Unemployment Insurance and the Role of Human Capital

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Abstract

This thesis studies the role of human capital formation for the design of an optimal unemployment insurance scheme. In a simple search-and-matching model agents can accumulate human capital on the job and face the risk of losing it when unemployed. Human capital serves as productivity-enhancing and therefore provides an additional incentive to avoid unemployment. Oversized unemployment insurance schemes with indefinite payments distort this incentive. They can cause persistent unemployment and make the economy more susceptible. In constrast, declining schedules can increase welfare, output and productivity.

1 Introduction

The optimal design of unemployment insurance (UI) programs is an issue of high interest for policy makers and economists. Being an integral part of social welfare policy, UI generally aims at providing financial compensation to persons who have lost their job. The economic rationale behind this is to insure risk-averse workers against the income loss associated with unemployment. If poorly constructed, though, unemployment insurance can also create undesirable side-effects on the behaviour of jobless persons. High benefit levels and long durations, for instance, are found to discourage workers to gain employment again. In times of rising rates of unemployment in many developed countries, it has naturally become a key problem of concern for labour economists to study and improve the incentives of UI schemes.

A tool that has proved to be very useful in analysing various issues of unemployment and labour market distortions are models of job search and matching.[1] The notion that is central to this approach is the existence of trade frictions in the labour market. Since transitions out of unemployment require time and other resources, the main difference to traditional static labour-market theory is that unemployment can arise as an equilibrium phenomenon. Due to their ability to explain many related issues, search-and-matching models have become a successful workhorse in labour economics.

First attempts to study the influence of UI on unemployment rates and welfare originate from the late 1970s. Seminal papers by Mortensen (1977) and Baily (1977) propose that oversized public benefit payments can prove to be distortionary for workers' job search behaviour and lead to significantly longer spells of unemployment. Since the UI provider is usually not capable of monitoring recipients, this constellation resembles a principal-agent problem with hidden action. In the following, finding a balance between the potentially welfare increasing effects of UI for consumption smoothing purposes and the negative implications of moral hazard has become the major objective when contemplating optimal schemes. Shavell and Weiss (1979) were the first to study an optimal sequence of UI payments over time. Their result, that a monotonically declining benefit schedule should be imposed, is confirmed in later contributions.

A feature that is ignored in most of the existing literature on optimal UI, is the role of human capital. Empirical studies (see e.g. Keane and Wolpin (1997)) suggest, however, that personal skills deteriorate during periods of unemployment, tarnishing

[1] A state-of-the-art survey of this class of models is provided in Rogerson, Shimer and Wright (2005).

workers' prospects to find a job again. This might have important implications for search behaviour which should be taken into account when contemplating UI schedules.

The purpose of this thesis is to shed more light on the interaction between workers' behaviour and the role of human capital under different UI schemes. Focusing on the supply-side of the labour market, I use a stationary model with heterogeneous agents who differ in their current skill level and their entitlement to unemployment benefits. When on the job, they have the possibility to accumulate human capital permanently, and when unemployed, they face the risk of losing it again. Production takes place in 'one worker - one-firm' relationships. The productivity of an employment is stochastically determined after the initial match and depends positively on the worker's skill level. In the following, it remains unchanged until the relationship is severed exogenously or an idiosyncratic shock arrives which leads to a new productivity draw. Wages are endogenously determined according to Nash bargaining at the beginning of each period. Furthermore, there are no hiring or firing restriction, and any party can terminate the relationship at any time. Matching probabilities depend only on workers' search effort.

Using this framework, I establish different UI schemes to study their impacts on population dynamics and the performance of the economy as a whole. I find that the evolution of human capital has an important influence on workers' decision making and reduces unemployment spells. The reason is that the threat of skill depreciation during unemployment periods constitutes an incentive to gain employment sooner. If poorly constructed, an UI scheme can distort these incentives and cause persistent problems of moral hazard and long-term unemployment. This is, for instance, the case if generous benefits are paid indefinitely. In contrast, UI schedules which decline over the unemployment spell, can raise aggregate output and welfare considerably compared to a laissez-faire setup.

This thesis is organised as follows. Section 2 briefly overviews and discusses the existing literature. The model is introduced in Section 3 and Section 4 proceeds with the model analysis. Section 5 breaks down the rather general framework by choosing a specific skill system and introducing various UI schedules. Furthermore, the model calibration is explained. An exhaustive analysis in equilibrium is presented in Section 6. Section 7 confronts the model with several variations. A brief summary and discussion of the most important findings can be found in Section 8 and Section 9 concludes.

2 Literature

Research on the optimal design of unemployment insurance (UI) is a relatively new field of study which has been strongly influenced by notions and methods in labour economics and the economics of information.[2] Contributions from labour economics have mainly been used to analyse and explain job-searching and job-matching processes on the labour market. Developments in information economics helped to identify important incentives and potential moral hazard and adverse selection problems. In fact, much of the research on optimal UI has been addressed to the effects of benefits on the spell of unemployment and the underlying problem of hidden action which often makes it impossible to monitor job search efforts.

Pioneering work has been done by Mortensen (1977) who uses a framework with fixed durations of benefit payments and probabilistic employment spells. By assumption, a workers has to be employed for a certain number of periods in order to become entitled to UI. Mortensen shows, firstly, that unemployed workers who approach the expiration date of their entitlements, constantly reduce their reservation wage and transfer back into employment more rapidly. Secondly, the exit rate out of unemployment is generally negatively influenced by the duration of benefit payments. Thirdly, unemployed workers who are currently not entitled to benefits are willing to accept *more* jobs when benefit payments increase ('entitlement effect'), while those who are currently entitled actually accept *less* jobs. Empirical evidence mostly supports these findings, see e.g. Layard, Nickell and Jackman (1991), Moffitt (1985), Meyer (1990) and Feldstein and Poterba (1984).

One of the first attempts to tackle the actual question of an optimal UI originates from Baily (1977). He develops a two-period consumption-saving model with an exogenous risk of an income loss ('unemployment') in the second period and a representative agent who seeks to maximise his expected utility. Baily shows that UI can function as a substitute for private saving which would otherwise work as a means of self-insurance. If job search efforts are not observable, though, moral hazard problems arise which can lead to longer unemployment spells. In his model, Baily addresses this issue by trying to deduct an UI schedule which balances the potentially welfare-increasing effects and the welfare losses due to longer unemployment spells.

In a similar approach, Flemming (1977) proposes a model with homogeneous workers

[2] The following section basically follows Karni (1999) and Frederiksson and Holmlund (2003).

who, after being hit by an idiosyncratic exogenous separation shock, have to spend part of their income for job search efforts. When trying to design an UI schedule that maximises the sum of agents' utilities, Flemming distinguishes between a perfect capital market and no capital market. He shows that the optimal level of benefits should be lower under a perfect capital market since agents have better opportunities of consumption smoothing. A major pitfall of this model is that agents accept any job offer and there are no reservation wages. Due to the homogeneity of workers and jobs, there is only one common wage rate for all employments.

The issue of the optimal UI benefit schedule over time has been addressed in a seminal paper by Shavell and Weiss (1979). They consider identical unemployed individuals who choose a path of search efforts and reservation wages in order to find employment (which works as an absorbing state). The objective of the UI provider is to maximise the expected discounted utility of the worker subject to a given UI budget. Shavell and Weiss find that in the absence of moral hazard benefit payments should be constant over time. Once moral hazard is allowed for, they show that the optimal benefit schedule should be monotonically declining over time and approach zero in the limit. For a more general case, when agents possess an initial stock of wealth or can borrow, the model cannot make any clear statements, though.

In a more recent work, Hopenhayn and Nicolini (1997) extend this framework by introducing wage taxes after reemployment as additional policy instruments. Their primary result conforms to the one in the Shavell and Weiss,i.e. that benefit payments should decline over the elapsed unemployment duration. Secondly, their model suggests that the UI provider should use wage taxes which increase with the previous spell of unemployment. Clearly enough, these instruments ought to encourage workers to intensify searching efforts and lower reservation wages. In a second step, Hopenhayn and Nicolini present some numerical calculations which suggest that the gains from switching to a policy regime including wage taxes could be quite large. However, although providing useful insights, the models of Shavell/Weiss and Hopenhayn/Nicolini are highly stylized and therefore exhibit some major shortcomings. For instance, their analyses ignores the demand side of the labour market completely. Furthermore, their assumption that employment works as an absorbing state (which rules out the possibility of becoming unemployed again) ignores the potential 'entitlement effect' put forward by Mortensen (1977).

In another interesting contribution, Wang and Williamson (1996) endogenise the probability of being laid off by making it dependent on the effort a worker makes while employed. Moreover, agents have be employed first in order to become eligible for UI benefits. In contrast to the previous setups, Wang and Williamson's model suggests an optimal UI schedule that is very low in the first period of unemployment ('waiting period'), then increases to a higher level in the second period, before declining again thereafter. The notion behind the low initial payment is that employed workers ought to be encouraged to increase their work efforts and avoid lay-offs. Since there is hardly any empirical evidence for a relationship between work effort and job destruction, this reasoning remains at least questionable.

In an attempt to scrutinise the implications of UI programs in a general equilibrium framework, Hansen and Imrohoroglu (1992) compare the welfare effects of UI under perfect and imperfect monitoring of job-search efforts. By also considering the distortionary effects of taxes on income which are levied to finance UI, the authors use a social-planner approach with identical individuals who choose optimal paths of consumption and saving. When unemployed, agents stochastically receive job offers which can be accepted or rejected. If, however, a worker is caught rejecting, he loses his entitlement to UI payments. The social planner seeks to maximise total welfare by choosing optimal plans for the replacement ratio of benefits and monitoring efforts. Hansen and Imrohoroglu show that under perfect monitoring welfare can actually be increased by UI since it helps individuals to smooth consumption. Once monitoring is imperfect, though, moral hazard problems arise which can depress total welfare below the level of no UI. Despite some fallacies, the major accomplishment of this paper is to consider also general equilibrium effects of UI.

In a model with a fixed number of jobs and a constant wage rate, Davidson and Woodbury (1997) examine the question whether benefit payments should be indefinite or finite. Unemployment is solely determined by the search effort of workers and the government seeks to choose the optimal benefit level and duration. Interestingly, the authors find that payments should actually be indefinite. However, their analysis suffers from the pitfall that the government, with only those two instruments at hand, can not influence the sequence of payments. Instead of allowing for e.g. declining benefits over time or introducing additional instruments like a basic assistance, workers simply receive nothing after finite UI payments have expired.

Cahuc and Lehmann (2000) try to illustrate the influence of endogenised wages being bargained between unions and firms. They argue that "insiders" who are involved in the bargaining process exploit short-term unemployment (in combination with UI entitlement) as a fallback position and thereby increase the wage pressure. Since the number of jobs is endogenous in this model, long-term unemployment increases. According to the authors, the optimal UI schedule should be declining over time in order to encourage job-searching. The decrease in the unemployment rate is, however, mitigated by endogenous wage bargaining, because a schedule with declining benefits actually improves the fallback position of the insiders.

A model that shares quite a few characteristics with the one proposed in this thesis comes from Fredriksson and Holmlund (2001). In their setup workers can be in three different states: employment, insured unemployment (which means that they are entitled to benefits), and uninsured unemployment (they receive social assistance). Transitions occur exogenously at constant rates from employment to insured unemployment and from insured to uninsured unemployment. When unemployed, a worker chooses his search effort which determines the probability of a job offer. Wages are set according to the Nash bargaining solution and borrowing and saving to smooth consumption is ruled out by assumption. All these features appear in a similar form in the model discussed in this thesis.

Not surprisingly, Fredriksson and Holmlund find that the level of social assistance should in general be lower than regular benefits. That is, the optimal payment schedule is declining which corresponds to the results in previous contributions. Furthermore, the authors show that the magnitudes of UI benefits and social assistance influence search effort of workers in a different way, depending on their current state. For instance, high benefits will encourage uninsured workers to increase their search effort which is the entitlement effect proposed by Mortensen, while insured workers will generally decrease their efforts. Moving from an optimal uniform schedule to a system with two levels of payments eventually does not have a large effect on the unemployment rate, though.

In a recent contribution, Shimer and Werning (2005) again call into question the results that the optimal UI schedule should be declining. Using a sequential job search framework like in McCall (1970), they allow workers to borrow and save privately. Their results suggest that in a stationary setting with homogeneous workers the optimal UI schedule should actually be constant over time. Under the condition that workers have sufficient access to liquidity and can therefore use the capital market for consumption smoothing purposes, Shimer and Werning claim that UI should solely serve as insurance against long periods of unemployment.

While there is a broad literature on the optimal design of UI systems, only few works have tried to capture the effects of human capital accumulation and depreciation. Brown and Kaufold (1988) use a simple labour-market model to study the impact of UI on human capital investment decisions by workers. They argue that the provision of UI can help to reduce the riskiness of investments into human capital and thereby encourage workers to choose a higher level. By also taking into account the positive relationship between higher benefits and the spells of unemployment, their analysis suggests that UI should not provide full insurance to workers, but at a generally higher level than without considering the effects on human capital investments.

On a more general level, Pissarides (1992) uses a highly stylized overlapping generations model to show that skill losses after a layoff can increase the persistence of employment shocks. The author assumes that firms adjust the number of job vacancies in the following period according to the current distribution of workers' skills. Since part of the jobs only remunerate if the worker possesses a sufficient skill level, employment shocks can endogenously lead to more long-term unemployment. Pissarides' model is restricted to explaining underlying dynamics, though, and does not permit an analysis of potential policy changes.

Other strands of research deal with human capital externalities and job-specific skills. Human capital externalities arise when the skills acquired by an individual affect the general knowledge of the society and, implicitly, also the productivity of other workers. See e.g. Acemoglu (1996) and Laing, Palivos and Wang (2003). In models with job-specific skills the productivity of a worker not only depend on his current stock of human capital, but also on the type of firm that he is matched to. See e.g. Marimon and Zilibotti (1999).

The model in this thesis builds upon the frameworks of Ljungqvist and Sargent (1998, 2004) and den Haan, Haefke and Ramey (2001, 2004). Since these contribution do not primarily address the issue of an optimal UI system, though, a closer description will be deferred to Section 7.3.

3 The Model

The model is set up in discrete time space. There is a continuum of workers and firms who interact in a decentralized labour market and a government which collects taxes and pays unemployment benefits. At any point in time, workers and firms make decisions which are based on their current-period information set, but without any effort to coordinate their actions. Expectations are rational.

3.1 Workers

Workers are either employed or unemployed. In this model they are heterogeneous with respect to two attributes. Firstly, they differ in their individual skill level which will be indexed by $i = 1, 2, \ldots, I$. That is, there is a finite number of different levels of human capital. Human capital here refers to "the knowledge, skills, competences and other attributes embodied in individuals that are relevant to economic activity" (OECD, 1998). At each point in time, every worker exhibits one of the possible skill levels. Moreover, this skill level can be observed by any agent in the economy. By assumption, the highest skill level will be indexed by $i = 1$, the second highest by $i = 2$ etc. The lowest possible skill level will be indexed by $i = I$.

