group of moments I used are (conditional and unconditional) moments on the wage earnings. One important feature of this model is that human capital is unobservable and varies with labor market experience. These changes in human capital not only lead to a worker's different search and training decisions but also job acceptance decisions. Since wage earnings contain important information on workers' human capital, checking how workers' wage earnings change with their labor market experience helps identify several important parameters. This thus also helps identify other parameters.

Particularly, I use the average wage earnings moments for those unemployed workers who never participate in training programs conditional on the length they have been unemployed. Given that high-skilled workers leave unemployment faster and workers' human capital depreciates during the search period, these wage earning moments decrease as the unemployment lengthens. In the model, the human capital depreciation rate, μ^u, drives how fast these wage-earning moments decrease. In addition, the level of the wage-earning reflects the average human-capital level among these unemployed workers. As I explained in previous paragraphs, the proportion of low-skilled workers on island U is mainly driven by the parameters $\lambda(L), \lambda(H)$ and μ^l. To further help distinguish them, I use the average last wage earnings for unemployed workers *before* they are unemployed. Notice this does not depend on the human capital transition probability at layoff, μ^l, but reflects the difference between the layoff probability of low-skilled workers, $\lambda(L)$, and that of high-skilled workers, $\lambda(H)$.[47] This thus helps identify $\lambda(L), \lambda(H)$ and μ^l.

I use the average wage growth rates for employed workers to help identify the human capital accumulation rate on the job, μ^e. This also puts restriction on the human capital accumulation rate on the training programs because when unemployed workers make training participation decisions, they not only take into account the human capital accumulation rate on the training programs but also that on the job. The faster the human capital accumulates on the job, the more incentive the unemployed workers have to become employed faster (by searching hard and reducing their reservation wages).

To sum up, the second group of parameters are jointly estimated to match the wage earnings conditional on workers' unemployment experience, statistics on wage earning distribution, the distribution of workers over different labor-market states and benefit entitlements, and transitions among different market states by Simulated Method of Moments. To circumvent the non-smooth and local optima problem in the computation of classical extremum estimators, I apply a recent approach proposed by Chernozhukov and Hong (2005). They develop a class of Laplace Type Estimators (LTE) which can be implemented by Markov Chain Monte Carlo simulations. The estimation details are listed in the Appendix. The estimated parameter values and matched moments are reported in Table 6, Table 7 and Figure 5 in the next section.

[47] It is also determined by the distribution of human capital among those who quit their jobs. But the number of these workers is quite small in the model.

6 Estimation Results

The estimated values of the parameters are reported in Table 6. The top panel reports the human capital transition probabilities at different labor market statuses. It shows that during the search period, a high-skilled unemployed worker's human capital depreciates (to the low level) with probability 0.1 every period. That means on average he loses 5 percent of his human capital every search period.[48] For a low-skilled worker who participates in training programs, the average probability that his human capital improves to the high level is 0.055 if he uses the average training effort. This means every period the human capital improves by 5.5 percent (on average) for a low-skilled worker in training programs. The human-capital accumulation rate on the job is about 30 percent of the average rate in the training programs. The estimation shows that the probability that a high-skilled worker's human capital depreciates at layoff times is very high. It implies that high-skilled workers on average lose 28 percent of their human capital when they are laid off. This looks a little surprising, but it is consistent with the fact that after unemployment, workers' average wage earnings are much lower than their wage earnings on their last jobs. In reality, this large difference can be caused by many different things, such as loss of job tenure, the loss of the firm specific skill, occupation-specific reasons, and deterioration of job opportunities after layoff. But in the model all these effects are summarized by the effect of the common factor, human capital. That is why the model generates a very high probability that human capital depreciates at layoff time.

The middle part of Table 6 shows the parameters values on the disutility function of search effort and the disutilities for different training efforts. It shows that the disutility associated with high training effort is very high. Actually, it is twice as much as the disutility brought by the average search effort level in the economy.[49] But this high disutility with the high training effort is compensated by the high human capital accumulation rate. The estimation shows another important trade-off between training and search: the job-offer arriving rate in training programs is much lower than that in the search period. Actually the parameters imply a 10 percent of full the search effort can bring the same job-offer arriving rate as that in training programs. These results highlight the important trade-off unemployed workers need to take into account when they make training participation decisions: training improves human capital but it requires higher effort and the job-offer arriving rate in the training period is lower than in the search period.[50] As shown at the bottom of the table, low-skilled workers face a much higher probability of being laid off than high-skilled workers face. This large difference is generated in the model to match the large difference between the average previous earnings for unemployed workers and the average earnings for employed workers.

Given these parameter values, Figure 4 shows the search and training decisions for workers with different human capital levels and unemployment benefit entitlements. It says high-skilled workers choose search and the search effort level decreases with the entitled benefit

[48] Since the high human capital level is 2 and the low human capital level is 1, a 0.1 probability of transiting from high human capital to low human capital means a 5% human capital depreciation.

[49] The computation results show that the average search effort in the benchmark economy is less than 0.3, which leads to a disutility level of 1.0.

[50] A lower job-offer arriving rate in training programs can be interpreted as the result of less time for workers in training programs to search for jobs. In other words, training takes time to improve human capital, which prevents unemployed workers from actively searching for jobs.

Table 6: Estimated Values of the Model Parameters

Paramters on human capital transitions		
skill depreciation rate during searching periods	μ^u	0.0997
skill accumulation rate at *high* training effort	μ^{th}	0.1087
skill accumulation rate at *low* training effort	μ^{tl}	0.0005
skill accumulation rate on the job	μ^e	0.0169
probability of transiting from high-skilled to low skill at layoff time	μ^l	0.5523
Disutility (per model period) for search and training activities		
search disutility function ($c(s) = A\frac{1-(1-s)^\gamma}{\gamma}$)	A	2.9794
	γ	0.3491
disutility for low training effort	$d(t^L)$	1.1918
disutility for high training effort	$d(t^H)$	1.9710
Job arriving rates conditional on different activities		
in search period ($\pi(s) = Bs^\xi$)	B	0.2277
	ξ	0.7259
in training programs	π^T	0.0426
on the job	π^J	0.0057
Other parameters		
laid-off probability for low skill	$\lambda(L)$	0.0158
laid-off probability for high-skilled	$\lambda(H)$	0.0054
mean of wage distribution	μ_w	0.9902
standard deviation of wage offer distribution	δ_w	0.1412