Employed and unemployed workers are subject to a stochastic accumulation or deterioration of their human capital. At the end of each period the skill status of the following period is stochastically determined and can be observed immediately. Workers have perfect information about the probabilities of transition between different skill levels. Furthermore, skill dynamics shall exhibit the Markov property, i.e. the conditional probability distribution of future states, given the current state and all states in the past, depends only on the current state and not on the path of the process in the past. Formally,

$$P\left[X_{t+1} = x \mid X_t = x_t, X_{t-1} = x_{t-1}, \ldots, X_0 = x_0\right] \overset{Markov}{=} P\left[X_{t+1} = x \mid X_t = x_t\right]$$

where X is a random variable with the state space $i = 1, 2, \ldots, I$. Transition probabilities depend on the current employment status, i.e. the evolution of the human capital is critically contingent on the fact whether the worker is currently employed or idle. The probability of a transition from skill level i^* to skill level i^{**} will be denoted by $P^i(i^{**}; i^*)$ for unemployed workers and by $Q^i(i^{**}; i^*)$ for employed workers. Without loss of generality, it will be assumed that a worker's skill level may not deteriorate while he or she is employed. Similarly, human capital may not grow during an unemployment period. Thus,

$$\begin{aligned} P^i(i^{**}; i^*) &= 0, \qquad \forall\, i^{**} < i^* \\ Q^i(i^{**}; i^*) &= 0, \qquad \forall\, i^{**} > i^*. \end{aligned}$$

Finally, I assume that employed workers' transition probabilites are independent of the employment status at the beginning of the next period. If, for instance, an exogenous job separation shock occurs at the end of a period, the worker may still have collected enough human capital during this very period to have increased his personal skill level. He will then transit to the pool of unemployed people for the following period, though with a higher skill level than in the previous period.

The second dimension of heterogeneity among workers is the individual entitlement to UI benefits. A finite number of different UI benefit levels b_j will be indexed by $j = 1, 2, \ldots, J$. The index $j = 1$ denotes the highest benefit entitlement level, the index $j = 2$ denotes the second-highest etc. The lowest possible unemployment benefit level will be indexed by $j = J$. Note that benefits b_j explicitly only refer to the actual financial payment given by the government.

Like the level of human capital, the entitlement to unemployment benefits is observable by agents at any point in time. After each period the benefit level is revised and may change. In contrast to the skill level, the entitlement to unemployment benefits may evolve stochastically *or* deterministically, depending on the calibration. In reality, workers usually have the possibility to collect definite information about their future entitlement to benefits due to the existing legislative framework. Therefore, the possibility to set all transition probabilities to either 0 or 1 will not be impeded. Since the level of benefits will also exhibit a Markov structure, though, a more general framework turns out to be useful.

Let $P^j(j^{**}; j^*)$ denote the probability of transition from benefit level j^* to j^{**} for an unemployed worker and $Q^j(j^{**}; j^*)$ for an employed worker. By assumption, unemployment benefits shall not rise while a worker is idle and entitlements shall not decrease during an employment period,

$$\begin{aligned} P^j(j^{**}; j^*) &= 0, \qquad \forall\, j^{**} < j^* \\ Q^j(j^{**}; j^*) &= 0, \qquad \forall\, j^{**} > j^*. \end{aligned}$$

After all, there is a two-dimensional state space with $I \times J$ different states. Conditional on being employed or unemployed, every worker is in one of these states at each point in time. Transitions occur at the end of each period. Probabilities for transitions in i and in j are assumed to be independent from each other. Combining the notation so far, the probability of a transition from current state (i^*, j^*) to a new state (i^{**}, j^{**}) will be denoted by $P(i^{**}, j^{**}; i^*, j^*)$ for an unemployed person and by $Q(i^{**}, j^{**}; i^*, j^*)$ for an employed person.

The objective of each worker is to maximise the infinite-horizon expected discounted utility

$$\max_{C_{t+r}} E_t \left[\sum_{r=0}^{\infty} \beta^r u(C_{t+r}) \right] = \max_{C_{t+r}} E_t \left[\sum_{r=0}^{\infty} \beta^r C_{t+r} \right] \tag{1}$$

where E_t denotes the mathematical expectation operator conditional on the information set available in period t, $\beta \in (0, 1)$ is the subjective discount factor and C_{t+r} is the worker's private consumption in period $t + r$. The period utility is assumed to be a linear function in C_{t+r} which allows us to abstract from wealth and saving effects. Depending on the current employment status, C_{t+r} either refers to the after-tax income from employment or to the sum of unemployment compensations and an extra value of leisure, l, net of searching costs. Here, l basically refers to a bunch of things, "distinguished by the fact that they have to be given up when the worker becomes employed" (Pissarides, 2000), e.g. home production, shadow market activities or simply recreation.

3.2 Unemployment and Matching

Workers who were laid off receive per-period UI benefits b_j according to their current entitlement level. In order to find a new job, they have to invest part of their earnings for searching efforts. Searching may or may not generate a successful match at the beginning of the next period. The probability of getting a job offer is incorporated in the matching function $\lambda(s)$ where s denotes the search effort. Note that in this model the matching probability is not influenced by the tightness of the labour market, i.e. the ratio of job seekers and vacancies, but only depends on a worker's search effort.

Only one match can occur per period. Workers who are successfully matched but reject the job offer remain unemployed for the rest of the period.

3.3 Employment

Production takes place in a 'one worker - one firm' relationship which both parties can terminate immediately at any point in time. There are no direct transaction costs like e.g. firing costs attached to a separation. Every worker-firm pair produces an output of z in each period, where z characterises the idiosyncratic productivity level. When a new relationship is established after a match, the initial productivity level is drawn from a skill-specific distribution function $d\nu_i(z)$. Workers with a large stock of human capital are generally more productive, i.e. they have an increased probability of getting a high productivity draw. Following the notation specified above, lower values in the skill level i indicate a large stock of human capital. Hence, I assume that $d\nu_k$ first-order stochastically dominates $d\nu_l$ for all $k < l$.[3] The productivity level of every worker-firm relationship is revised at the end of each period. Three different scenarios can occur:

1. The productivity level z remains unchanged. This possibility is denoted by $f = 1$.
2. The relationship experiences a productivity switch, i.e. the previous productivity level z is replaced by a new value. It is drawn from a distribution which depends on the current skill level of the worker. The new draw can be observed immediately at the beginning of the following period by both the worker and the firm. This possibility is denoted by $f = 2$ and occurs with a constant probability of κ.
3. The relationship is terminated exogenously. Exogenous separations refer to those events where the productivity of a relationship is permanently set to zero, e.g. due to demand shifts or changes in the worker's or firm's preferences. This possibility is denoted by $f = 3$ and occurs with a constant probability of σ.

After the current-period productivity is determined, the worker and the firm negotiate about the wage. Wages are determined in a Nash bargaining game. The relative bargaining power of the worker will be denoted by π with $0 \leq \pi \leq 1$.

Both parties can terminate the relationship whenever they want without having to bear direct costs. In that case the worker flows into the pool of unemployment and the job becomes vacant. When a worker is engaged in an employment relationship, he cann not switch jobs from one period to the next, i.e. 'on-the-job' search is excluded.

[3] Formally, $\nu_k(z) \leq \nu_l(z), \ \forall z$ or $\nu_k \succeq_1 \nu_l$.

3.4 Government

The government pays UI benefits to unemployed workers. Each worker receives a per-period payment corresponding to his current entitlement level. The government does not have the ability to monitor workers' behaviour in the job-seeking process. That is, insufficient search effort or the rejection of a job offer after a successful match cannot be sanctioned. Moreover, the government purchases other commodities with a per capita value of χ.

In order to finance expenditures for UI and commodity purchases, taxes are levied on output. By assumption, the government has to meet its budget constraint in every period, i.e. public lending or borrowing is not possible.

4 Model Analysis

4.1 Zero Surplus Condition

In this model an employment relationship is only established or sustained if it generates a surplus that both the worker and the firm are willing to aspire to. Since there are no hiring or firing restrictions, both parties are in a position to sever an existing relationship or not engage in a new one following a match without having to pay any costs. This implies that every single employment opportunity has to bring about a value that is at least not lower than the value of the respective alternative at any point in time. Since the surplus of a match critically depends on its productivity, evidently, the underlying decision problem is of a threshold structure. That is, worker and firm are only willing to accept their match or continue an existing relationship, if the productivity level z exceeds a critical value. By assumption, both parties negotiate efficiently the terms of their contract which implies that they base their decision on the *joint surplus*. At this stage, it is irrelevant which part of the surplus goes to either party. Under the condition of a non-negative joint surplus (only in this case a relationship will arise), even with a minor relative bargaining power the surplus of any negotiator will never become negative - an immediate quit would be the consequence. Clearly enough, the decision problem of a worker is also affected by his current skill level and his entitlement to unemployment benefits. For instance, employed workers who have transited to a new status at the end of the previous period might well face a different decision problem than in the period before, even if the productivity level has remained the same.

Let $\tau(z)$ denote the productivity-dependent profit tax rate and V the outside option of a firm. Then the joint surplus is given by

$$S(i,j,z) = (1-\tau(z))z + G(i,j,z) - V - U(i,j) \tag{2}$$

where $G(i,j,z)$ is the total post-production value of staying in the relationship for a firm-worker pair and $U(i,j)$ denotes a worker's future value from entering the unemployment pool in the current period. As long as the tax structure is not set too progressively, $S(i,j,z)$ is an increasing function of z in equilibrium. That is, there exists a threshold value of z above which the joint surplus is never negative. This *zero* *surplus level* or *reservation productivity* is denoted as

$$z^*(i,j) = \min\{z \mid S(i,j,z) \geq 0\}\,. \tag{3}$$

For any productivity level z that lies below $z^*(i,j)$ the joint surplus is negative, existing relationships are terminated and new matches are rejected. Workers will only accept a job offer or stay on the job if $z > z^*(i,j)$. Therefore, $z^*(i,j)$ constitutes an unambiguous acceptance rule that every existing match has to adhere to in equilibrium. Note again, that the zero surplus level is very much affected by a worker's current skill level and his entitlement to unemployment benefits. A formerly sufficient productivity in the previous period might suddenly induce a rejection decision after a transition to another state.

4.2 Equilibrium Conditions

The post-production continuation value for a firm-worker pair satisfies the following Bellman equation:

$$\begin{aligned} G(i,j,z) \;\; = \;\; \beta\, [\, (1-\kappa-\sigma) & \sum_{i',j'} Q(i',j';i,j) F_1(i',j',z) \\ + \kappa & \sum_{i',j'} Q(i',j';i,j) F_2(i',j') \\ + \sigma & \sum_{i',j'} Q(i',j';i,j) F_3(i',j')\,] \end{aligned} \tag{4}$$

where $Q(i',j';i,j)$ denotes the probability that an unemployed worker with skill level i and entitlement to unemployment benefits j moves to a new state with skill level i' and entitlement to unemployment benefits j'. With probability σ the relationship will be destroyed exogenously ($f = 3$). κ characterises the probability for a switch in the productivity level at the beginning of the next period ($f = 2$). The remaining probability defines the case in which the productivity remains unchanged and no exogenous separation takes place ($f = 1$). Then

$$F_1(i,j,z) = V + U(i,j) + \max\{S(i,j,z), 0\} \tag{5}$$

indicates the pre-production total value for a firm-worker pair in the current state (i, j) and current productivity level z for scenario $f = 1$. Similarly,

$$F_2(i, j) = V + U(i, j) + E(i, j) \tag{6}$$

defines the asset value accruing to a firm-worker pair before a new productivity level is drawn, depending on the current state (i, j). $E(i, j)$ denotes the joint surplus that can be expected, given the current state (i, j). Finally,

$$F_3(i, j) = V + U(i, j) \tag{7}$$

characterises the value of an exogenous separation for a firm-worker pair, depending on the current state (i, j).

The expected surplus, which is not only crucial for the evaluation of an upcoming productivity switch, but also for the assessment of a future match is then given by

$$E(i, j) = \int_{z \geq z^*(i,j)} S(i, j, z) d\nu_i(z) \tag{8}$$

where $z^*(i, j)$ indicates the acceptance rule depending on the current state (i, j) and $d\nu_i(z)$ is the skill-dependent distribution from which a new productivity value is drawn.

Let s denote a worker's search intensity, $\pi(s)$ the probability of a job offer at the beginning of the following period depending on his effort and $c(s)$ the search costs. Furthermore, let b_j denote the per-period payment of unemployment benefits depending on the current entitlement level and l the extra value of leisure. Then a worker's future value from entering (or staying in) the unemployment pool satisfies the following Bellman equation:

$$U(i, j) = \max_s \left\{ l + b_j - c(s) + \beta \left[\sum_{i',j'} P(i', j'; i, j) \; (\; \lambda(s)\pi E(i', j') + U(i', j') \;) \right] \right\} \tag{9}$$

where $P(i', j'; i, j)$ is an employed worker's probability of transition from state (i, j) to a new state (i', j') and π denotes his relative bargaining power in the wage negotiation process, $0 \leq \pi \leq 1$.

Equations (4) – (9) characterise the equilibrium conditions which can be used to find the relevant decision rules. Associated with the solution are two functions: $z^*(i, j)$

which indicates the threshold productivity as a basis for job acceptance and rejection decisions and $s^*(i,j)$ which gives the optimal search intensity depending on a worker's current status. Using the optimal decision rules will later allow us to determine population distribution dynamics.

Note that the budget constraint of the government has not been included so far. Obviously, total tax revenues and expenditures for unemployment benefits depend on the distribution of the population. Instead of solving for the decision rules and the distribution dynamics simultaneously, I apply a sequenced approach. First, I use fixed points in the UI benefit setup to compute the optimal decision rules and, in a second step, the corresponding population distribution. In an iterative procedure, I then determine a tax schedule which is associated with a stationary equilibrium and satisfies the budget constraint of the government.

4.3 Wage Determination

In equilibrium, an occupied job yields a pure economic rent $S(i,j,z)$ that is to be shared among the contractors. Once a firm and a worker decide to establish a new employment relationship or continue an existing one, they have to negotiate about the terms of their contract which is in this model the per-period wage rate $w(i,j,z)$. More specifically, I assume that the surplus is shared according to the Nash solution to the bargaining problem. The relative bargaining power of the worker is denoted by π with $0 \leq \pi \leq 1$. The firm's relative bargaining power then amounts to $1-\pi$.

Let $G^w(i,j,z)$ denote a worker's post-production continuation value, given his current status (i,j) and the current productivity level z. Then the following asset value equation holds:

$$\begin{aligned} G^w(i,j,z) \quad = \quad & \beta \, [\, (1-\kappa-\sigma) \sum_{i',j'} Q(i',j';i,j) F_1^w(i',j',z) \\ & + \kappa \sum_{i',j'} Q(i',j';i,j) F_2^w(i',j') \\ & + \sigma \sum_{i',j'} Q(i',j';i,j) F_3^w(i',j') \,] \end{aligned} \tag{10}$$

with

$$F_1^w(i,j,z) \quad = \quad U(i,j) + \pi \max\{S(i,j,z), 0\} \tag{11}$$

$$F_2^w(i,j) \quad = \quad U(i,j) + \pi E(i,j) \tag{12}$$

$$F_3^w(i,j) \quad = \quad U(i,j). \tag{13}$$

The Nash bargaining solution implies that π is the worker's share of the total rent which an occupied job creates. Therefore,

$$\begin{aligned} w(i,j,z) + G^w(i,j,z) - U(i,j) &= \pi S(i,j,z) \\ &= \pi\left[(1-\tau(z))z + G(i,j,z) - V - U(i,j)\right] \end{aligned} \tag{14}$$

where the left-hand side of equation (14) characterises the worker's net expected return. Moreover, let $Option(i,j)$ denote a worker's discounted on-the-job option value of transiting to a new state regarding the unemployment benefit level, given the current state (i,j),

$$Option(i,j,z) = \beta \sum_{i',j'} Q(i',j';i,j)(U(i',j') - U(i,j)) \tag{15}$$

Then, after some rearranging, the following wage equation can be obtained:

$$\begin{aligned} w(i,j,z) &= \pi\left[(1-\tau(z))\, z - (1-\beta)V\right] \\ &= +(1-\pi)\left[(1-\beta)U(i,j) - Option(i,j)\right] \end{aligned} \tag{16}$$

Note that in the extreme case $\pi = 1$ the worker receives almost the entire joint surplus. That is, he solely has to compensate the firm for the annuity value of a vacancy. In the opposite case $\pi = 0$ the major part of the surplus accrues to the firm. The wage payment then only consists of the annuity value of being unemployed and the option value of transiting to a more valuable state. In both cases, the party with zero bargaining power simply receives a payment that is equal to its respective opportunity costs.

4.4 Population Dynamics

In order to study the steady-state population distribution and dynamic adjustments to shocks, it is necessary to define the relevant transition equations for worker stocks and flows. This model requires careful accounting of the various population movements occurring in every period, which makes the final formulae look rather tedious at first sight. Note that part of the workers flow from unemployment to employment and vice versa in each period, even when the system is in steady state. Figure 1 depicts an overview of the relevant population dynamics.

Let $u_t(i,j)$ denote the mass of unemployed people with skill level i and entitlement level to unemployment benefits j in period t and let $e_t(i,j)$ be the respective mass of people in employment. Given the threshold productivity levels $z^*(i,j)$, the optimal search intensities $s^*(i,j)$, and the population shares in period $t-1$,

$$\begin{aligned} u_t(i',j') \quad = \quad & \sum_{i,j} P(i',j';i,j)\,[\ (1-\lambda(s^*(i,j))\cdot u_{t-1}(i,j)\ ] \\ & +\sum_{i,j} P(i',j';i,j)\,[\ \lambda(s^*(i,j))\cdot u_{t-1}(i,j)\cdot \nu_{i'}(z^*(i',j')\ ] \\ & +\sum_{i,j} Q(i',j';i,j)\,[\ \sigma\cdot e(i,j)\ ] \\ & +\sum_{i,j} Q(i',j';i,j)\,[\ \kappa\cdot e(i,j)\cdot \nu_{i'}(z^*(i',j'))\ ] \\ & +\sum_{i,j} Q(i',j';i,j)\,[\ (1-\sigma-\kappa)\cdot e(i,j)\cdot \nu_{i}(z^*(i',j'))\ ] \end{aligned} \tag{17}$$

where the first two lines refer to the stock of unemployed workers and the last three lines characterise inflows into the unemployment pool. More specifically, the first term refers to the mass of workers who were not matched at the end of the previous period. The second term refers to the mass of workers who received a job offer but rejected it. The third term refers to the mass of workers who were displaced exogenously. The fourth term refers to the mass of workers whose employment relationship had been subject to a new productivity draw which was eventually rejected, and the last term refers to the mass of workers whose productivity level had remained unchanged and who severed the relationship voluntarily. Similarly,

$$\begin{aligned} e_t(i',j') \quad = \quad & \sum_{i,j} Q(i',j';i,j)\,[\ \kappa\cdot e(i,j)\cdot (1-\nu_{i'}(z^*(i',j')))\ ] \\ & +\sum_{i,j} Q(i',j';i,j)\,[\ (1-\sigma-\kappa)\cdot e(i,j)\cdot (1-\nu_{i}(z^*(i',j'))\ ] \\ & +\sum_{i,j} P(i',j';i,j)\,[\ \lambda(s^*(i,j))\cdot u(i,j)\cdot (1-\nu_{i'}(z^*(i',j'))\ ] \end{aligned} \tag{18}$$

where the first two lines characterise the stock of employed workers and the last line describes the inflow into employment (= outflow from unemployment). Specifically, the first term refers to the mass of workers whose relationship had been subject to a productivity switch and was resumed anyway. The second term refers to the mass of employed workers who, with an unchanged productivity, decided not to quit, and the last term refers to the mass of previously unemployed individuals who were matched to an employer and accepted the job offer. Note that in steady state gross worker flows from unemployment to employment must exactly equal gross worker flows from employment to unemployment and that $\sum_{i,j} [\ u_t(i,j) + e_t(i,j)\ ] = 1, \quad \forall\ t$.

The budget constraint of the government then reads as

$$\sum_{i,j} \left[e(i,j) \cdot \int_{z^*(i,j)} \tau(z)\ z\ d\nu_i(z) \right] = \sum_{i,j} u(i,j) \cdot b(j) + \chi \tag{19}$$

where total tax revenues are given on the left-hand side. Total expenditures for unemployment benefits and commodity purchases are covered on the right-hand side. Total output per capita calculates as

$$y^{total} = \sum_{i,j} \left[e(i,j) \cdot \int_{z^*(i,j)} z\ d\nu_i(z) \right] \tag{20}$$

and the average productivity of all employed workers is given by

$$z^{avg} = \frac{\sum_{i,j} \left[e(i,j) \cdot \int_{z^*(i,j)} z\ d\nu_i(z) \right]}{\sum_{i,j} e(i,j)}. \tag{21}$$

Similarly, the average wage is determined by

$$w^{avg} = \frac{\sum_{i,j} \left[e(i,j) \cdot \int_{z^*(i,j)} w(i,j,z)\ d\nu_i(z) \right]}{\sum_{i,j} e(i,j)}. \tag{22}$$

4.5 Numerical Solution Strategy

Numerical calculations are divided into two parts. In a first step, equation system (4) – (9) is solved by using an iterative value function approach in order to find the optimal search intensities and threshold productivity levels. Initially, some arbitrary starting values are plugged into (4) and the value of the left-hand side is computed. In a similar manner, the algorithm then calculates through (5) – (9) by using the respective values of the previous steps. After that, the next iteration starts etc. until a convergence criterion eventually stops the algorithm. Furthermore, the continuous distribution functions for productivity draws and search intensities are being approximated by discretising on the possible state space. Since the wage values are not crucial for the other equations, they are calculated only once after the final solution is obtained.

In a second step, the steady-state decision rules are used to calculate the distribution of agents in the different states (equations (17) and (18)). Again, an arbitrary initial distribution is used to start the algorithm which proceeds recursively. In case of convergence, the algorithm stops and additional values like total output, tax revenues, average productivity etc. are calculated (equations (19) – (22)). In case the budget constraint of the government is not adequately met, tax rates are adjusted and the calculations are repeated.

The *MATLAB* code for the numerical computations is provided in the Appendix.

5 Specific Choices and Parametrisation

This section consists of three parts. In the first part I will break down the rather general framework and determine a particular skill system. The second part overviews the benchmark calibration of the model. Finally, I specify four unemployment benefit schedules so as to analyse different UI systems.

5.1 The Skill System

The number of different skill levels is set to $I = 4$. Furthermore, I assume that there are three different levels of human capital: high, medium and low. The status of high human capital is divided into two different sublevels: robust high human capital ($i = 1$) which characterises the highest possible skill level, and fragile high human capital ($i = 2$), the second-highest. The probability distribution for productivity draws is assumed to be the same for both of these skill levels. However, workers with fragile high skill have a higher probability of "breaking down" to a lower skill level, i.e. to the states of medium ($i = 3$) and low human capital ($i = 4$).

Tables 1 and 2 report benchmark values for the probabilities of transition between different skill levels for unemployed and employed workers. Periods are set to be quarters. Notice that transitions between states $i = 1$ (robust high) and $i = 2$ (fragile high) occur at a much higher rate than transitions between different magnitudes of human capital (high, medium, low).[4] This reflects the fact that the accumulation and deterioration of human capital is a continuous and time-consuming process which does not happen overnight.

For instance, it takes on average five quarters of unemployment to transit from $i = 2$ to $i = 3$ and even 10 quarters (or 2.5 years) to drop from $i = 3$ to $i = 4$. On the other hand, the transition process back to higher skill classes in an employment period is usually quite time-consuming as well. For instance, an employed worker with a medium stock of human capital who tries to accumulate enough knowledge on the

[4] Very few empirical studies have managed to compute reliable estimates for the magnitude of skill depreciation during periods of unemployment. Keane and Wolpin (1997) estimate that white-collar skills deteriorate by ca. 30 percent after a year of absence from work, while blue-collar skills under similar circumstances are only ca. 10 percent lower. Results of other studies (e.g. Neumann and Weiss (1995)) seem to indicate that the rate of skill depreciation increases with the level of education. The benchmark paramters in this model try to capture these findings by assuming higher transition rates between the first three skill classes compared to transition rates between the lower skill classes.

job to advance to the fragile high-skill class, has to wait on average 12 periods (or 3 years). As can be seen, the skill system is calibrated such that it generates a certain persistence. This persistence will actually allows us to identify the major economic forces in the model.

5.2 Calibration

Table 3 documents numerical values for the benchmark parametrisation. The skill-dependent probability distributions ν_i are taken to be uniform with support $[\underline{\nu_i}, \overline{\nu_i}]$. Note that productivity draws are restricted to an interval between 1 and 3 and that the average value of 2 serves as a threshold. Above this threshold, productivity draws can only occur with a decent stock of human capital (medium or high), and workers with high skills will never receive draws below that value. The degree of economic uncertainty is highest for medium-skilled workers due to the large range of possible draws. Existing job relationships are severed exogenously at a quarterly rate of 3 percent and idiosyncratic shock leading to a switch in the productivity level occur with a per-period probability of 7 percent. Thus, firm-worker pairs are hit by exogenous productivity shock on average every 10 periods or 2.5 years.

The matching function which maps the search intensity of an unemployed workers into the probability of receiving a job offer is assumed to have the general functional form $\lambda(s) = a \cdot s^b,\ \lambda \in [0,1]$. More specifically, I choose values of $a = 0.85$ and $b = 0.3$ which yields a concave function in s, reflecting the notion that the marginal utility of additional searching effort is constantly declining. At the maximum search effort of 1, a worker has a fairly high matching probability of 0.85 which, however, still leaves the significant risk of a failure. Workers *have to* search, otherwise they never receive a job offer. The disutility of searching is captured by the linear function $c(s) = \widehat{c} \cdot s$ with a value of $\widehat{c} = 0.7$ in the benchmark case. The extra value of leisure in case of unemployment is set to $l = 0.7$. Thus, a worker who decides to search at maximum intensity has to pay costs equalling exactly the additional utility of leisure. Graphical representations of $\lambda(s)$ and $c(s)$ are shown in Figure 2.

The profit tax schedule is set to

$$\tau(z) = \overline{\tau} + \tau^p \cdot z \tag{23}$$

where $\overline{\tau}$ denotes a flat rate and τ^p is a coefficient characterising the degree of progressiveness in the tax system. The per capita value of other government purchases is set to $\chi = 0.1$. Since the budget constraint of the government requires total tax revenues to equal total transfers and purchases, I fix τ^p to a value of 0.01 and adjust the flat rate $\overline{\tau}$ to balance the budget. Finally, the outside option of the firm is assigned a value of 0 and wage negotiations between workers and employers take place with equal relative bargaining powers. The discount factor is set to $\beta = 0.99$, making the annual interest rate 4.1 percent.

5.3 Four Different Model Economies

In order to study the effects of different UI systems, I establish four different benefit schedules (Table 4). In model economy 1, called 'laissez-faire' economy, there is no UI system whatsoever. That is, unemployed workers do not receive any financial support from the government. Note that the government is still supposed to exist, and that it levies taxes on output in order to finance other commodity purchases. Since the analysis primarily aims at comparing UI systems (and the distortionary effects of taxes to finance them), the results are best comparable when making this assumption.

For the other three economies I specify three different benefit levels: b_1 ('high benefits'), b_2 ('low benefits') and b_3 ('social assistance'). Entitled to high benefits are, by assumption, all those workers who have been lastly employed when possessing a high stock of human capital. The previous productivity and the wage are irrelevant, only the skill level during the last employment period matters. This specification might sound weird, but it reflects the fact that well-trained workers earn a higher wage than those in the lower skill classes. More importantly, it keeps the analysis tractable.

Furthermore, I assume that entitlements do not adjust immediately, but only with a constant probability of 0.25. That is, a worker has to be employed on average for four periods (1 year) until the entitlement level is changed according to his current skill level. This rule applies e.g. for employed workers with low entitlements who transit from $i = 3$ to $i = 2$, or for unemployed workers with high entitlements who gain employment in $i = 3$ or $i = 4$ again. The reason for this specification is that the magnitude of UI is supposed to be determined by a worker's medium- and long-term employment history and not only by the very last period. Note again that only the skill level during the last *employment* matters, and *not the current* skill level.

In model economy 2, there are only two entitlement levels. Its setup represents an UI schedule with a fairly high replacement ratio of 65 % and indefinite benefit payments. In contrast, benefit payments are finite in model economies 3 and 4. In model 3, it takes, on average, just two quarters until a worker loses his entitlements to unemployment benefits and is downgraded to social assistance. Furthermore, replacement ratios are with 50 % quite low. The UI schedule in model economy 4 is set such that replacement ratios amount to about 70 % of the previous earnings and workers remain entitled to regular benefits for four periods or one year.

The purpose of these varying specifications is to study the implications of different policy instruments on the performance of an UI system as a whole. The next section provides an overview of the most important steady-state results.

6 Steady-State Results

An overview summarising the most important results of the steady-state calculations is provided in Table 5. At first glance, the four model economies seem to exhibit amazingly similar characteristics. Total output values differ only to a very small extent and also the average productivity of employed workers and the average wage rate are almost indistinguishable. However, the fairly large difference in the unemployment rates reveals that there have to be some important economic mechanisms lurking in the background which are covered only superficially by these raw numbers. Values for the share of high-skilled workers in the population, i.e. the percentage of workers who are either in state $i = 1$ or in $i = 2$, are a further indicator for that observation. Apparently, there are certain incentives inducing workers to decide diversely in changing economic environments.

6.1 Economic Forces at Work

A good starting point for the investigation of the economic forces at work is to have a closer look at the two economies which seem to be most different from each other. Model 2, the 65% replacement ratio economy with indefinite entitlements to unemployment benefits, exhibits a rate of unemployment that is more than twice as high as the respective value in the laissez-faire economy. Furthermore, almost three percent of the population have dropped out of the high-human-capital states compared to only a mere half percent. In the absence of any exogenous disturbances and recalling that separation rates are constant and equal in all setups, the question naturally becomes: Does the behaviour of workers in varying surroundings differ at all and, if yes, what are the reasons for that?

If we want to know more about their behaviour, the first thing to do is to recall the relevant decisions that workers have to make. In this model, there are just two decisions which an individual can possibly face. The first one is to accept or reject a job offer. Unless he has not been matched after a period of unemployment or has just been laid off exogenously, every worker faces this decision at the beginning of each period. The second decision concerns the effort that an unemployed worker is willing to make in order to be matched to a vacant job at the end of the period. Knowing these decisions, the next step is to investigate the relevant decision variables which are in this model the reservation productivities and the optimal search intensities.

Recalling the notation above, the reservation productivity (or zero surplus level) $z^*(i,j)$ defines the threshold above which productivity draws are accepted and an employment relationship is established or resumed. The optimal search intensity $s^*(i,j)$ determines the probability of a successful match and the inherent disutility of searching. Both variables critically depend on the current status of a worker.