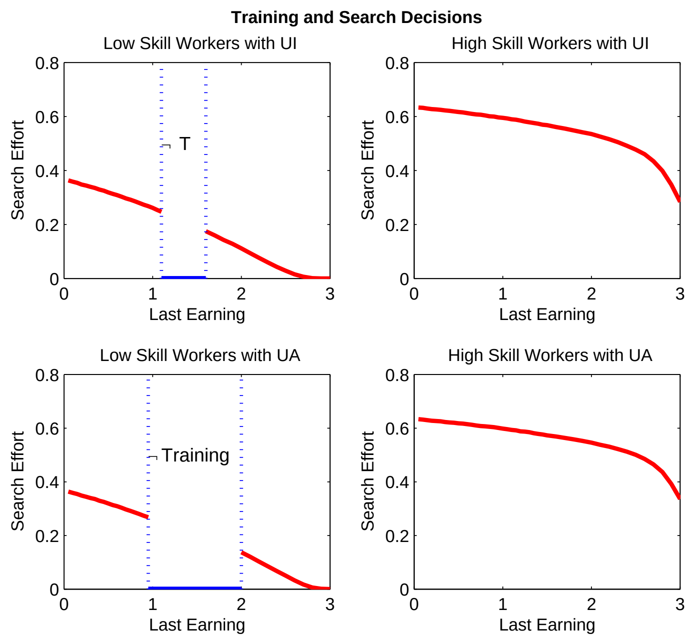


Figure 4: This figure shows the training and search decisions for workers with different human capital levels and benefit entitlements (UI and UA). The x axis shows workers' previous wage earnings (UI and UA are equal to their replacement ratios times the workers' previous wage earnings), y axis shows the search effort level and training decisions.

level. When the entitled benefit level is low, low-skilled workers search and choose relatively high effort level. As the entitled benefit level increases, low-skilled workers prefer to training. And when the entitled benefit is very high, they will choose low search effort level. These policy functions show that a very low level of unemployment benefit discourages training participation while a very high level of unemployment benefit discourages both training participation and job-search.

6.1 Model Fit

Table 7 and Figure 5 compare the moments generated by the model and the corresponding statistics in the data.[51] The model generates a distribution (of workers in different labor-market status) very close to the one shown in the data. The proportion of employed workers in the data is 86.4 percent and in the model it is 86.3 percent. There are 12.2 percent of workers who search in the data, and in the model this figure is 12.4 percent. The model generates 1.3 percent of workers in training programs, while in the data it is 1.4 percent. The model matches almost exactly the proportion of workers entitled to UI, UA and SA benefits

[51] These are the moments I chose to be matched. As explained in the previous section, in total I use 17 parameters to match 36 moments.

as shown in the data.

The transitions among different labor-market states in the model are also close to that in the data. But compared with other fairly well matched transitions, the model generates a much lower transition from search to training than that in the data. One possible explanation is that unemployed workers can choose whether to participate in training program. In reality, although the current training programs policies in Germany say the only requirement for participation is the *necessity requirement*[52], which means workers who need the training programs should be eligible, the evaluation process is usually done by a caseworker. It is possible that there are some workers who are "recommended" to participate in training even when they do not want to do so.[53] This will increase the transitions from search to training programs in the data.

Table 7: Moments Matched

Moments	*Model*	*Data*
Distribution		
employment rate	0.8627	0.8640
proportion of people who search	0.1243	0.1222
proportion of people who take training	0.0130	0.0141
proportion of people entitled with UI	0.0591	0.0586
proportion of people entitled with UA	0.0273	0.0274
proportion of people entitled with SA	0.0509	0.0503
Transitions		
from employment to unemployment	0.0091	0.0104
from search to employment	0.0642	0.0622
from search to training	0.0103	0.0206
from training to employment	0.0418	0.0464
from training to search	0.1073	0.1175
Other wages statistics		
wage growth rate on the job	0.0062	0.0078
coefficient of variation	0.5140	0.4568
average previous wages	0.8417	0.7200
average wages conditional on (previous) benefit entitlement and activities		
Search + UI	0.7080	0.7430
Training + UI	0.6187	0.7097
Search + UA	0.6886	0.5784
Training + UA	0.5982	0.5909

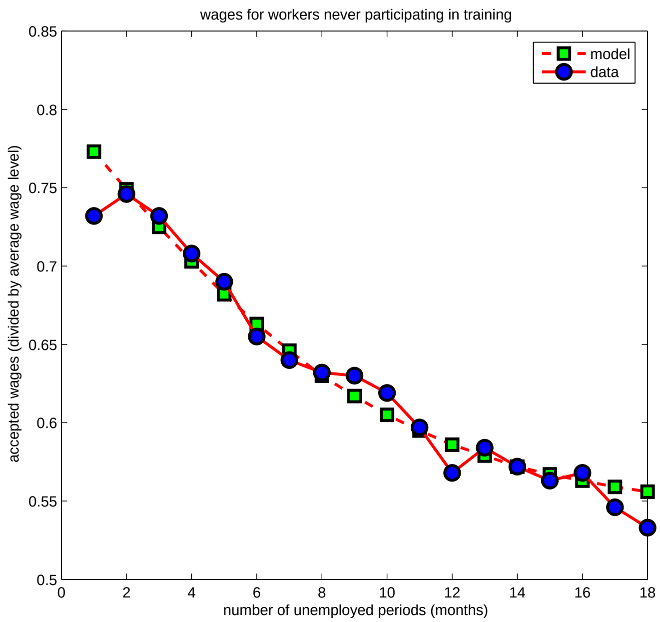
Figure 5 shows the wage earnings for unemployed workers who never participate in training programs (in the current unemployment spell) conditional on the unemployment length[54]

[52]For the details see Conny Wunsch (2005), for example.

[53]Before 2000, some unemployed workers were required to participate in certain active programs to be eligible for unemployment benefits.

[54]In this case, the unemployment length is the total number of search periods.

Figure 5: Earning Moments Conditional on Unemployment Length



in the data and the model. The x axis is the length of unemployment measured in the number of model periods. The y axis is the ratio of the average wage earnings of the unemployed workers at the time they find a job to the average wage earnings of employed workers. For instance, a pair of values of (x, y), $(2, 0.75)$, means for all the unemployed workers who never participate in training programs and become employed after two periods of search, the average earning at the time they accept their jobs is 75 percent of the average level of all employed workers. As shown in the data (the squares in the figure), the longer the workers search, the lower the wage earnings they end up with. Given the same wage offer distribution workers face every period, this means the average human capital decreases as the unemployment spell stretches.[55] So, as explained before, these conditional wage earning moments contain important information on both the human-capital depreciation rate and the initial distribution of workers' human capital when they enter unemployment. This figure shows that the model successfully matches these conditional wage earnings.

[55]But notice there are two reasons accounting for this change of average human capital level. First, it is because of the heterogeneity. That is, unemployed workers' human capital levels already differ at the time they become unemployed. Since high-skilled workers leave unemployment faster than low-skilled workers, as unemployment length increases, the proportion of low-skilled workers in the unemployment pool increases. Second, it is because of the duration dependence. That is, since unemployed workers' human capital depreciates, the average human capital level decreases (no matter whether heterogeneity exists or not) as unemployment length increases.