Steady-state solution values for the threshold productivities can be found in Table 6.[5] In the laissez-faire economy, workers in all four skill classes are willing to accept virtually any productivity draw which is not too surprising in the absence of any financial support from the government. Although leisure brings about some extra value, part of it has to be used immediately to finance searching with unknown success. Simply put, waiting for a 'good' productivity draw never pays out. For instance, workers in the lower skill classes find it more attractive to accept a job offer with a very poor draw (close to 1) than staying unemployed. They hope to accumulate enough human capital on the job to attain a higher skill level and, sooner or later, receive a new draw. For high-skilled workers, the wage differential between z's close to 2 and z's close to 3 simply never justifies a period of unemployment which is associated with heavy financial losses and the risks of skill depreciation and failures in the matching process. After all, the fact that agents accept any new job offer explains the very low unemployment rate in this economy.

Economy 2 shows a different picture. Reservation productivity values above 2 for the top two skill classes and above 1 for the bottom two skill classes indicate situations in which new job offers are not accepted arbitrarily. For instance, employees with robust high human capital who are entitled to the highest level of unemployment benefits (state (1,1)) are only willing to engage in an employment opportunity if the corresponding productivity draw exceeds 2.2. That is, under the assumption of a uniform productivity distribution, 20 percent of all job offers for workers in this state are rejected. Evidently, it is profitable for them to undergo a period of idleness with fairly ample financial support and hope for a better draw in the future. A job search without a match, even in several consecutive periods, would be just as good as a bad productivity draw *as long as* the high stock of human capital does not become fragile. In that case, the worker immediately gives up his pickiness and takes what he gets.

[5] Note that zero surplus values below the usual support of the distribution in a skill class are only relevant for employed workers who have just made a transition from a lower skill class and might consider an immediate voluntary quit.

Note that in an economy with indefinite benefit payments workers never lose their entitlement to the highest benefits if they are in one of the high-human-capital classes. That is, the only scenario which forces them to diminish their demands in terms of productivity draws (and implicitly wages) is skill depreciation. This is an important feature which distinguishes economy 2 from the other setups. Notice also that workers in $(2,1)$ who decide to accept a job offer with a z near 2.000 and later experience a transition to $(1,1)$ will resign voluntarily in order to wait for a better job offer. The influence of voluntary quits on population dynamics is rather small, though, and will be explained in more detail in section 6.5.

Agents who have dropped out of the top skill classes and are entitled to high unemployment benefits have a strong incentive to be very picky with the next job offer. Having in mind that their entitlements will most likely decrease after a couple of periods in a medium- or low-skill employment, the only scenario they have to fear is a further drop into the very lowest skill class. Their reservation productivity in the medium-skill class amounts to 1.614 which yields a probability of almost a third that a new job offer is rejected. Apparently, the vague hope to accumulate enough human capital to ascend to $j = 2$ again (which happens in merely 1 out of 12 cases) and to avoid descending any further is in many cases dominated by the anticipated downgrade in the entitlement level. Recalling the highest share of non-high-skilled workers of all setups, steady-state reservation productivities may therefore provide a first explanation for the relatively high rate of unemployment in model economy 2.

A closer look at workers' behaviour in terms of job search intensities confirms the reasoning brought up so far. Table 7 reports numerical values for the steady-state calculation and Table 8 translates them into the resulting matching probabilities. Not surprisingly, in the laissez-faire economy agents prefer to choose the maximum search intensity of 1 in almost any situation which means that they consume their extra value of leisure entirely to find a new job. Opportunity costs due to forgone wages are very high and, in the lack of any financial compensation from the government, their best option is to spend as much as they can to get into employment again and not run the risk of skill depreciation. A slight exception can be observed in the lowest skill class where workers prefer to consume at least some of their leisure value and renounce full search effort. Opportunity costs are not as high as in the other skill classes since chances to receive a good job offer and move up to a higher skill class are rather low. However, the overall effect on the population distribution and the unemployment rate is eventually very small as only a negligible fraction of all workers will ever slip off to $j = 4$.

Again, the high-replacement economy with indefinite benefit durations offers a picture that is much more manifold. It turns out that only a very small fraction of unemployed workers decides to expend full energy in searching for a job, namely those in state $(2, 2)$. Why is that? First of all, the concave form of the matching function implicates relatively fair chances to receive a job offer even with a minor search intensity of maybe 0.5. Diminishing returns in the matching probability bring about relatively small advantages at the top of the scale with linearly increasing costs. Surrendering just 10 percent of the effective matching probability means to save more than one third of the costs of full search effort. Secondly, reservation productivity levels lying above the lower support of the distribution decrease the chances of a successful match even further. Since attractive job offers are harder to find, agents may prefer to lower their efforts to get into employment again and, instead, consume part of their leisure. For instance, workers with a robust high stock of human capital and high benefit entitlements put in less than half of the maximum search effort. Taking into account the risk of an insufficient productivity draw (20 percent), their chance to find a profitable job offer decreases from $0.85 \cdot 0.80 = 0.68$ to $0.85 \cdot 0.66 = 0.53$ while, at the same time, they save $(1 - 0.44) \cdot 0.7 = 0.39$ of the costs. That is, generous and indefinite unemployment benefits not only increase employees' pickiness in terms of job offers; they also create incentives to reduce efforts to leave the pool of unemployment again as soon as possible. Both economic forces undoubtedly lead to a larger stock of unemployment since workers are willing to put up with the risk of longer periods of idleness.

The 'disciplining' factor in this model is the risk of skill depreciation. When individuals slip off to the edge to a lower stock of human capital, they immediately decide to give up their reserve. For instance, remaining unemployed with a fragile stock of high human capital means to run a significant risk of losing good perspectives for a long and contingent period of time. Workers try to avoid this scenario by increasing efforts to get into employment again, although their benefits are still fairly high. Metaphorically speaking, the risk of getting stuck in low-wage employments hangs over workers' heads like the sword of Damocles and causes them to strive for a new job more consequently. In model economy 2, for instance, the transition from robust to fragile high skill in $j = 1$ eventually leads to an effective matching and job acceptance probability of 0.76 compared to 0.53 before. The reason why high-skilled workers in $j = 2$ use significantly more effort than those in $j = 1$ is based on an extra incentive: their benefits are by far less generous and, moreover, they have the perspective of moving to $j = 1$ pretty soon when employed.

The difference between the two magnitudes of unemployment benefits also leads to a quite discrepant behaviour in the lower skill classes. The most astonishing values are certainly those of unemployed agents in status $(4, 1)$ who are only willing to accept jobs with a productivity draw of 1.701 or higher and whose search intensity amounts to a mere 0.02. Combining these numbers yields a probability of just 7.8 percent that they leave the pool of unemployment at the end of the period. This translates into an average duration of more than 12 periods or 3 years. A worker in this state knows that he remains entitled to high unemployment benefits for an unlimited period of time as long as he does not start working again. Therefore, he reacts extremely picky with new job offers and prefers to consume most of his leisure instead of "wasting" it for the costly job search. Notice, though, that a productivity draw at the top of the distribution near 2 would still make him better off. Using a tiny search effort of 0.02 (which corresponds to a matching probability of 0.25) thus simply means to keep this unlike option alive.

Medium-skilled workers with general entitlements exhibit a comparable behaviour, though not as extreme. Again, the risk of further skill deterioration constitutes the motivation to increase efforts at least by some extent which translates into a probability of 45 percent that they receive an acceptable job offer. Not surprisingly, search efforts increase even further when unemployment benefit payments are less generous. In combination with lower reservation productivities, agents are much more eager to leave the unemployment pool as soon as possible if compensations are less attractive.

6.2 Unemployment Dynamics

The next step is to investigate the influence of different behaviour in terms of search intensities and reservation productivities on the distribution dynamics in the population. The hazard rate of unemployment is a particularly useful tool to understand the effects of workers' behaviour on the unemployment spell. By definition, the hazard rate denotes the conditional probability that a worker leaves the unemployment pool in a certain period, given that he has not left it before. Another way to interpret it is to imagine a cohort of commonly laid-off workers and calculate the respective fraction of still-unemployed workers who gain employment in each of the following periods.

Hazard rates for workers in state $(1,1)$ are shown in Figure 3. For the laissez-faire economy, search intensities at the top of the scale and minimum reservation productivities translate into the highest probabilities of re-gaining employment over the entire interval of five years. The mild decrease after about 5 periods is due to the fact that an increasing fraction of the cohort reaches the lowest skill class where the optimal search intensity is slightly lower. The curve for model economy 2, on the other hand, tells a very different story. After a short increase in the first couple of quarters, the hazard rate peaks out at about 0.6 and then sinks dramatically over the following 10 periods before leveling out at a value of less than 0.1. The initial increase can be explained by those workers who deteriorate to the fragile high-skill class very rapidly and are then forced to accept any job offer. Once more and more workers drop even further to the lower skill classes, hazard rates start to decrease again. Workers wish to receive very good job offers before giving up their generous unemployment benefits. In combination with lower search intensities, the hazard of gaining employment eventually settles down to hardly 8 percent. The initial increase can be explained by those workers who deteriorate to the fragile high-skill class very rapidly and are then forced to accept any job offer. Once more and more workers drop even further to the lower skill classes, hazard rates start to decrease again. Workers wish to receive very good job offers before giving up their generous unemployment benefits. In combination with lower search intensities, the hazard of gaining employment eventually settles down to hardly 8 percent.

Hazard rates have an important influence on the average duration of unemployment which itself is one of the main factors for the equilibrium rate of unemployment. Clearly enough, higher probabilities of gaining employment have a direct negative influence on the expected spell of unemployment. However, given the particular shape of the hazard rate curves which are downward-sloping in the medium and long term, there is also an indirect second effect. The less workers leave the unemployment pool in one of the first periods, the higher is the number of those who face even lower rates in the future. In the laissez-faire economy, for instance, high hazard rates in the first periods translate into a negligibly small fraction of still-unemployed workers after 1 year. That is, the slight drop in the hazard function de facto has no influence on the equilibrium distribution.

Table 9 reports values for the average spell of unemployment depending on the current state (i, j). Note that due to the Markov character of the model these are unconditional averages, regardless of the fact whether a worker has just been laid off or whether he had already been idle before. Furthermore, the probabilities of becoming long-term unemployed[6] are summarised in Table 10. In the laissez-faire economy, the average duration of unemployment is rather short in any of the four states. Since workers choose to search intensively and accept any job offer they receive, typically, unemployment spells last for only one period. Only in very rare cases workers remain jobless for several consecutive periods. Hence, the risk of long-term unemployment is literally zero. After all, the steady-state unemployment rate of 3.42 percent in this economy is chiefly frictional due to exogenous separations and the assumption that matching requires at least one period of idleness. The rest probability of a matching failure with full search effort contributes the small additional part. That is, given the model's specification and calibration, the unemployment rate can never fall below 3.42 percent.

Workers in the economy with indefinite benefit entitlements are, on average, much longer unemployed. By reducing their job search efforts and rejecting bad job offers, they implicitly put up with longer periods without employment, especially if benefits are generous. The most extreme values can be found in states $(3, 1)$ and $(4, 1)$ where durations average at more than 8 or even 10 years. Workers in these states are rather stuck. Their prospects of gaining an attractive employment opportunity are so small that the majority ends up living on benefits from the government for a long time. In the lowest skill class, the risk of long-term unemployment amounts to even 72 percent. Evidently, there are some strong incentive problems in this part of the economy.

In the upper skill classes, the average durations still exceed 1 period for workers with high benefits. Although both values are partly "biased" by the ultra-long spells in the lower categories, they still signalise a significantly longer transition process back into employment compared to the laissez-faire case. Moreover, probabilities values of becoming long-term unemployed are with approximately three percent the highest among all setups. In contrast, the situation in the second column (low entitlements) seems to be rather uncomplicated. In the higher skill classes agents are willing to spend considerable effort to get back into employment very fast which drives down the average spell to values of less than half a period. Only in the very lowest skill class the average duration jumps up to almost 4 periods which is primarily due to the radically

[6] Unemployment will be referenced as "long-term" if its duration exceeds 4 periods or 1 year.

reduced search effort in this state.

6.3 The Population Distribution

The analysis in the previous sections has demonstrated rather large difference in agents' behaviour between the laissez-faire case and the economy with generous and indefinite benefit entitlements. Up to now, however, we were not able to quantify the implications of these differences, because the relative shares of the population in the various states have not been taken into account yet. Giant differences in some of the states can have almost no effect if their population share is actually close to zero. The steady-state distribution of agents is therefore an important tool to evaluate the previous results and generalise them.

Table 11 provides numerical values for the various setups. In the laissez-faire economy, probably the most striking number is the extraordinarily large share of robust high-skilled agents which accounts for more than 96 percent of the entire population. Furthermore, hardly any employee ever sees his human capital deteriorating to a medium or even low level - a mere 0.54 percent of all workers are in the bottom skill classes. Labour transitions seem to be rather restricted to states $(1, 1)$ and $(2, 1)$. That is, workers being laid off in state $(1, 1)$ usually find a new employment after one period. Quite occasionally they drop to the fragile high-skill class where they have to work for an upgrade again. Transitions to the medium-skill class occur only rarely; they are simply due to the fact that a (rather improbable) series of failures in the matching process despite full search effort may eventually lead to an inevitable downgrade in the skill class.

The steady-state population distribution of model economy 2 offers a quite different picture. The share of unemployed people in the highest skill class is more than twice as high as in the laissez-faire case. The reason is that workers accept only 80 percent of the productivity draws and search with less effort. As a consequence, their skills deteriorate more often which explains the total share of 7.5 percent in the fragile high-skill class. Furthermore, one might be puzzled by the fact that the share of workers in the lower skill classes is six times as high as in model 1 although the share of unemployed people "on the edge" in $i = 2$ is not even 1 percent. However, our previous analysis has suggested that workers in these categories are rather stuck, especially when generously benefited. Their prospects of gaining attractive employment are very which leads to long unemployment spells. Amazingly, state $(4, 1)$ is the only one among all setups which exhibits a share of unemployed people being higher than the respective share of employed people. Such traps explain part of the high unemployment rate in this economy, though not the most important ones since their share of total unemployment is eventually rather small.

To summarise, two results are most striking: firstly, the model with indefinite generous benefits exhibits a much higher rate of unemployment. The reason is that laid off workers do not search at full intensity immediately and are more picky with new job offers. Secondly, the fraction of agents experiencing skill deterioration is much larger. This leads to a considerable share of unemployed workers ending up in states with a "dead-end" character. One way to cope with particularly the last incentive problem could be to limit the duration of regular unemployment payments and thereby persuade workers to gain employment again faster. In the next part, the two setups including such limitations will be discussed.

6.4 Finite Benefit Payments

A quick glance at Table 5 reveals that most of the statistics in model 3 and 4 lie somewhere in between those of the first two setups. In some sense, model economy 4 with a 70% replacement ratio and an average payment duration of 1 year appears to resemble model 2 while model economy 3 with a replacement ratio of 50% and an average payment of 2 periods exhibits properties being more similar to those of model 1. Unemployment rates in both economies exceed the laissez-faire value of 3.42 considerably, but are way lower than 8 percent. Furthermore, temporary restrictions for benefit payments seem to slow down skill depreciation processes: the shares of high-skilled workers in both economies exceed 98.5 percent compared to 97 percent in model 2. Less unemployment and finite benefit payments mean less expenses for transfers which explains the lower equilibrium tax rates.

How does workers' decision making react to a policy change which limits regular payments to a few periods and imposes social assistance payments of lower value thereafter? Table 6 confirms that reservation productivities in $(1, 1)$ are slightly lower in setup 4 than in setup 2 and almost reach the bottom support in setup 3. In both cases, employees are still willing to reject draws at the very bottom end of the scale. Note that unemployed workers are aware of the fact that transitions to another state occur at a much higher rate than in the model with indefinite benefit payment. For instance, the probability of remaining in the best possible state (1,1) after the following period drops from $\frac{12}{16}$ in setup 2 to $\frac{9}{16}$ in setup 4 and $\frac{6}{16}$ in setup 3.

Once a transition occurs, agents give up their pickiness immediately as reservation productivities of 2 in all other states of the top skill classes reveal. A skill depreciation to $(2,1)$ means to run the risk of heavy financial losses in case of a further descent. That is, agents are still quite well-off with their high stock of human capital and generous benefit payments. However, they want to avoid remaining unemployed because of pending risks. This economic force is rather "future-orientated" and has already been detected in previous setups. The new aspect in models with finite benefit payments is the fact that enduring periods of idleness sooner or later lead to a downgrade in entitlements. An unemployed worker in state $(1,3)$ is not in direct danger of heavy losses in the future. His losses are actually very present and concern the immediate costs of unemployment. Rejecting job offers simply means to accept further periods of costly searching without generous compensations and without full certainty of a matching success. Furthermore, opportunity costs of gaining employment are higher due to the additional option value of a transition back to the highest entitlement level. These incentives are clearly stronger than the vague hope of a brilliant productivity draw in the future.

Reservation productivity values in the two lower skill classes tell a similar story. Workers in $j = 1$ do not want to accept lousy productivity draws as long as they are still generously benefited. Their slight prospects of accruing enough human capital to overcome the gap to the higher skill categories are contrasted by the disincentive of an anticipated downgrade to low entitlements (recall that being employed in $i = 3$ and $i = 4$ leads to a reduction in entitlements). The latter does not apply any longer once they move to $j = 3$. Regardless of the current skill level, zero surplus levels in these states are very close to the lower support of the productivity distribution in both models. Again, the desire to accumulate human capital instead of risking to lose it is complemented by the large direct costs of unemployment *and* the option value of regaining entitlements to regular benefits.

How does search behaviour change in response to stricter insurance rules? Individuals generally use more effort than in a setup with indefinite benefit payments as Table 7 documents. When in possession of a high stock of human capital, they want to avoid any transitions to less profitable states and since transitions occur more often, they decide to search more intensely. Table 8 confirms that matching probabilities approach the maximum value of 0.85 across nearly all states. Note that values in model 4 are slightly lower than in model 3 as workers are usually longer entitled to high benefits.

The analysis of model 2 has manifested some serious incentive problems in states $(3, 1)$ and $(4, 1)$. For instance, recall that the probability of gaining an acceptable job offer was a mere 7.8 percent in state $(4, 1)$ due to extremely low search effort and a very high reservation productivity. A glance at the respective values for setups 3 and 4 clearly documents a mitigation of that incentive problem. Compared to model 2, matching probabilities are more than twice as high in the low-skill class and reach values of more than 70 percent in the medium-skill category. In combination with considerably lower reservation productivities, the effective probability of finding an acceptable job offer in state $(4, 1)$ increases to about 44 percent in setup 3 and 29 percent in setup 4. These numbers may still seem fairly low at first; however, note that only very few workers ever see this state since entitlements to unemployment benefits most likely have decreased already before. When entitled to low benefits or social assistance, the situation gets even less problematic. Search intensities move up significantly and workers are willing to accept almost any job offer they receive which leads to considerably shorter unemployment spells.

Not surprisingly, hazard rates for a cohort of workers being laid off in state $(1, 1)$ lie in between those of the two economies discussed before (Figure 3). Both curves exhibit an initial increase and peak after about four quarter. In this period more and more still-unemployed workers transit out of $(1, 1)$ into states where optimal search intensities lie close to 1 and reservation productivities are low. In the following periods hazard rates start to fall, because an increasing share of still-unemployed workers drops to the lower skill classes. While the difference between hazard rates in economy 3 and economy 4 amounts to circa 8 percent over the first 6-8 quarters, in the following the gap widens quite dramatically to almost 20 percent. Hazard rates in economy 3 eventually converge to a value of nearly 65 % percent, and the shape of the curve suggests fairly short spells of unemployment. In economy 4 hazard rates are considerably lower, especially in the medium and long term, but still far away from being comparable to those of model economy 2.

The negative influence of higher hazard rates on the average spell of unemployment is confirmed in Table 9. In model 3 only few values exceed 0.5 which means that the vast majority of laid off workers transits back into employment after just one period.

Knowing that unemployment benefit payments are restricted to a very short sequence of quarters, they invest a lot of resources into searching and accept almost any job offer. Long-term unemployment does virtually not exist in this setup (Table 10). Do these results depend on the low replacement ratio and on the very short duration of benefit payments? Respective values for model 4 prove that the answer is no. Average unemployment durations are slightly higher than in model 3, but still low enough to drive down the probability of becoming long-term unemployed to values near zero in any state except $(4, 1)$ (which is rather irrelevant as explained above). Apparently, the temporary restriction of benefit payments serves to solve some incentive problems causing long spells of idleness otherwise.

How does the steady-state population distribution change after such a policy change? Interestingly, the share of employed workers in the best possible state $(1, 1)$ is with slightly more than 80 percent almost the same in all economies with an UI system. Major differences emerge in the distribution of the other 15 percent of the population though. In model 2, we observed that unemployed workers in the highest skill class lower their efforts and become picky which explains the unemployment share of six percent in $(1, 1)$. The very same share, six percent, can also be found in model 3 - yet already back on the employment side in $(1, 3)$. That is, instead of living from generous benefits and hoping for matching luck, workers in model 3 and 4 have strong incentives to return into the productive part of the economy soon. As an important side-effect, the share of agents slipping off to the lower classes is much lower, especially in model 3. Not even one percent of all workers see their skills deteriorating to medium or low, which eventually guarantees constantly high productivity draws among the entire population. Unemployed workers in the highest skill class lower their efforts and become picky which explains the unemployment share of six percent in $(1, 1)$. The very same share, six percent, can also be found in model 3 - yet already back on the employment side in $(1, 3)$. That is, instead of living from generous benefits and hoping for matching luck, workers in model 3 and 4 have strong incentives to return into the productive part of the economy soon. As an important side-effect, the share of agents slipping off to the lower classes is much lower, especially in model 3. Not even one percent of all workers see their skills deteriorating to medium or low, which eventually guarantees constantly high productivity draws among the entire population.

6.5 Aggregate Terms

The analysis so far has provided reasonable explanations for the large differences between the rates of unemployment in the four economies. It is not clear yet, though, why the average productivity is highest in setup 2 (see Table 5), why total output in setup 3 is higher than in setup 1, why average wage rates do hardly differ at all, etc. Furthermore, effects on welfare (being measured as the average expected discounted consumption stream) are to be discussed in the following.

Abstracting from the details, unemployed workers face a trade-off between two major incentives. On the one hand, there is the aspiration for high productivity draws as they imply higher wages. On the other hand, there is the sheer necessity to gain employment again sooner or later due to the inherent costs and risks of unemployment. Policy rules can influence both of these incentives by means of insurance systems. In the absence of any social safety, for instance, the first incentive is weakened so drastically that workers are generally forced to accept even bad job offers. This drives down the unemployment rate, but also leads to a relatively high number of jobs with a productivity at the bottom of the scale.[7] Things are different when workers can afford to be more picky and reject poor draws. Jobs near the lower supports vanish and are replaced by more productive employments - at the expense of a higher unemployment rate.

A higher average productivity is certainly not desirable per se. However, values for total output demonstrate an interesting phenomenon: although the absolute share of employed people in model 3 is significantly lower, total output exceeds the corresponding value in model 1. Here, the introduction of an unemployment insurance system increases the performance of the entire economy as jobs are selected more carefully.[8] If poorly constructed, though, an insurance system can also have very negative effects on economic performance as the respective value for model 2 illustrates. We have seen that indefinite entitlements to generous benefit can create dangerous disincentives with some workers ending up in long-term unemployment.

Effects on overall welfare seem to be rather small. While values for the average expected discounted utility of employed and unemployed workers are very similar in model 2, 3 and 4, agents are considerably worse-off in the laissez-faire case. This might

[7]Some are even below the support of the regular distribution in a skill class. Recall the possibility of a firm-worker pair that had been formed in one of the lower skill classes with a z between 1 and 2, and later has advanced to one of the high-skill classes.

[8]Other studies proposing this result include Acemoglu (2001) and Acemoglu and Shimer (2000).

seem puzzling at first: wages are as high as in the other scenarios and unemployment is quite rare. Large income differences between employment and unemployment periods are not a problem either - note that utility is linear in consumption which makes costly intertemporal smoothing obsolete. The explanation is actually hidden in the search functions: recall that the matching probability function is strictly concave while search costs are linear. At the upper end of the scale, increments in search effort cost as much as at the lower end, but yield only small improvements in the matching probability. In the laissez-faire economy laid-off workers are forced to "bite this bullet" and choose the maximum intensity of 1. In contrast, in the other setups the maximum value almost never appears. Due to the concavity of the matching function, agents can afford not to give up all their leisure while at the same time still obtaining decent probabilities. From an aggregate point of view, being forced to search at full intensity is therefore not efficient and has a negative impact on welfare.

7 Model Variations

7.1 A Transient Unemployment Shock

In this section I will test the model economies' vulnerability to an unexpected and transient unemployment shock (e.g. think of a recession). Each economy is assumed to be in its steady-state equilibrium in period -1, before a one-time shock arrives and hits the economy in period 0. Specifically, I assume that the exogenous separation rate rises, once and for all, from 0.03 to 0.06, and matching probabilities are halved on the entire interval from 0 to 1. These modifications are not anticipated by agents and apply only to period 0, i.e. steady-state decision rules remain unaffected all along. Additional expenditures for unemployment benefits are assumed to be financed by lump-sum taxation. The following analysis shall trace out impulse responses of various economic variables and the expected time until the economy is about to return to its steady state.

Figure 4 shows that total rates of unemployment initially shoot up by roughly four percentage points in all model economies. In the following periods, the curves exhibit a quite different shape, though. While the laissez-faire economy converges to its steady state very quickly, the curve of economy 2 looks much flatter. Even one year after the shock, the unemployment rate still lies considerably above its equilibrium value. Like in the benchmark steady-state analysis, economy 4 is closer to economy 2 while economy 3 seems to resemble the laissez-faire setup. In the latter two setups, workers react to unemployment with intensive searching and modesty in terms of job offers. The flow back into employment goes on very rapidly since workers are afraid of skill depreciation and long-term unemployment with little or no benefits. Only two periods after the shock, employment rates are back to their high initial level which demonstrates the powerful flexibility in these economies. In contrast, in setup 4 and particularly in setup 2 this process takes significantly more time. After the shock, most of the laid-off workers are for the time being generously benefited and not in immediate danger of losing their high stock of human capital, so they reduce their search efforts and wait for good job offers. Only when their entitlements have decreased (model 4) or when they find themselves on the edge of losing their high skills, they change behaviour and strive out of the employment pool more consequently.

Figure 5 provides a more precise documentation of unemployment dynamics by distinguishing between the various skill classes. The different behaviour of agents in $i = 1$

is particularly well-illustrated by the shape of the respective curves. For the laissez-faire case, the curve takes a very steep course down immediately after the shock and compensates for almost 90 percent of the previous deviation in just one quarter. After two quarters, the unemployment rate in this skill category already reaches its regular level. Exorbitantly high hazard rates for agents in state $(1, 1)$ and a negligibly low ratio of workers remaining unemployed for more than 2 periods eventually allow for the fastest recovery among all setups. Impulse responses for model economy 3 look quite similar, though not as extreme. The small fraction of workers rejecting productivity draws at the very bottom of the scale makes the curve for $i = 1$ slightly flatter. However, the quick expiration of high benefit entitlements and the relatively low replacement ratio of 50 % drives workers back into employment quite soon. Unemployment shares in the lower skill classes hardly exhibit any shift and the economy virtually returns to its steady state after about 3 periods.

The chart for model 4 illustrates that an increase in the average duration of benefit entitlements to 4 quarters and a higher replacement ratio of 70 % do not damage the economy's performance critically. Although impulse response curves look slightly flatter, the impact of the initial shock is absorbed after less than one year. The effective combination of disciplining mechanisms, i.e. skill deterioration and finite benefit payments, makes sure that workers do not slip off to long-term unemployment. In contrast, the absence of one of these mechanisms can cause persistent problems with unemployment as the chart for model 2 demonstrates. Pretentious reservation productivities and moderate search effort make the curves for $i = 1$ and $i = 2$ considerably flatter than in the other scenarios. As a consequence, part of the workers leaving these skill classes do not flow back into employment but slip off to the lower skill classes which explains the upshift of the curves for $i = 3$ and $i = 4$. Problematic about this shift is not its magnitude which is in a sense rather small - the actual problem lies in its persistence. Figure 6 depicts, at a lower scale, the continuation of impulse responses in setup 2 on an interval between 1 and 4 years after the arrival of the shock. As can be seen, the share of unemployed workers with robust high human capital intersects its steady-state level 6 periods after the shock before falling slightly below it. At the same time, the share of idle workers in the lowest skill class reaches its peak after one-and-a-half years and decreases only very slowly thereafter. Even four years after the arrival of the shock, model economy 2 has not yet returned to its steady state completely. A significant fraction of workers gets stuck in states with a dead-end character which leads to a perennial problem of long-term unemployment.

How are key variables describing the economies' performances affected? Responses of total output and average productivity per employee are displayed in Figure 7 and Figure 8. Output per capita initially drops by roughly 4 percent in all setups. Like unemployment, recovery paths for total output differ substantially in he following periods. Steady-state levels are reached after only 2 periods in the laissez-faire economy and after about 4 periods in the two models with finite benefit entitlements. Workers in these setups mostly return to employment quite fast and without losing their high skills. In model 2 output recovers much slower; even after 6 periods the economy does not reach its former performance. Skill depreciation and problems with prolonged unemployment have excluded part of the working population temporarily from the highly productive part of the economy and keep impairing its potential even years after the shock. In contrast to output, the average productivity per employee in this framework hardly reacts at all to an unemployment shock. That is, percentage deviations amount to a mere 0.05 % of the respective steady-state value. After a slight increase in the period of the shock[9], the curves' shapes look like a very wide U in the following. Due to the tiny dimension of the variation, the impact on the economy as a whole is negligible though.

As can be seen in Figure 9, a transient unemployment shock can lead to a persistent phase of budgetary deficits. With the exception of the laissez-faire economy where tax revenues decrease only marginally and no transfers have to be paid, the budget deficits in the other economies amount to 2-2.5 percent of the steady-state output in the period of the shock. Since unemployment rates return to their steady-state level only gradually, the government is forced to keep financing its deficits by lump-sum taxation in the following periods. Even one year after the shock the impact on the fiscal balance is still significant in model economy 2.

[9] In the highest skill class part of the workers are engaged in employments with a z below 2 but above the respective reservation productivity. In the shock period, the absolute inflow into this particular group of workers from skill class $i = 2$ is smaller than its absolute outflow into unemployment. The relative share of this low-productivity group in the highest skill class thus decreases which is the explanation for the small increase in the total average productivity. See also footnote 5.