7 Policy Analysis

Given the structural model has matched the data in different important dimensions, I am able to use it to do the following four types of policy analysis. First, I apply the model to study the actual reforms implemented in Germany in 2003, 2005, and 2006. I will quantitatively investigate how these reforms affect the workers' training participation and how these reforms affect the unemployment rate, the employment rate, and the output in the long run. Second, I use the model to simulate the transition dynamics between and after these reforms. Third, I will do a series of counter-factual experiments to explore the macroeconomic effects of alternative policies on the economy. Fourth, I use the structure model to study the effects of training on the employment probability and wage earnings of the unemployed workers.

7.1 Studying the Actual Reforms in Germany

Table 8 compares the main aggregate statistics in the steady states of different economies. The first four columns compare the benchmark economy (which corresponds to Germany between 2000 and 2002) with the economies with the new policies implemented under the reforms in 2003, 2005 and 2006 in Germany. (I label these three reforms as Reform 1, Reform 2 and Reform 3 in the table and also below.)

Table 8: Comparison of the Steady States of Different Economies

	Benchmark[a] *(2000-02)*	*Reform 1 (2003)*	*Reform 2 (2005)*	*Reform 3 (2006)*	*No Training (2006)*	*Training U.S.*[b]	*No Training U.S.*
percent of							
Unemp.[c]	12.6	13.2	13.5	11.3	13.7	5.3	8.9
Employ.	86.3	86.1	86.1	86.6	86.3	91.2	91.1
percent of							
Training	1.3	0.8	0.4	2.4	0.0	3.7	0.0
Searching	12.4	13.0	13.5	11.0	13.7	5.1	8.9
UI	5.9	6.1	6.0	4.6	5.0	2.7	2.9
UA	5.1	5.1	5.2	5.9	5.9	0.0	0.0
SA	2.7	2.7	2.7	2.9	2.7	6.1	6.0
Welfare	100.0	100.0	100.1	100.0	100.5	103.5	104.2
Output	100.0	99.0	98.3	102.4	97.7	109.9	103.0
Tax (%)	5.4	5.3	5.2	5.6	4.9	2.7	1.5

[a]The benchmark economy corresponds to Germany between 2000 and 2002.

[b]The U.S. economy is described by a UI replacement ratio of 0.6, maximum duration of 6 months, no UA benefit and a SA level equal to 25% of average net wage earning.

[c]The unemployment rate is calculated as the percent of searching workers among all the workers except those in training programs.

The first column shows the unemployment rate, the employment rate, the percentage of workers searching and in training programs and the percentage of workers entitled to each type of benefit. For the convenience of comparison with other model economies, I normalize the welfare and output level in the benchmark economy to be 100. As shown in the section of estimation results, these statistics match fairly well their counterparts in the data.

Reforms 1 and 2 gradually remove the extra benefits (only) for those unemployed workers in training programs. According to Reform 1, unemployed workers entitled to UA no longer receive higher benefits in training programs than those who search[56] and the maximum UI duration in training programs decreases from 43 months to 38 months.[57] This reduces the incentive for unemployed workers to participate in training. Therefore, the percentage of unemployed workers in training decreases by nearly 40 percent (from 0.9 to 0.3 percentage point). At the same time, the percentage of unemployed workers who search increases from 12.7 to 13.7 percentage points. This has two effects on the employment rate. Since workers have a better chance of finding jobs when they search, it increases the employment rate. Second, with fewer unemployed workers participating in training, the proportion of low-skilled unemployed workers increases. Since low-skilled unemployed workers have lower probability of finding good jobs (i.e., jobs with high wage earnings), it reduces the transition rate from unemployment to employment.[58] This reduces the employment rate. Taking into account these two effects, Reform 1 reduces the employment rate by 0.2 percentage point. The unemployment rate increases by 0.6 percentage point. The percentage of workers who search increases by 0.6 percentage point.[59] The output (i.e., the total wage earnings in the economy) decreases by 1.0 percentage point due to the decrease in average productivity.

Similarly, since Reform 2 further reduces the maximum duration of UI entitlement from 38 months to 19 months for unemployed workers in training programs,[60] workers are less likely to participate in training. As a result, in the long run the percentage of training workers is only 30 percent of the benchmark level. The unemployment rate goes up to 13.5 percentage points. Notice that the employment rate doesn't change. This is because the two effects of more search workers on the employment rate (as discussed above) offset each other in this case. But the output falls by another 0.7 percentage point because the workers' productivity further goes down when even fewer workers choose training.

Reforms 1 and 2 together actually remove all the extra benefits for unemployed workers in training programs. So unemployed workers face the same benefit structure no matter whether they participate in training or not. Reform 3 (in 2006) further reduces the maximum duration of the UI benefit from 19 months to 13.5 months. And the target is *all* the unemployed workers (not just those workers in training programs as in Reforms 1 and 2). This actually generates completely different results from those in the first two reforms. As shown in the fifth

[56]Before 2003, unemployed workers entitled with UA may receive higher levels of benefits if they participate in training.

[57]The actual reform is that the UI benefit duration will be reduced by half of the training programs duration. Thus, the maximum UI benefit duration is given by $19 \times 2 = 38$ months under Reform 1.

[58]Since wage earning is given by the product of the wage rate (per unit of human capital) and the worker's human capital and workers face the same wage rate distribution, a low-skilled worker is less likely to find jobs with high wage earnings.

[59]Again, notice that the increase in the percentage of workers who search is more than the decrease in the percentage of workers who participate in training.

[60]Therefore, participating in training doesn't extend the maximum duration of UI entitlement. In other words, workers in training programs have the same maximum duration of UI benefit entitlement as those who search.

column of Table 8, compared with the benchmark economy, it almost doubles the percentage of workers in training programs. The unemployment rate decreases by 1.3 percentage points and the employment rate increases by 0.2 percentage point. The output increases by 2.4 percentage points. The tax rate increases because the total expenditure on training costs increases.

Instead of explaining again what causes these changes separately, I want to point out the main channel through which different policies affect the economy in the model, the trade-off between search and training. This helps us to understand why more unemployed workers choose training under Reform 3 and why Reform 3 has a completely different effect on workers' training participation decisions. The important difference between training and search is as follows. Training takes time to improve human capital. During the training period there are fewer opportunities for finding a job, which means workers in training programs have to forgo more labor income. On the contrary, search helps to find a job faster, but it doesn't improve human capital (it even depreciates). When the UI benefit duration is very long, not only can unemployed workers receive this generous benefit for a very long time, but they also have enough time to search for good jobs. This makes unemployed workers choose search even though they know their human capital may depreciate during the search period. As the duration of UI becomes shorter, more workers begin to participate in training because they know they can find good jobs faster after their human capital improves through the training programs. And this is important to them if they know the period in which they can receive UI benefits is much shorter than before. This is why the reduction of the UI benefit duration in Reform 3 will push more workers to participate in training.

Thus, the most important thing I want to emphasize is that a worker does *not* make decisions on search and training *separately*. Workers always look at the trade-off between training and search to make the best choice. Although like Reform 3, Reforms 1 and 2 also reduce the maximum UI benefit duration, they reduce the number of workers in training programs because they *only* reduce the UI benefit duration for workers in training programs, reducing the incentive of training participation. However, Reform 3 reduces the UI benefit duration for *all* unemployed workers, which in the end "forces" more workers to choose training, because workers know under the new policy, training becomes more important for them so they can leave unemployment before their UI benefits expire.