7.2 Higher Tax Rates

This section evaluates the economies' performance in a setting with higher tax rates on profits. Since taxes in this model are endogenous, the most convenient way of influencing their magnitude is to change the value of commodity purchases by the government, χ. Specifically, χ will be increased from 0.1 to 0.2 which corresponds to a size of about 8 percent of total per capita output. Moreover, the coefficient of progressiveness in the tax schedule τ^p is readjusted to 0.2, i.e. the taxation gap between low- and high-productivity jobs effectively opens up. Like before, $\overline{\tau}$ is endogenous and takes the lowest value balancing the government's budget.

Which effects can be expected from these changes? First of all, higher tax rates on profits c.p. diminish the surplus of any employment relationship, i.e. the asset value of employment will generally decrease. Furthermore, higher values of $\tau(z)$ raise the zero-surplus level $z^*(i,j)$ above which new employment relationships are established and existing ones are resumed. If $z^*(i,j)$ lies within the support of the respective productivity distribution, the fraction of accepted draws might therefore be reduced. On the other hand, the zero-surplus level is negatively affected by the more progressive tax scheme, because high-productivity employments suffer from a relatively higher taxation and therefore lose some of their attractiveness. A priori, the overall effect remains ambiguous.

Tables 12 – 15 present results for the alternative parametrisation. As can be seen, the laissez-faire economy is left completely unaffected by a higher level of government expenditures. Steady-state decision rules match those of the original setting and the population distribution remains the same, too. After all, unemployment in this setup is futile and the small value of leisure just keeps functioning as a subsidy for searching. More insightful results are obtained for model economy 2. When trying to solve for an equilibrium with the original benefit values, no stable solution can be obtained anymore. Unemployed workers in state $(4,1)$ then find it optimal to not search at all. Their prospects of finding an attractive employment are lower than the asset value of living on generous benefits forever. That is, in the absence of any outflows from this state, transfer payments and taxes would sooner or later explode. The value of high benefits is therefore reduced from 1.34 in the original setup to 1.28 in order to get a feasible solution.

The malicious effects of higher taxes in an economic environment with generous and indefinite unemployment payments are documented best in terms of search intensities which are generally lower than in the benchmark case. Financial incentives to become employed are considerably reduced by higher taxation which leaves skill accumulation instead of deterioration as the only strong incentive left. Lower search effort leads to longer unemployment spells and more and more workers ending up unemployed in the lower skill classes. Not surprisingly, a very high rate of unemployment and by far the lowest output among all setups are the consequence.

The most interesting results are obtained for the two economies with finite benefit payments. In contrast to the investigations so far, their performances in an environment with higher and more progressive taxes differ significantly. While the rate of unemployment in model economy 3 only rises by a mere 0.12 percentage points compared to the benchmark case, the respective increase in model economy 4 amounts to more than one percentage point (1.06). Furthermore, total welfare, being measured in average workers' utilities, is by far the highest in setup 3, while values were hardly distinguishable in the benchmark setting. The explanation for these divergences can not be found in terms of reservation productivities. In both economies they hardly differ from those in a low-tax setting, i.e. the positive influence of higher tax rates on the zero-surplus level and the negative influence of more progressiveness seem to offset each other. Like in model economy 2, the driving economic force which lead to quite different outcomes are the search intensities. In setup 3, workers decide to reduce their search effort only marginally. Although the asset value of employment is generally lowered by higher taxes, workers are still much worse off when unemployed, because the replacement ratio is modest and average entitlement spells are short. In contrast, higher taxation induces agents to lower their search effort considerably in setup 4. The fairly benevolent unemployment insurance structure apparently makes economy 4 more susceptible to policy changes, if they lower the value of being employed. Particular when being entitled to generous benefit payment, laid-off workers prefer to moderate their search effort and risk a loss of human capital. The resulting increase in unemployment is mainly of short- and medium-term nature.

To summarise, modifying the benchmark environment to a welfare economy with higher government purchases and implicitly higher labour taxation has spawned some interesting results. While the laissez-faire economy is left completely unaffected and workers' behaviour in setup 3 changes only slightly, the performances of economies 2 and 4 are seriously impaired. This is particularly surprising for setup 4 which seemed to exhibit very similar characteristics like setup 3 in the analysis so far. Apparently, policy changes which reduce the attractiveness of employment can arouse certain disincentives in workers' behaviour and lead to considerably more short- and medium-term unemployment.

7.3 Economic Turbulence

The model presented in this thesis builds upon the frameworks in Ljungqvist and Sargent (1998, 2004) and den Haan, Haefke and Ramey (2001, 2005). Ljungqvist and Sargent (LS) have proposed that the persistently high unemployment rates in Europe are the consequence of what they call 'more turbulent economic times'. They argue that the rapid technological changes like e.g. the transition from heavy industry and manufacturing to service sectors or the increasing importance of information technologies, in combination with the inability of European welfare states to cope with these changes, might help to explain the divergent behaviour of European and US unemployment rates over the last decades. LS incorporate this higher degree of 'economic turbulence' into a job-matching model by introducing the risk of an instantaneous loss of skill after a displacement. Their models predict that higher rates of turbulence will lead to significantly more long-term unemployment. In a reply, den Haan, Haefke and Ramey (dHHR) use a similar approach to put the results of LS into question. In their model, higher turbulence actually leads to a *decrease* in unemployment rates.

The following section shall shed some light on the underlying assumptions and mechanisms in both papers, and, furthermore, examine the implications of higher turbulence in the model considered here. Following the approach in LS (1998), I model turbulence γ as an increased probability to suffer from an instantaneous loss of skill after an exogenous job separation. dHHR actually extend turbulence to endogenous separations as well which has important implications for workers' behaviour, as explained below. Specifically, I fix the turbulence parameter at a value of $\gamma = 0.5$, i.e. 50 % of all exogenously laid-off workers instantaneously transit to a lower skill level.

Steady-state equations are modified as follows. Equation (7) is extended to

$$F_3(i,j) = V + (1-\gamma) \cdot U(i,j) + \gamma \cdot U(\min(i+1, I), j) \tag{24}$$

and equation (17) changes to

$$
\begin{aligned}
u_t(i',j') \quad = \quad & \sum_{i,j} P(i',j';i,j)\,[\ (1-\lambda(s^*(i,j))\cdot u_{t-1}(i,j)\ ] \\
& + \sum_{i,j} P(i',j';i,j)\,[\ \lambda(s^*(i,j))\cdot u_{t-1}(i,j)\cdot \nu_{i'}(z^*(i',j')\ ] \\
& + \sum_{i,j} Q(i',j';i,j)\,[\ \sigma\cdot(1-\gamma)\cdot e(i,j)\ ] \\
& + \sum_{i,j} Q(\max(i'-1,1),j';i,j)\,[\ \sigma\cdot\gamma\cdot e(i,j)\ ] \\
& + \sum_{i,j} Q(i',j';i,j)\,[\ \kappa\cdot e(i,j)\cdot \nu_{i'}(z^*(i',j'))\ ] \\
& + \sum_{i,j} Q(i',j';i,j)\,[\ (1-\sigma-\kappa)\cdot e(i,j)\cdot \nu_{i}(z^*(i',j'))\ ]\,. \qquad (25)
\end{aligned}
$$

Tables 16 – 19 report steady-state results in the presence of increased turbulence. As can be seen, unemployment rates react very differently compared to the benchmark case. While the increase amounts to 0.1-0.2 percentage points in setups 1, 3 and 4, the respective value for setup 2 shoots up by more than 2.5 percentage points. Apparently, the economy with indefinite UI payments is much more susceptible to the presence of turbulence than the other schedules. Another important observation can be made about the share of high-skilled workers: a 50 % probability of an immediate skill loss after an exogenous separation eventually doubles the share of agents in the lower two skill classes. In model 2 the share is even quadrupled.

How do workers adjust their behaviour in an economy with higher turbulence? LS argue that laid-off workers who suffer from an instant skill loss and are entitled to generous UI benefits, refuse to make much search effort and become very picky with job offers. As a consequence, higher turbulence will actually lead to more unemployment. However, their reasoning seems to be critically dependent on the assumption that only exogenous separations are affected by higher turbulence. DHHR, on the other hand, propose that when extending turbulence to endogenous separations, unemployment should actually decline. According to them, workers want to avoid the risk of bearing a skill loss after a separation and therefore demand lower wages.

In this model, I have adopted LS's approach. Unemployment rates increase in all setups, as predicted by LS. Does their rationale apply to this model as well? Interestingly, optimal decision rules suggest that it actually does not: workers do *not* become more picky and they hardly reduce their searching effort (Tables 17, 18). There are two explanations for that. First of all, in contrast to the frameworks proposed by LS and dHHR, this model distinguishes between a larger number of clearly distinct skill levels. A high-skilled worker with generous entitlements who is laid off and loses one skill level, is not in a position to become very picky. There is still the threat of a further skill downgrade which works as a strong incentive to gain employment again. In a framework with only two levels of human capital like in dHHR (2001, 2005 and LS (2004)) this is not the case: generously benefited workers in the lower skill class have actually nothing to lose and can wait for very good job offers. In LS (1998), on the other hand, skill depreciation is a continuous process which allows workers to adjust their behaviour quite instantly. In contrast, the utility gap between different skill levels is much larger in this model, and transitions are, although less probable, always pending.

Secondly, LS's reasoning for a positive relationship between more turbulence and higher unemployment seems to be critically contingent on the fact that regular UI payments are indefinite. However, the analysis in Section 6 clearly suggested that workers' incentives are strongly influenced by the duration of benefit payments. Since most countries in Europe use UI systems with finite regular payments, LS's proposal that the "European Unemployment Puzzle" can be explained by a higher degree of economic turbulence remains doubtable at least.

Evidently, the correlation of turbulence and higher rates of unemployment in this model is not primarily caused by workers' decisions. Instead, the explanation is rather to be found in the population distribution. Table 19 documents that the presence of turbulence causes an exogenous shift to lower skill levels. Now recall that steady-state values for the benchmark case indicated considerably longer unemployment spells in the lower than in the upper skill classes (Table 9). This is simply due to the fact that agents in $j = 3$ and $j = 4$ are relatively poorer and UI benefits have a relatively higher value. They prefer to consume part of their leisure value instead of spending it entirely for the costly job search. Furthermore, their prospects of advancing to a higher skill level are rather low which induces them to reject very poor job offers. As a result, the expected unemployment duration lies significantly above the respective values in the higher skill classes where workers are much more concerned about skill depreciation.

Hence, the shift in the distribution of the population explains the slight increase in the rates of unemployment in setups 1,3 and 4. How about economy 2 which sees a rather dramatic increase by 2.5 percentage points? Not surprisingly, the explanation lies in a specific feature of this economy that has already been detected before: it is the high share of unemployed people in the 'dead-end' state $(4, 1)$. Almost three percent of the entire population are (voluntarily) stuck there, with only marginal prospects to gain employment again. Long-term unemployment, large fiscal deficits and a considerably lower output compared to the other setups are the consequence.

To summarise, economic turbulence, if restricted to exogenous separations as proposed by LS, in this framework leads to significantly higher unemployment rates *only* in an economy with indefinite UI payments. An extension of turbulence to endogenous separations like in dHHR is left to future research.

8 Discussion

The comparison of different UI schemes in the preceding sections has spawned a couple of interesting results. Most importantly, it was shown that the personal stock of human capital and its evolution has important implications for workers' decisions and employment dynamics. The risk of skill deterioration during periods of unemployment clearly constitutes an incentive to gain employment. Similarly, the prospect of accumulating human capital on the job can strengthen that incentive even further. The reason is that high-skilled workers are usually more productive and receive a higher remuneration. Taking care of skills is thus essential, because they promise future income, in a sense. This is an important difference to settings where all workers are homogeneous. All other things being equal, skill evolution creates incentives to gain employment faster and, therefore, reduces unemployment spells and rates.

However, there are also counter-incentives. Firstly, job search is costly and does not guarantee a matching success at the end of the period, even when surrendering the entire leisure value. Secondly, a job offer with a low productivity draw can evoke the desire to wait for a better opportunity. Thirdly, generous UI payments from the government help to compensate for the income loss (compared to regular wage payments). In this model, workers' behaviour is completely determined by the optimal balance between those incentives. Note that when designing an UI scheme, the provider can *only* influence the last element as monitoring is not possible.

Results for the laissez-faire setup demonstrate that in this economy the balance is strongly in favour of workers' desire to avoid being unemployed at any price. When laid off, they consequently seek employment and accept any job offer. Here, the driving force is the large income loss, not the issue of skill evolution. The unemployment rate is by far the lowest among all setups. Transient employment shocks or a more difficult economic environment do not alter this result, which underpins its enormous flexibility. However, workers are, on average, significantly worse off than in the UI economies. This finding is in line with previous studies (e.g. Baily (1977), Flemming (1977), Hansen and Imhororoglu (1992)). In this model, welfare losses arise due to the inefficiency of surrendering all leisure value, and is, thus, based only indirectly on the issue of consumption smoothing. Furthermore, the urge to accept any employment impedes workers to choose carefully among job offers. As a result, the average productivity is lower than in the other setups, a finding that is in concordance with Acemoglu (2001).

Results for model 2 suggest that an UI scheme where benefits are payed indefinitely, can impair an economy's performance seriously and promote problems of moral hazard and long-term unemployment. Selectiveness in terms of job offers and minor search intensities lead to a higher share of workers seeing their skills deteriorate. Instead of reacting with intensified searching, they even decrease their effort and end up in 'trap' states. Here, skill accumulation as an incentive for higher earnings in the medium- and long-run is dominated by the short-term value of generous benefits and leisure. Higher tax rates or economic turbulence aggravate this problem even further.

Implementing a finite schedule of regular payments and, after expiration, a lower value of social assistance virtually eliminates this weakness. It is the 'entitlement effect', described in Mortensen (1977), which constitutes another incentive to leave unemployment faster. That is, workers who receive social assistance not only wish to find a job, because current payments are low. They also want to become entitled to regular UI benefits again, which only works through employment. Here, workers can only afford to select among job offers carefully as long as high UI benefits subsidise them. We have seen that longer benefit durations like in setup 4 raise average productivities. However, they also lead to slower transitions out of unemployment and, thus, a higher unemployment rate. It turns out, though, that the specific choice of replacement ratio and benefit duration does not have a large effect on output and welfare.

To summarise, most of the results are in line with the current literature and seem to make reasonable sense. It is shown that skill depreciation poses an additional threat of unemployment and can, therefore, induce workers to increase their efforts in the job-seeking process. When poorly designed, an UI scheme can corrupt this mechanism and lead to serious problems of moral hazard and long-term unemployment among the low-skilled population. Declining UI schemes over time can prevent these potential weaknesses and make individuals considerably better off than in a laissez-faire case.

A major weakness of the model is that it focuses entirely on the supply side of the labour market. Matching success does not depend on the tightness of the market, but only on workers' searching efforts. Moreover, firms' decisions are taken as rather exogenous. Business cycles and their influence on the interaction between the production process and employment dynamics cannot be examined properly. In its chosen calibration the model is, furthermore, not capable of reflecting long-term unemployment, especially among older people, in countries with finite UI schemes. Including life-cycle characteristics and modifying the parametrisation might, thus, provide new insights.