The middle panel of Table 8 also reports the effects of these reforms on the percentage of unemployed workers entitled to each type of benefit. Reforms 1 and 2 slightly increase the percentage of workers entitled to UI and UA, but has almost no effect on the percentage of workers entitled to SA. Reform 3 reduces the percentage of workers entitled to UI while increasing the percentage of workers entitled to UA and SA. There are several things worthy of more explanation here. First, the main reason more unemployed workers are entitled to UI under Reforms 1 and 2 is that there are more low-skilled workers (both employed and unemployed) because of the low participation in training programs. The increase of low-skilled employed workers increases the average layoff probability because low-skilled workers have a greater chance of being laid off.[61] This increases the transition to unemployment and generates more workers receiving UI. Second, the reason the percentage of workers entitled to UA does not increase under Reform 1 is that the removal of extra benefits for workers

[61] As shown in the estimation results, $\lambda(L) > \lambda(H)$.

entitled to UA in training programs lowers their reservation wages; thus, workers entitled to UA leave unemployment faster than the benchmark economy. Third, since Reform 3 reduces the maximum UI benefit duration, it directly reduces the percentage of workers receiving UI and increases the percentage of workers receiving UA and SA.

7.2 The Transition Dynamics After the Actual Reforms

After investigating the long-run effects of these reforms, it is also interesting to look at the transition path between and after these reforms were implemented in Germany.

The benchmark model is estimated using the German data between 2000 and 2002. The three reforms took place in 2003 (labeled Reform 1), 2005 (labeled Reform 2) and 2006 (labeled Reform 3), respectively. So, I will start with the benchmark economy and simulate the transition periods following Reform 1 and including Reforms 2 and 3.

The transition path is simulated in the following way. Let N be the total number of periods to be simulated.[62] Let period $t = 1$ be the initial period (which is in the benchmark stationary economy), which is the last period right before Reform 1. So the first reform (i.e., Reform 1) is announced at the beginning of period $t = 2$. I assume the workers in the model economy are not aware that the government will announce Reforms 2 and 3 in the future. Then I simulate the transition path from the initial period to the new stationary economy under the new policies in Reform 1. Since the model period is one month, the economy will go along this path until period $t = 25$, which is the last period before the government suddenly announces Reform 2. Given the same assumption that workers are not aware of Reform 3, I simulate the transition path from economy in period $t = 25$ to the new stationary economy. And the economy will go along this new transition path until period $t = 37$, which is the last period before the government announces Reform 3 at the beginning of period $t = 38$. Since Reform 3 is the last reform in the model economy, I simulate the transition path from period $t = 38$ until the economy reaches the stationary economy under the new policies in Reform 3. Thus, I get all the transition periods $t = 1, 2, 3, ..., N$, which start from the benchmark economy and include all three reforms. (The detailed algorithm to compute the transition dynamics is listed in the Appendix.)

The unemployment rate, employment rate and percentage of workers who search and participate in training along the transition path are shown in Figure 6. It shows that the unemployment rate keeps rising after Reforms 1 (in 2003) and 2 (in 2005), until Reform 3 (in 2006). It then begins to fall. The employment rate increases slightly right after Reform 1 because the removal of the extra UA benefits for unemployed workers in training programs lowers their reservation wage and pushes more workers to employment. After several periods, it begins to fall until 2006. After Reform 3, the employment rate begins to rise again. The two graphs on the right of the figure show how the percentage of workers who search and participate in training changes following the reforms.

As a check on the model's performance out of the sample period, I plot the actual unemployment rates between 2003 and 2008.[63] By comparing the simulated path of the unemployment rate shown in Figure 6 with the actual one shown in Figure 7, I find the model

[62] I let N be large enough so the simulated period covers the period 2003-2008.

[63] The actual unemployment rates in the period 2003-2008 are taken from *Bundesagentur für Arbeit*. The data set I used in this paper, IEBS, does not cover this period.

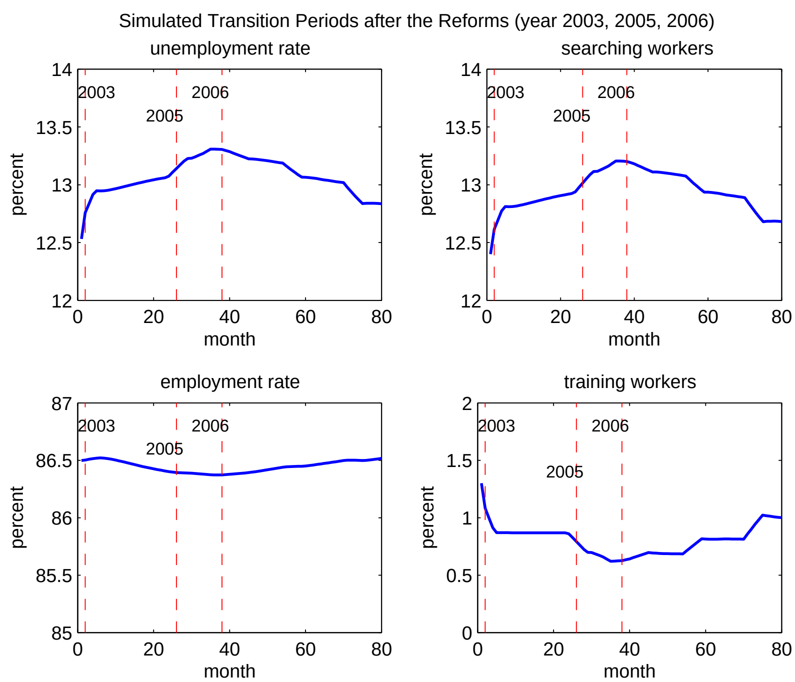


Figure 6: This figure shows the unemployment rate, the employment rate, the percentages of workers who search and participate in training along the transition path following the Reform 1, 2 and 3 in year 2003, 2005 and 2006. The transition path is simulated under the assumption that the workers in the model economy are not aware that the government will announce Reforms j in the future when government announce Reform i (where $i = 1, 2$ and $j > i$).

correctly predicts the pattern of the changes of the unemployment rate between 2003 and 2008: that is, it first increases after 2003 until 2006 and decreases after that. This suggests that large-scale labor market reforms can have important effects on aggregate outcomes.

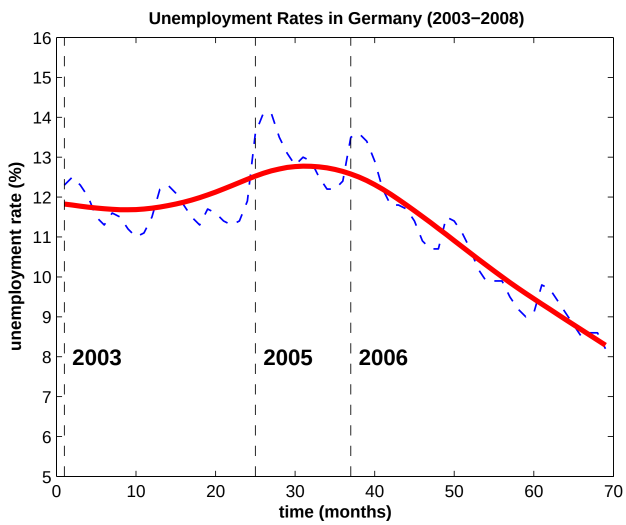


Figure 7: This figure plots the actual unemployment rates in Germany between Jan.2003 and Sept.2008. (Data source: *Bundesagentur für Arbeit*)

7.3 Assess Alternative Policies

By doing counterfactual experiments, the structural model can be used to assess alternative policies. Specifically, I ask the following questions. (1) Instead of reducing the maximum benefit duration, what are the effects of reducing the level of the unemployment benefits (i.e., the replacement ratio) on the aggregate statistics that have been studied above? (2) What will happen if Germany uses the US benefit structure? (3) How do the unemployment rate and employment rate change if there are no training programs in Germany under the new policies? I will answer these questions one by one.

7.3.1 Change the Replacement Ratios

Two important aspects of the unemployment benefits are the replacement ratio, which measures the level of the benefit, and the maximum entitlement duration, which measures the length of the availability of the benefit. Since most reforms focus on changing the maximum duration of the unemployment benefit, it is also interesting to explore the effects of changing the replacement ratios.

To be comparable with the benchmark economy, I keep all other features of the benefit structure when I change the replacement ratios in the counterfactual experiments. For example, I keep the relative difference between the replacement ratio of UI and that of UA.

So, if the replacement ratio of UI decreases by 5 percentage points, the replacement ratio of UA also decreases by 5 percentage points so the difference between them doesn't change. In other words, when I reduce the replacement ratio of UI, it reduces the structure of the unemployment benefit (which includes both UI and UA). Also, as in the benchmark model economy, I still assume workers can get extra benefits when they are in training programs (i.e., longer duration of UI and higher level of UA).

Figure 8 shows the employment rates, the unemployment rates, outputs, and welfare in the economies with three different UI replacement ratios (i.e., 53 percent, 63 percent and 73 percent). At each level of replacement ratio, I let the maximum UI duration vary from one to 25 months. For all three different replacement ratios, employment rates, output, and welfare decrease as the maximum UI duration increases. Unemployment increases with a maximum UI duration. But one common and significant feature of the four pictures is that changing replacement ratios can generate larger effects on these aggregate statistics than does changing the maximum UI duration. This provides an alternative and important policy suggestion for Germany. That is, to reduce unemployment and increase employment, Germany can reduce the level of the unemployment benefits instead of (only) the length of the UI benefit.

7.3.2 German Training Programs Plus the U.S. Benefit Structure

The United States does not have large training programs such as those in Germany. Also, the United States has a much tighter unemployment benefit structure than that in Germany. So it's interesting to look at an economy with both the German training programs and the U.S. benefit structure.

The seventh column (labeled "Training U.S.") of Table 8 reports the statistics in such an economy. The U.S. benefit structure is described by a UI replacement ratio of 0.6, maximum duration of six months, no UA benefit, and a SA level equal to 25 percent of average net wage earning.[64] As we can see, the percentage of workers in training programs increases from 1.3 percent to 3.7 percent. With more workers participating in training programs, the average productivity increases. The output thus increases by about 10 percentage points. The unemployment rate falls dramatically from 12.6 percent to 5.3 percent, and the employment rate also increases by about 5 percentage points. This change on the benefit structure sharply reduces the number of workers receiving UI benefits by more than 50 percent. Since there is no UA benefit, fewer unemployed workers are receiving SA. But the number of workers receiving SA is less than the total number of workers receiving UA and SA in the benchmark economy. The higher employment and fewer workers receiving unemployment benefits lead to a 50 percent cut in the tax rate.

7.4 Economies Without Training Programs

What will happen to the unemployment rate, the employment rate, and output if we take away the training programs? To answer this question, I compare the different economies of the case with training programs and the case without training programs.

To follow the discussion in the previous section, I will start with the economy with the U.S. benefit structure and German training programs. Suppose now that training programs

[64]The SA benefit is calibrated by using the benefit from the Food Stamp Program in the United States.

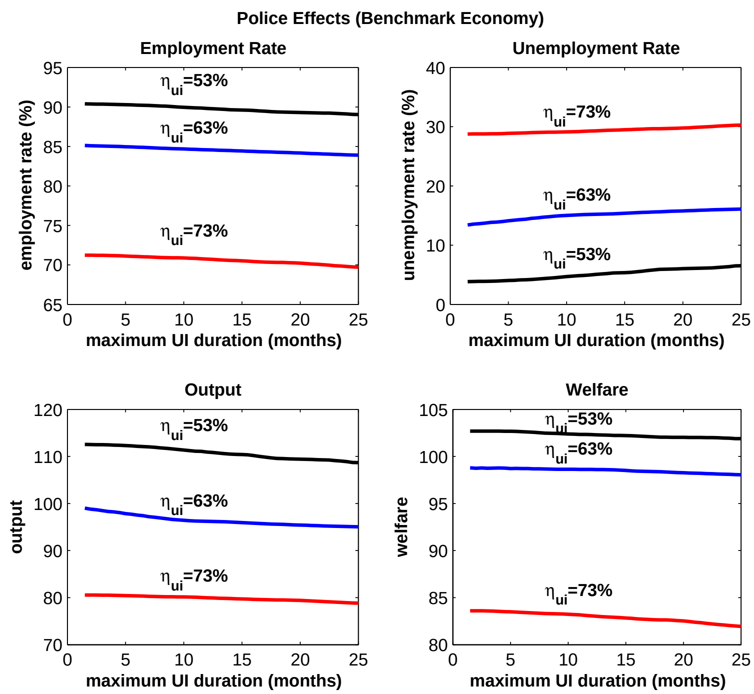


Figure 8: The economies with different replacement ratios. This figure shows the unemployment rates, the employment rates, output and welfare in the economies with different replacement ratios and maximum UI durations. I set the relative difference between the replacement ratio of UI and that of UA to the same level in the benchmark economy when I change the UI replacement ratio. Also, like in the benchmark model economy, I still assume workers can get extra benefits when they are in training programs (i.e., longer duration of UI and higher level of UA).

are not available in this economy. The last column of Table 8 reports the statistics for this new economy. Compared to the old economy (i.e., the one with the U.S. benefit structure and German training programs), the employment rate doesn't change much. This is because the U.S. benefit structure is already tough (i.e., much shorter UI duration, no UA, and lower SA), which pushes workers to search hard and lower their reservation wages (compared with the benchmark economy). This generates the high employment rates in both economies.[65] The unemployment rates differ because of the differences in the percentage of workers in training programs. But under similar levels of employment, the outputs in the two economies differ by 7 percentage points which is quite large. This large difference is created by the training programs. In other words, without training, although the tight benefits can still push workers to leave unemployment faster (compared to the benchmark economy), the workers are not compensated for the loss of human capital, which is the most important aspect regarding to the output. Two more things deserve attention: (1) Without training programs, the tax rate is much lower because training programs are costly and (2) It may be a little surprising to see that welfare[66] in the new economy (without training programs) is higher than in the old one (with training programs). This is mainly because of the lower tax in the economy.