9 Concluding Remarks

This thesis was concerned with the role of human capital for the design of an optimal UI system. Using a simple search-and-matching model with heterogeneous agents, I study workers' behaviour and employment dynamics under different UI schemes. Agents are heterogeneous with respect to their stock of human capital and their entitlement to unemployment insurance benefits. When on the job, skills and entitlements tend to rise, when unemployed, they tend to fall. Human capital is important, because it positively influences the productivity and, inherently, the wage in an employment. Consequently, workers try to take care about their own skills. They tend to flow out of unemployment faster in order to avoid the risks of skill depreciation.

Unemployment insurance can make use of this mechanism. If regular benefits are limited to a finite number of periods and, after expiration, replaced by basic assistance, workers are encouraged to intensify their search effort soon after displacement. In the initial periods, fairly generous UI benefits allow workers to reject very poor job offers. When skills start to depreciate or regular benefits have expired, though, workers have strong incentives to join the productive part of the economy again. The combination of skill evolution and a wisely constructed UI scheme can impede problems with long-term unemployment almost entirely. Furthermore, results suggest that the specific choice of the replacement ratio and the (limited) duration of benefits constitutes a trade-off between the average productivity and the unemployment rate, but leave output and welfare rather unaffected.

Skill evolution works as a strong incentive for employment, but it can be corrupted by a poorly constructed UI system. I have shown that the indefinite payment of fairly generous benefits can lead to persistent unemployment and parts of the population being permanenty excluded from the productive part of the economy. Workers are rather stuck in a situation where the short-term value of leisure and benefits outweighs the potential future value of skill accumulation. The main difference to model with homogeneous agents is that the way back to a highly-productive is long and contingent. Furthermore, poor UI schedules make an economy prone to more difficult exogenous circumstances, and employment shocks can cause long recessionary periods of lower output, budget deficits and high rates of unemployment.

Finally, the finding that UI can have increasing effects on welfare, output and productivity stands in line with previous contributions. It could be overturned when allowing for private saving and borrowing, as recent research suggests. Introducing a capital market might therefore provide some new insights. Furthermore, the model focuses on the supply side of the labour market and ignores firms' behaviour almost entirely. An extension to a more general framework could e.g. allow for additional statements about business cycle implications.

References

[1] Acemoglu, Daron (1996), "*A Microfoundation for Social Increasing Returns in Human Capital Accumulation*", The Quarterly Journal of Economics; *111(3)*, p.779–804.

[2] Acemoglu, Daron (2001), "*Good Jobs versus Bad Jobs*", Journal of Labor Economics; *19(1)*, p. 1–21.

[3] Acemoglu, Daron and Shimer, Robert (2000), "*Productivity Gains from Unemployment*", European Economic Review; *44(7)*, p. 1195–1224.

[4] Baily, Martin N. (1977), "*Unemployment Insurance as Insurance for Workers*", Industrial and Labor Relations Review; *30(4)*, p. 495–504.

[5] Brown, Eleonor and Kaufold, Howard (1988), "*Human Capital Accumulation and the Optimal Level of Unemployment Insurance Provision*", Journal of Labor Economics; *6(4)*, p. 493–514.

[6] Cahuc, Pierre and Lehmann, Etienne (2000), "*Should Unemployment Benefits Decrease with the Unemployment Spell?*", Journal of Public Economics; *77*, p. 135–153.

[7] Davidson, Carl and Woodbury, Stephen A. (1997), "*Optimal Unemployment Insurance*", Journal of Public Economics; *64*, p. 359–387.

[8] den Haan, Wouter J., Haefke, Christian and Ramey, Garey (2001), "*Shocks and Institutions in a Job Matching Model*", CEPR Discussion Paper *No. 2970.*

[9] den Haan, Wouter J., Haefke, Christian and Ramey, Garey (2005), "*Turbulence and Unemployment in a Job Matching Model*", Journal of the European Economic Association *3(6)*, p. 1360–1385.

[10] Feldstein, Martin and Poterba, James (1984), "*Unemployment Insurance and Reservation Wages*", Journal of Public Economics, *23*, p. 141–167.

[11] Flemming, John S. (1977), "*Aspects of Optimal Unemployment Insurance: Search, Leisure, Savings and Capital Market Imperfections*", Journal of Public Economics; *10*, p. 403–426.

[12] Fredriksson, Peter and Holmlund, Bertil (2001), "*Optimal Unemployment Insurance in Search Equilibrium*", Journal of Labor Economics; *19*, p. 370–399.

[13] Fredriksson, Peter and Holmlund, Bertil (2006), "*Improving Incentives in Unemployment Insurance: A Review of Recent Research*", Journal of Economic Surveys; *20*, Issue 3, p. 357–386.

[14] Hansen, Gary D. and Imrohoroglu, Imre (1992), "*The Role of Unemployment Insurance in an Economy with Liquidity Constraints and Moral Hazard*", Journal of Political Economy; *100*, p. 118–143.

[15] Hopenhayn, Hugo A. and Nicolini, Juan P. (1997), "*Optimal Unemployment Insurance*", Journal of Political Economy; *105(2)*, p. 412–438.

[16] Karni, Edi (1999), "*Optimal Unemployment Insurance: A Survey*", Southern Economic Journal; *66(2)*, p. 442–465.

[17] Keane, Michael P. and Wolpin, Kenneth I. (1997), "*The Career Decisions of Young Men*", Journal of Political Economy; *105(3)*, p. 473–522.

[18] Laing, Derek, Theodore Palivos and Ping Wang (2003), "*The Economics of 'New Blood'*", Journal of Economic Theory; *112(1)*, p. 106–156.

[19] Layard, Richard, Nickell, Steven and Jackman, Richard (1991), Oxford University Press.

[20] Ljungqvist, Lars and Sargent, Thomas J. (1998), "*The European Unemployment Dilemma*", Journal of Political Economy; *106(3)*, p. 514–550.

[21] Ljungqvist, Lars and Sargent, Thomas J. (2004), "*European Unemployment and Turbulence Revisited in a Matching Model*", Journal of the European Economic Association; *2(2–3)*, p. 456–468.

[22] Marimon, Ramon and Zilibotti, Fabrizio (1999), "*Unemployment vs. Mismatch of Talents: Reconsidering Unemployment Benefits*", Economic Journal; *109, no. 455*, p. 266–291.

[23] McCall, John J. (1970), "*Economics of Information and Job Search*", The Quarterly Journal of Economics; *84(1)*, p. 113–126.

[24] Meyer, Bruce D. (1990), "*Unemployment Insurance and Unemployment Spells*", Econometrica; *58(4)*, p. 757-782.

[25] Moffitt, Robert (1985), "*Unemployment Insurance and the Distribution of Unemployment Spells*", Journal of Econometrics; *28(1)*, p. 85–101.

[26] Mortensen, Dale T. (1977), "*Unemployment Insurance and Job Search Decisions*", Industrial and Labor Relation Review; *4*, p. 505–517.

[27] Neuman, Shoshana and Weiss, Avi (1995), "*On the Effects of Schooling Vintage on Experience-Earnings Profiles: Theory and Evidence*", European Economic Review; *39(5)*, p. 943–955.

[28] OECD (1998), "*Human Capital Investment: An International Comparison*", Centre for Educational Research and Innovation; Organization for Co-operation and Development.

[29] Pissarides, Christopher A. (1992), "*Loss of Skill During Unemployment and the Persistence of Employment Shocks*, Quarterly Journal of Economics; *107(4)*, p. 1371–1391.

[30] Pissarides, Christopher A. (2000), "*Equilibrium Unemployment Theory*", MIT Press, Cambridge; 2nd Edition.

[31] Rogerson, Richard, Robert Shimer and Wright, Randall (2005), "*Search-Theoretic Models of the Labor Market: A Survey*", Journal of Economic Literature; *43(4)*, p. 959–988.

[32] Shavell, Stephen and Weiss, Laurence (1979), "*The Optimal Payment of Unemployment Insurance Benefits*", Journal of Political Economy; *87*, p. 1347–1362.

[33] Shimer, Robert and Werning, Ivan (2005), "*Liquidity and Insurance for the Unemployed*", NBER Working Paper 11689, National Bureau of Economic Research, Inc.

[34] Wang, Cheng and Williamson, Stephen (1996), "*Unemployment Insurance with Moral Hazard in a Dynamic Economy*", Carnegie-Rochester Conference Series on Public Policy *44*, p. 1–41.

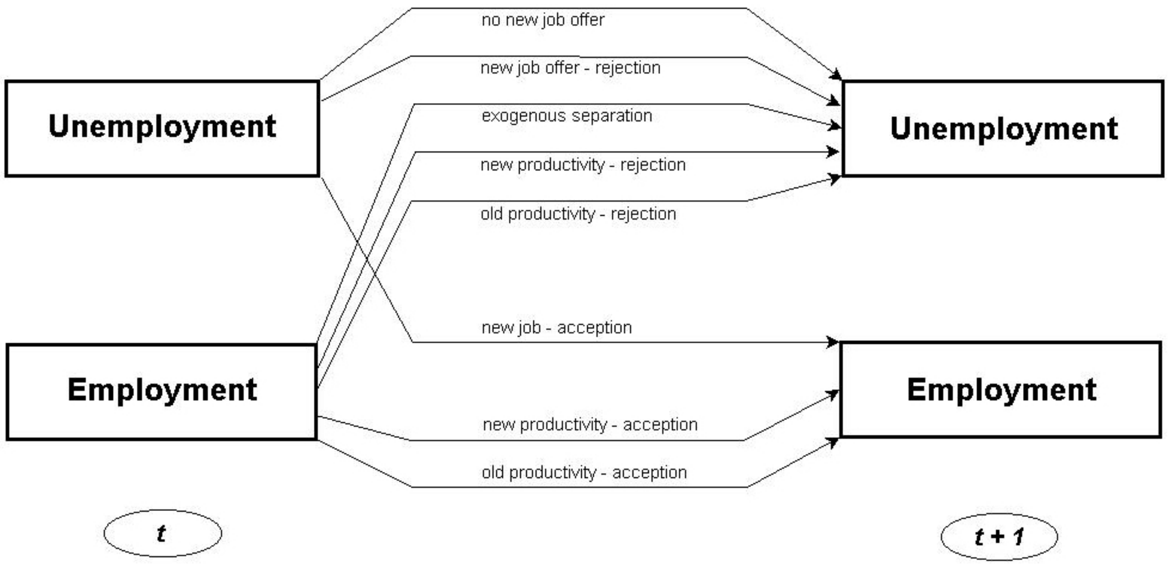

Figure 1: Population flows in the economy

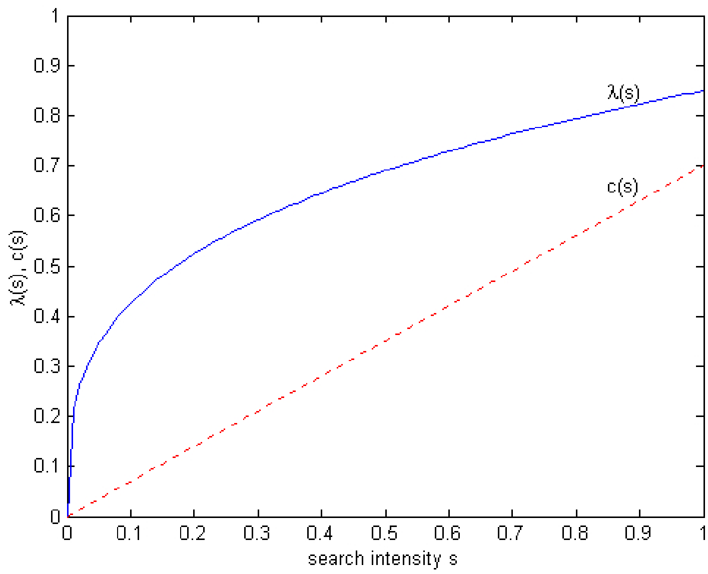

Figure 2: $\lambda(s)$ and $c(s)$

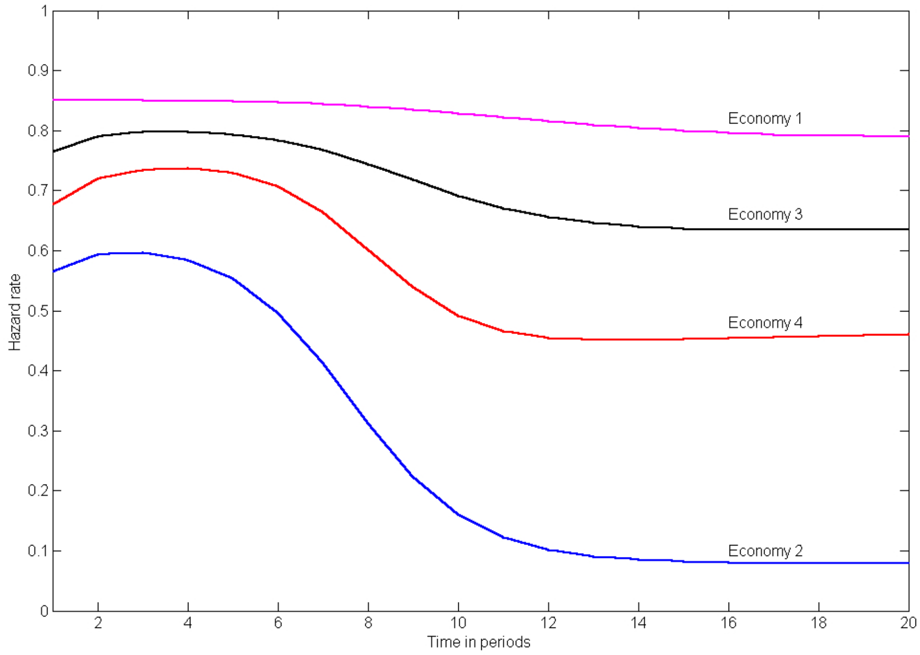

Figure 3: Hazard rates for a cohort of unemployed workers in state $(1, 1)$

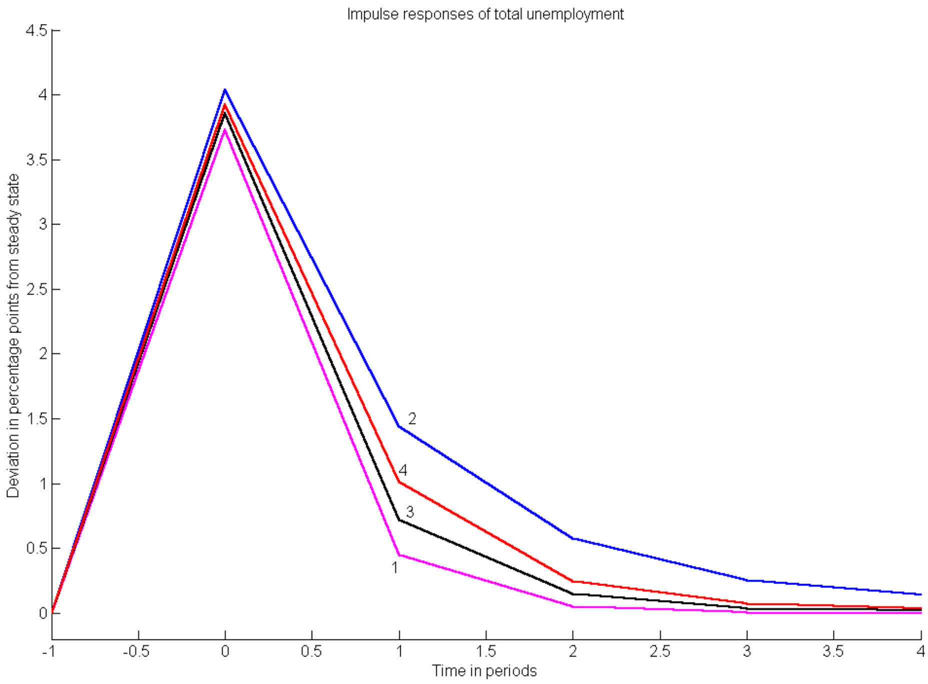

Figure 4: Impulse responses of total unemployment to an unemployment shock in the four model economies