Next, I will look at the economy after Reform 3 is implemented. As I discussed before, by cutting the maximum UI benefit duration for all unemployed workers, Reform 3 successfully increases the employment rate by 0.3 percentage points and increases the output by 2.4 percentage points compared with the benchmark economy. Now suppose there are no training programs in this economy. As shown in the sixth column of Table 8, the employment rate is no more than the level in the benchmark economy, while the output even decreases by 2.3 percentage points. Thus, the success of Reform 3 on increasing the employment and output of the economy relies on the existence of the training programs.

The general conclusion from the above two counterfactual policy experiments is that in an economy with a generous benefit structure such as that in Germany, the presence of training programs can increase the employment rate significantly when government tightens the benefit structure (such as by reducing the maximum UI benefit duration in Reform 3). And this additional increase on the employment rate decreases as the benefit structure becomes tighter (such as in an economy with the U.S. benefit structure). But in all economies, training programs significantly increase the outputs. In addition, since training programs are costly, the higher tax rates resulting from an increase in the number of training programs has a negative effect on welfare.

7.5 Effects of Training on Employment Probability and Wage Earnings

Workers with different human capital levels and unemployment benefit entitlements make different training participation decisions. In the long run, training programs can improve workers' human capital, increasing wage earnings when workers find a job. Higher human capital makes it easier for workers to find good jobs (i.e., the jobs with high-wage earnings,) which also indirectly increases the employment probability. But training is time consuming, so in the short run, workers participating in training have fewer opportunities to find a job.

[65] That is, the economy with the U.S. benefit structure and German training programs and the economy only with the U.S. benefit structure but no German training programs.

[66] Welfare is calculated as the average lifetime utility for all workers in the economy.

Therefore, it is interesting to explore how the training programs affect unemployed workers' employment probability and wage earnings over time.

To do this, I simulate the workers' employment probabilities and average wage earnings[67] over the next N periods under two different assumptions. First, I simulate these paths under the assumption that training programs are available to unemployed workers (as in the benchmark economy). Second, I simulate these paths given that training programs are suddenly not available. Then I compute the differences in employment probability and wage earnings between these two cases. These differences reflect the effects of training programs.

The left two pictures in Figure 9 show the average training effects on employment probability and wage earnings for unemployed workers in training programs. The picture on the upper left panel shows that when unemployed workers participate in training programs, the probability of leaving unemployment in the short run is lower (by as much as 5 percentage points) than if they do not participate in training programs. As times goes on, this difference becomes smaller and smaller and finally becomes positive after about 12 periods. This is because when more and more unemployed workers in training programs improve their human capital, they can search more effectively and leave unemployment faster than those who did not participate in training programs. The bottom picture on the left shows the difference on wage earnings for the same group of workers. Compared with the picture on the upper left, it shows that the positive effect on wage earnings is much larger than that on employment probability. The two pictures on the right panel of the same figure show the average training effects for all unemployed workers. They show a similar shape to the two pictures for training workers, but the magnitudes are much smaller. This is due to the selection problem. That is, not all unemployed workers will choose training programs at a given time.

8 Conclusion and Future Work

Training programs for unemployed workers are commonly used in OECD countries. By improving workers' human capital, governments intend to help integrate unemployed workers back to employment. In several OECD countries such as Germany, they also interact with the main passive type of labor-market policy, unemployment insurance programs, by providing unemployed workers longer or higher unemployment compensation in training programs. In this paper I develop and estimate a structure framework to study the workers' search and training decisions in an economy with both large active (e.g, training) and passive (e.g., unemployment insurance) types of policies. The effects of these large-scale, government-sponsored training programs on the aggregate unemployment rate, employment rate and output have been studied.

I extend Ljungqvist and Sargent's model (JPE, 1998), in which workers' human capital varies stochastically (but exogenously) with labor-market experience, by endogenizing workers' training decisions. Training programs provided by the government feature a key trade-off with respect to unemployment insurance programs: they offer more generous replacement rates but require more time and effort to improve workers' skills. Thus unemployed workers

[67] Since a worker may receive different shocks every period, he may experience different employment and wage earning paths. The employment probability is calculated as the ratio of employment times in that period to the total simulated times. The average wage earning for a given period is the average of all realized wage earnings in that period.

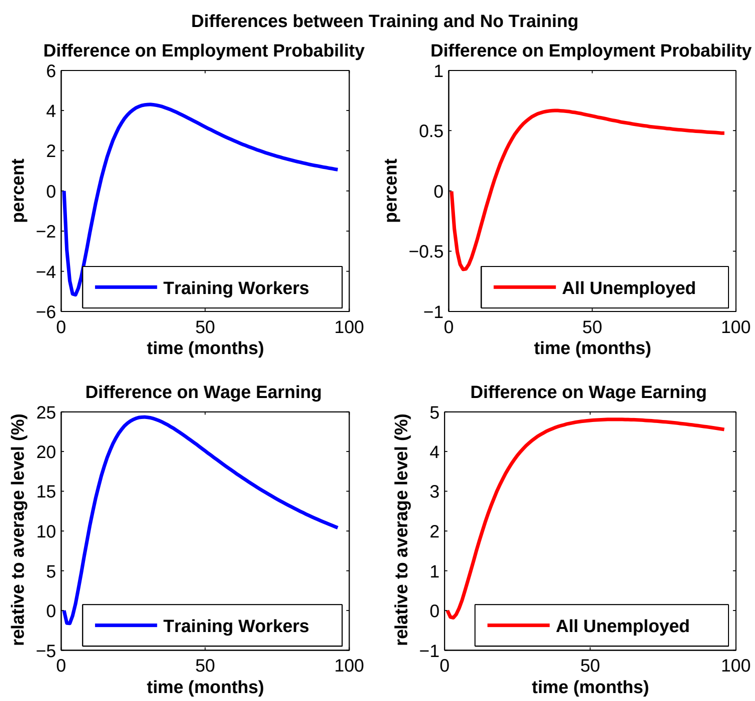


Figure 9: This figure shows the average effects of training programs on employment probability and wage earnings for workers in training programs and all unemployed workers.

with different human capital levels and different benefit entitlements make different training, search, and job acceptance decisions. The variety of choices provides a useful strategy for identifying key structural parameters of the model through the observed distribution of workers among labor-market status (working, searching and training), labor-market transitions across these states, and earnings conditional on different labor-market experience.

The Simulated Method of Moments was applied to estimate the model by using a recently released German administrative data set, the Integrated Employment Biographies Sample (IEBS), a unique data set that contains detailed information on workers' employment histories, wages and benefits, training participation records, and job-search information. The estimation results confirm an important trade-off between workers' search and training decisions: while training improves workers' human capital, they had a lower job finding rate and required higher effort. Searching helps unemployed workers find a job faster, but it is more difficult to find better jobs because of the possible skill depreciation in search periods. The model is used to study the actual reforms in Germany, and to run a series of counterfactuals. First, I find that a reform like the one implemented in Germany in 2005 (which reduced the extra benefits only for unemployed workers in training programs) decreases training enrollment by 69 percent in the long run. More workers search, instead of training, and the proportion of low-skilled unemployed workers increases. As a result, the unemployment rate rises by almost one percentage point, while output decreases by 1.7 percentage points. In contrast, a reform like the one implemented in 2006 (which reduced benefit duration for all unemployed workers) doubles training enrollment in the long run. The unemployment rate falls by 1.3 percentage points, and output increases by 2.4 percentage points respectively. I conclude that these two reforms, enacted in Germany within a year, were in marked contrast with each other.

Second, when I simulate the transition path under back-to-back unexpected reforms in 2003−2006, the dynamics of the model's unemployment rates between and after these reforms (2003 − 2008) are very close to the actual path for Germany's unemployment as shown in the data, suggesting that large-scale labor-market reforms can have important effects on aggregate outcomes.

Third, in a counterfactual experiment in which I model an economy with a German-training system and a US-like unemployment benefit structure, I find that the unemployment rate falls by over 7 percentage points with the output increasing by 9.9 percentage points. Hence, an injection of elements of the U.S. system would greatly enhance the performance of the German labor market.

Overall, this paper is the first step toward understanding how training programs affect the aggregate economy in the context of multiple types of interacting labor-market policies. Thus, it has several possible extensions for future work.

First, in order to focus on the workers' decisions (the supply side), I abstract the demand side by using an exogenous wage offer distribution that is fixed over time. Considering that the change in the distribution of workers' skill levels may also change the demand for different skills on the production side, it is worthwhile to incorporate these equilibrium effects on the demand of skills. In the next stage, I will introduce the standard matching and bargaining feature into the model to extend it to a general equilibrium framework.[68]

[68] For a search-island model with production, see Alvarez and Veracierto (2001) and Ljungqvist and Sargent

Second, although it is natural to choose human capital and unemployment benefits as the two state variables since they are the key elements of the two targeted policies (training and unemployment insurance programs), the model can be easily extended to incorporate more heterogeneity. For example, because workers of different ages may have different incentives to participate in training programs, one interesting extension is to include the age variable. By including another state variable of age, the model can look at workers' training decisions over the life cycle. This might also be important if the model is used to analyze long-term unemployment.

Another possible extension is to assume workers also differ in other aspects, such as their innate ability. For example, workers may differ in their ability to learn new skills. While workers' human capital varies with their labor-market experience, their innate ability does not change over time (like a fixed effect). By introducing this additional variable, it may help to explain better the heterogeneity of workers' previous wage earnings. It also allows the researcher to look at some other interesting aspects, such as the relation between education levels and training participation. All these extensions will be ongoing and future research.

9 Appendix

9.1 Classification of Different Labor Market States in the Data

The data set used in this paper, **Integrated Employment Biographies Sample (IEBS)**, is a recently released German administrative data set. It combines spells of the following four different data sets of the Federal Employment Agency (BA), and thus contains both unemployment and employment, unemployment insurance, and training information.

- The IAB employment history (BeH), which contains 12,594,862 spells between 1990 and 2003
- The IAB benefit recipient history (LeH), which contains 2,388,627 spells between 1990 and 2004
- The participants-in-measures data (MTG), which contains 238,232 spells between 2000 and 2004
- Data on job search originating from the applicants pool database (BewA), which contains 1,828,266 spells between 2000 and 2004

IEBS was constructed by selecting people born on one of eight designated days of the year from the sample frame, making this data set a representative 2.2 percent sample of the target population.

The common data period from these four data sets is from January 1, 2000, to December 31, 2003.

To use the data for the estimation, I need to define the states for each individual in the data set for every data period. There are three different labor market states in the model: employment (E), search (S) and training (T). But in the data, a worker can show up in more

(2007).

than one data set at the same time. For example, a worker may have a minor job when he is in a training program thus both BeH and MTG simultaneously contain his information in that period. To tidy up the data for the use of the estimation, I classify the workers' labor market states in every period according to the following criteria.

a) Whenever a worker has a full-time job,[69] I classify his state as employment (E) for that time.

b) A worker is classified into search (S) state if he is searching for a job and doesn't show up in a training program or have a full-time job.[70]

c) A worker is classified into training (T) state if he is in a training program and does not have a full-time job at a given time.

In addition, LeH provides the information as to whether a worker receives any benefits (UI, UA, SA) or not, and to which type of benefit he is entitled. So, taking into account both a worker's labor market status and his benefit entitlement, I can classify the workers into seven groups: (1) Employment; (2) Search with UI; (3) Search with UA; (4) Search with SA;[71] (5) Training with UI;[72] (6) Training with UA;[73] (7) Training with SA. Through these classifications, both the model and the data have the same labor market states and thus the model is linked to the data to be estimated.

9.2 Computation Algorithm

This appendix describes the algorithm to compute a stationary equilibrium of the model and the transition dynamics between and following the three reforms.

9.2.1 Computation of the Steady State

The model is a heterogeneous-agent model with workers differing in their labor market states, human capital levels, and benefit entitlements. So the solution algorithm is similar to that which solves the standard Bewley-Aiyagari type of heterogeneous agent models.[74]

Step 1. Guess a set of value functions for each group of workers (i.e., employed workers, workers who search with UI, workers who search with UA, workers who search with SA, workers who participate in training with UI, workers who participate in training with UA, workers who participate in training with SA) and a tax rate, which government imposes on employed workers to finance the expenditure on training costs and different benefits.

Step 2. Solve individual problems for each type of workers, derive policy functions, and update a new set of value functions.

Step 3. Use the policy functions derived in Step 2 and specifications on the exogenous shocks to construct the transition matrix and compute the invariant distribution Λ.

[69] In the data set, there is one variable to distinguish a full-time job and a part-time job.

[70] A worker is said to be searching for a job if BewA has his record at that time.

[71] Since SA is not contained in LeH, I assume all workers without unemployment benefits receive SA.

[72] Since the IM benefit a worker receives in a training program has the same level of UI benefits (if he is entitled to UI), Training with UI includes two cases: Training with UI and Training with IM.

[73] Notice that when a worker is entitled to UA benefits, he may receive higher benefit when in a training program.

[74] See Aiyagari (1994), Bewley (1977).

Step 4. Compute the total tax revenue, total expenditure on training programs and different benefits. Check if the government budget is balanced. If not, adjust the tax rate and go back to Step 2.

9.2.2 Computation of the Transition Path

The benchmark model is estimated using the German data between 2000 and 2002. The three reforms took place in 2003 (labeled Reform 1), 2005 (labeled Reform 2) and 2006 (labeled Reform 3), respectively. So, the transition path starts with the benchmark stationary economy and experiences Reform 1, 2 and 3, until the economy reaches the new stationary equilibrium which is induced by Reform 3.

I divide the total transition path into three parts: (1) from the benchmark economy to the period right before Reform 2 is announced, which includes 25 periods,[75] (2) from the period in which Reform 2 is announced to the last period right before Reform 3 is announced, which includes 12 periods, and (3) from the period in which Reform 3 is announced until the time the economy reaches the new stationary equilibrium. I assume in each part, the agents in the economy are not aware that the government will announce new reforms except the one announced in this part.[76] I first simulate the path from the initial steady state (the benchmark economy) to the new stationary economy which is induced by Reform 1. Thus the 25 periods contained in part (1) are given by the first 25 periods along this path. For part (2), I use the economy in the last period of part (1) as the initial state and simulate the transition path from it to the new stationary economy induced by Reform 2. The next 12 periods in part (2) are given by the 2nd period to the 13th period along this path. Finally, I use the economy in the last period of part (2) as the initial state to simulate the remaining periods contained in part (3).

So, to find the transition dynamics in each part, I need to compute the transition path from the initial state (which is known) to the new stationary equilibrium which is induced by the new policy announced in that part. Assume that in period 1 the economy is in the initial state and the new policy is announced and implemented in period 2. The economy reaches the new stead state in period T. Then, the algorithm to compute the transition path from period 1 to period T is as follows.

Step 1. Guess the path of tax rates.
Step 2. Use the value functions of the final steady state for the period T to solve for the workers' problems backward from period T-1.
Step 3. Use the distribution of the initial state and policy functions from Step 2 to compute the path of the distribution.
Step 4. Compute the total tax revenue, total expenditure on training programs and different benefits in each transition period. Check if the government budget is balanced in each transition period. If not, adjust the guessed path of tax rates and go back to Step 2.

[75] This part includes Reform 1

[76] This means that agents in the model economy do not know the government will announce Reform $i+1$ when government announces Reform i ($i = 1, 2$).

9.3 Estimation Method

To circumvent the computation difficulty from the optimization problem with nonsmooth and local optima, I apply a recent approach proposed by Chernozhukov and Hong (2005). They develop a class of Laplace Type Estimators (LTE) which can be implemented by Markov Chain Monte Carlo simulations. In this appendix, I will describe the details about the estimation method.

9.3.1 Details about the GMM LTE in CH (2005)

Let Θ be the set of parameters to be estimated and $\theta \in \Theta$ be a particular parameter vector $(L \times 1)$. Let $\{m_1, m_2, ..., m_K\}$ be K selected moments from the data (for example, m_i can be the sizes of certain groups, wages earnings conditional on certain labor-market experience and so on) and $\{\tilde{m}_1(\theta), \tilde{m}_2(\theta), ...\tilde{m}_K(\theta)\}$ be the corresponding moments simulated from the structural model at parameter vector θ. Now define the GMM objective function as follows:

$$L_n(\theta) = -\frac{1}{2}\sum_{k=1}^{K} w^k (m_k - \tilde{m}_k(\theta))^2$$

A more general matrix form is given by

$$L_n(\theta) = -\frac{1}{2}(\frac{1}{\sqrt{n}} g_n(\theta))' W_n(\theta)(\frac{1}{\sqrt{n}} g_n(\theta))$$

where $g_n(\theta)$ is a $K \times 1$ vector $(m_1 - \tilde{m}_1(\theta), m_2 - \tilde{m}_2(\theta), .., m_K - \tilde{m}_K(\theta))'$ and n is the sample size.

The GMM estimator is therefore the $\theta \in \Theta$ which maximizes the objective function $L_n(\theta)$. In practice, it is difficult to find the maxima when there exist many local maxima or the objective function is not well behaviored (such as the existence of multiple kinks). Therefore, this paper uses the Laplace type estimator (LTE) which can be easily computed through Markov chain Monte Carlo simulation methods.
The GMM LTE is given by

$$\hat{\theta} = \int_{\Theta} \theta p_n(\theta) d\theta$$

$$p_n(\theta) = \frac{e^{L_n(\theta)} \pi(\theta)}{\int_{\Theta} e^{L_n(\theta)} \pi(\theta) d\theta}$$

where $p_n(\theta)$ is called *quasi-posterior* in CH's paper. More formally, GMM LTE $\hat{\theta}$ minimizes the quasi-posterior risk functions which is defined as

$$\mathcal{Q}_n(\zeta) = \int_{\Theta} \rho_n(\theta - \zeta) p_n(\theta) d\theta$$

with the squared loss function $\rho_n(x) = |\sqrt{n}x|^2$.

Under the assumption 1-4 in the paper, CH (2005) the shows the LTE is asymptotically equivalent to the GMM extremum estimator.

9.3.2 Estimation Procedure

To implement the estimation, I use Metropolis-Hastings algorithm to simulate the quasi-posterior distribution. Then the parameter estimator θ is given by the sample mean of this simulated distribution. The procedure is as follows.

Step 1. Start with an initial parameter vector $\theta^{(0)}$. Solve the structural model and construct the moments $\{\tilde{m}_1(\theta^{(0)}), \tilde{m}_2(\theta^{(0)}), ...\tilde{m}_K(\theta^{(0)})\}$ based on the generated stationary distribution.
Step 2. Use the simulated moments and data moments to form the GMM objective function $L(\theta^{(0)})$. (In this paper I use diagonal weighting matrix with specified weights to each moments.)
Step 3. Apply Metropolis-Hastings algorithm to generate $60,000$ draws $(\theta^{(1)}, \theta^{(2)}, ..., \theta^{(60,000)})$.

- The probability of the move from current ("old") draw $\theta^{(i)}$ to the next ("new") draw, $\delta(\theta^{(i)}, \theta^{(i+1)})$, is given by

$$\delta(\theta^{(i)}, \theta^{(i+1)}) \quad = \quad \inf\left(\frac{e^{L(\theta^{(i+1)})}\pi(\theta^{(i+1)})}{e^{L(\theta^{(i)})}\pi(\theta^{(i)})}, 1\right)$$

- The transition kernel, $q(\theta^{(i+1)}|\theta^{(i)})$, takes the form of

$$q(\theta^{(i+1)}|\theta^{(i)}) \quad = \quad f(|\theta^{(i+1)} - \theta^{(i)})|)$$

  where f is Gaussian density.

Step 4. The parameter estimator $\hat{\theta}$ then is the mean of the last $50,000$ simulated draws (the first $10,000$ draws are in the "burn-in" period).

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