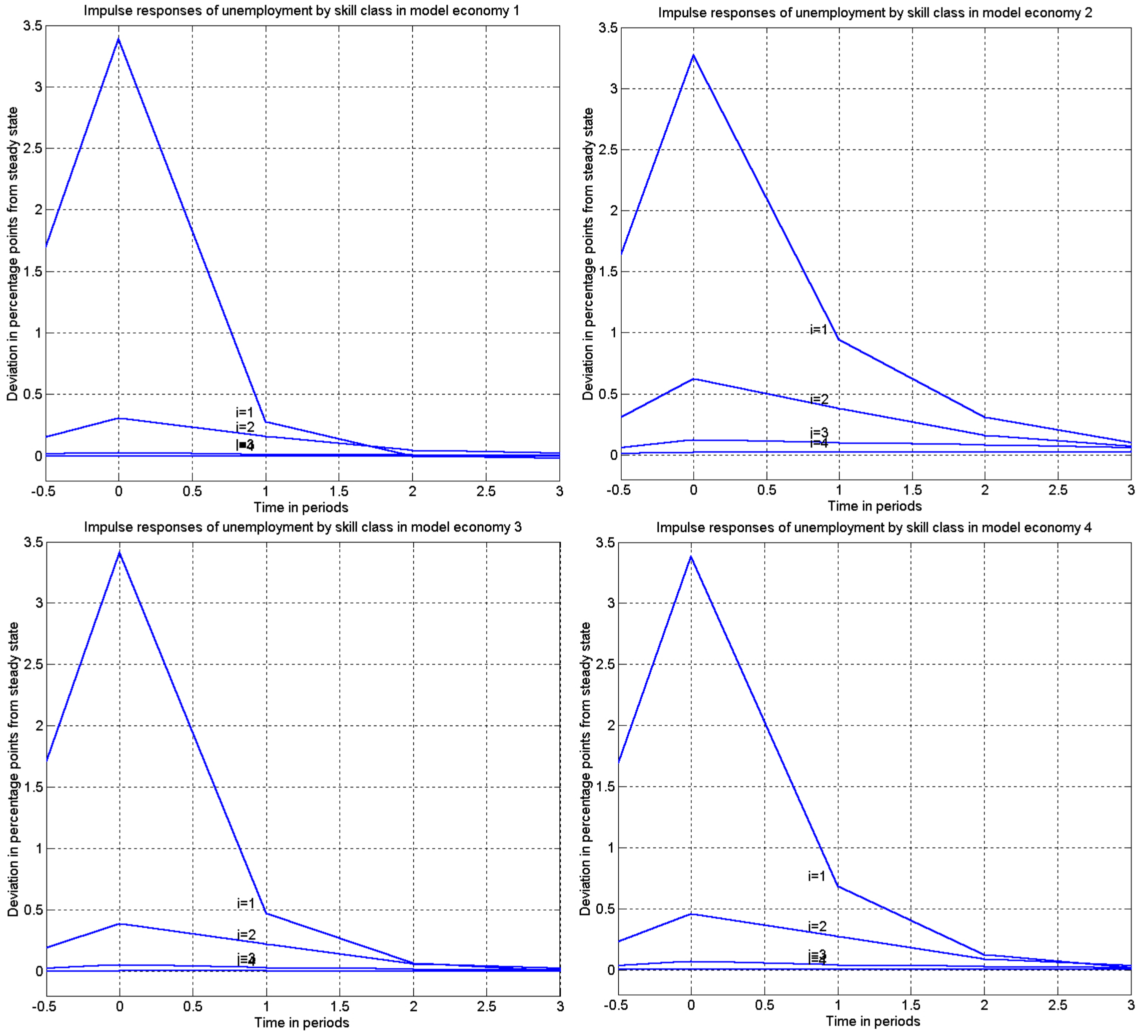

Figure 5: Impulse responses of unemployment by skill level to an unemployment shock in the four model economies

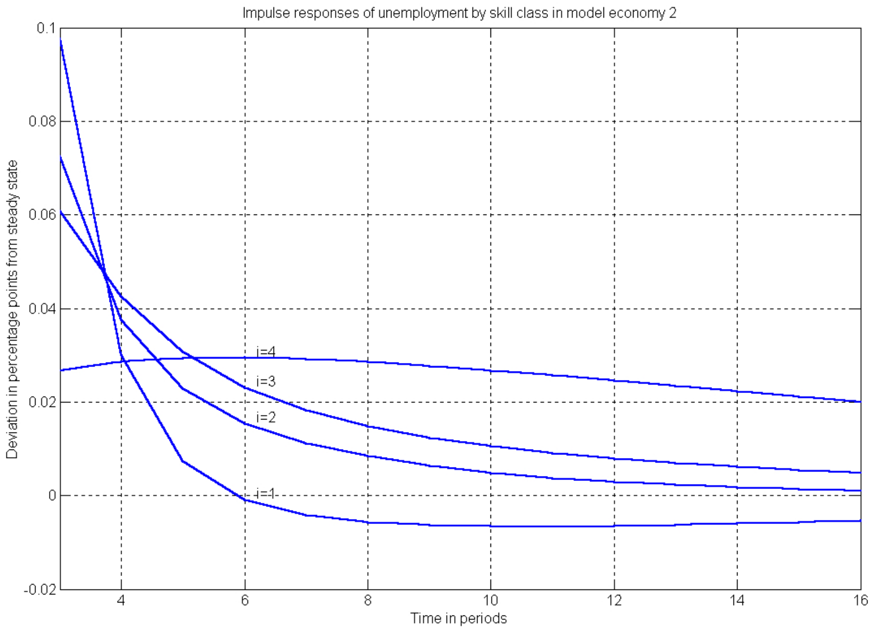

Figure 6: Impulse responses of unemployment by skill level to an unemployment shock in model economy 2 (continued)

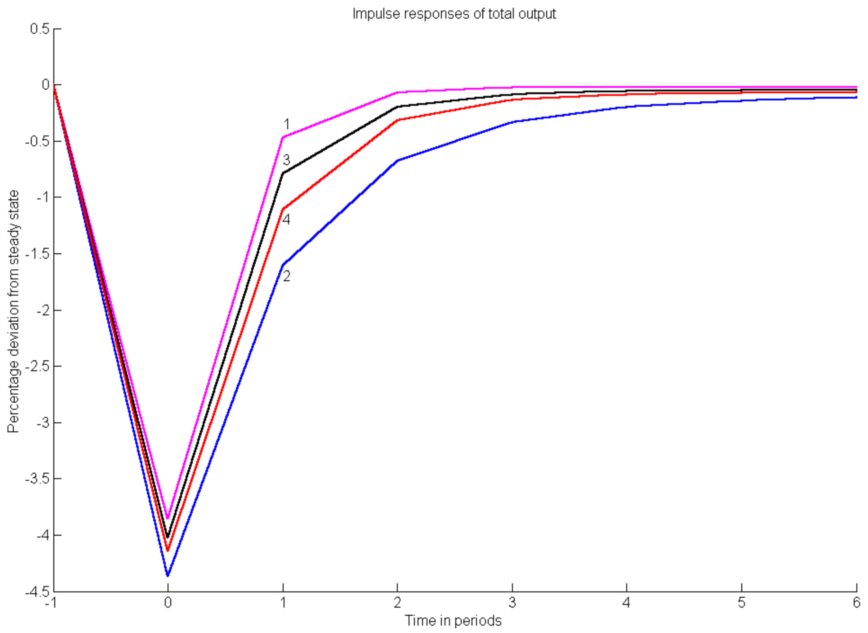

Figure 7: Impulse responses of total output to a transient unemployment shock in the four model economies

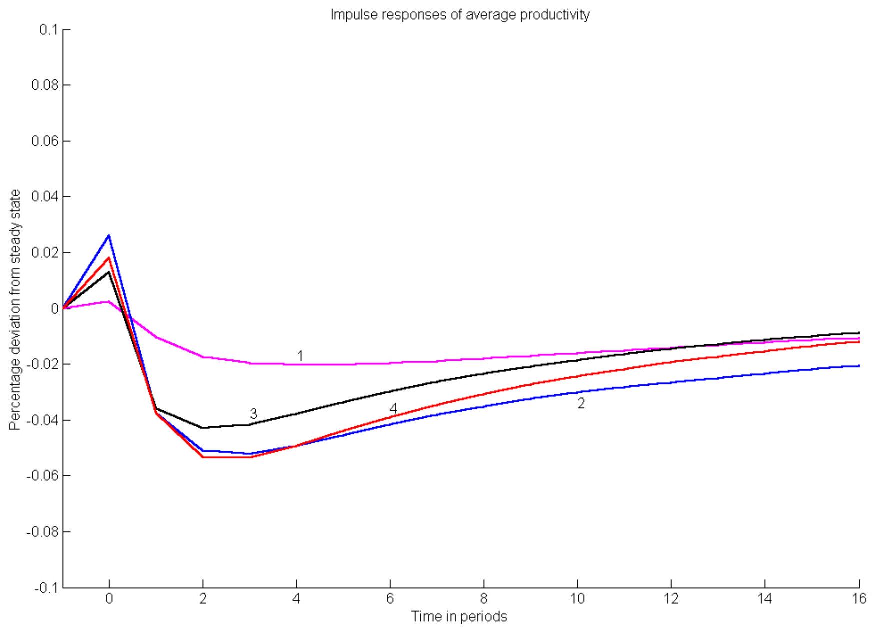

Figure 8: Impulse responses of employed workers' average productivity to a transient unemployment shock in the four model economies

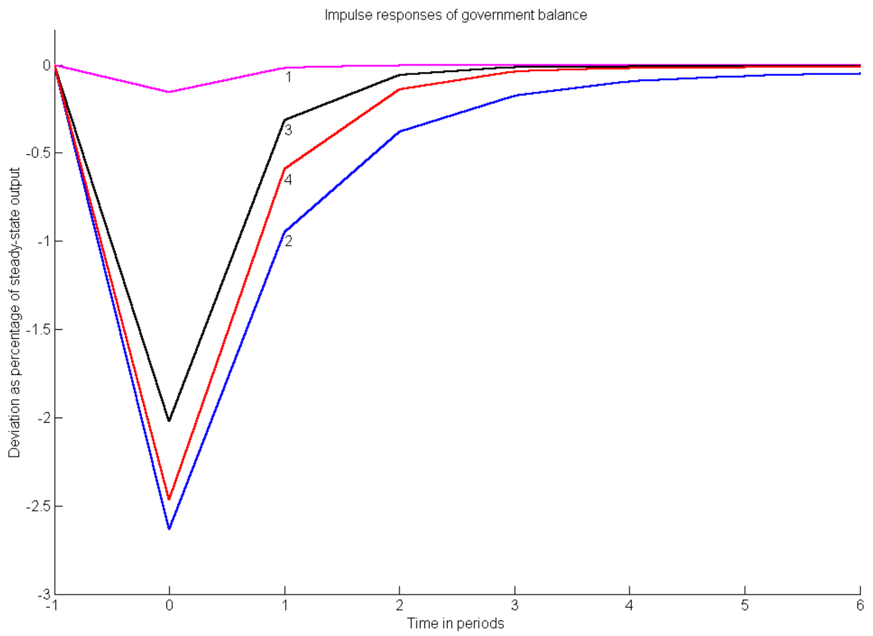

Figure 9: Impulse responses of the government balance to a transient unemployment shock in the four model economies. Deviations are measured as percentages of the steady-state output.

$P^i(i';i)$	$i'=1$	$i'=2$	$i'=3$	$i'=4$
$i=1$	0.75	0.25	0	0
$i=2$	0	0.80	0.20	0
$i=3$	0	0	0.90	0.10
$i=4$	0	0	0	1

Table 1: Transition probabilities for i while *unemployed*

$Q^i(i';i)$	$i'=1$	$i'=2$	$i'=3$	$i'=4$
$i=1$	1	0.25	0	0
$i=2$	0.25	0.75	0	0
$i=3$	0	0.0875	0.9125	0
$i=4$	0	0	0.10	0.90

Table 2: Transition probabilities for i while *employed*

Parameter	Value	Parameter	Value	Domain	Support
β	0.99	a	0.85	$[\ \underline{\nu_1}\ ,\ \overline{\nu_1}\ ]$	[2 , 3]
σ	0.03	b	0.3	$[\ \underline{\nu_2}\ ,\ \overline{\nu_2}\ ]$	[2 , 3]
κ	0.07	$\widehat{c}$	0.7	$[\ \underline{\nu_3}\ ,\ \overline{\nu_3}\ ]$	[1 , 3]
π	0.5	l	0.7	$[\ \underline{\nu_4}\ ,\ \overline{\nu_4}\ ]$	[1 , 2]
V	0	τ^p	0.01		
χ	0.1				

Table 3: Benchmark parameter values

Model	b_1	b_2	b_3	$P^j(3;1)$	$P^j(3;2)$	$Q^j(1;3)$	$Q^j(2;3)$
1: laissez-faire	-	-	-	-	-	-	-
2: 65%, indefinite	1.34	1.00	-	-	-	-	-
3: 50%, 2 periods	1.20	0.95	0.70	0.50	0.50	0.25	0.25
4: 70%, 4 periods	1.40	1.10	0.80	0.25	0.25	0.25	0.25

Table 4: Calibration of UI parameters in the four model economies

	Model 1	Model 2	Model 3	Model 4
output per capita	2.411	2.381	2.413	2.407
average productivity of employed	2.496	2.590	2.528	2.549
average wage of employed	2.255	2.254	2.252	2.251
unemployment rate (%)	3.42	8.09	4.54	5.56
share of high-skilled workers (%)	99.45	97.08	99.02	98.56
total tax revenues	0.096	0.205	0.158	0.182
total transfers	0.000	0.108	0.051	0.074
$\overline{\tau}$	0.04	0.06	0.04	0.05
τ^p	0.00	0.10	0.10	0.10
average utility (employed)	217.65	220.50	220.16	221.03
average utility (unemployed)	213.79	218.75	218.25	219.53
average utility (total)	217.52	220.36	220.07	220.95

Table 5: Steady-state values for the four model economies

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	1.801	-	-	i = 1	2.200	1.808	-
i = 2	1.000	-	-	i = 2	1.439	1.004	-
i = 3	1.002	-	-	i = 3	1.614	1.313	-
i = 4	1.000	-	-	i = 4	1.701	1.254	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	2.052	1.935	1.853	i = 1	2.122	1.935	1.783
i = 2	1.257	1.144	1.006	i = 2	1.351	1.154	1.000
i = 3	1.314	1.255	1.151	i = 3	1.433	1.321	1.131
i = 4	1.237	1.114	1.002	i = 4	1.402	1.210	1.000

Table 6: Reservation productivities in the four model economies

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	1.00	-	-	i = 1	0.44	0.66	-
i = 2	1.00	-	-	i = 2	0.70	0.99	-
i = 3	1.00	-	-	i = 3	0.40	0.69	-
i = 4	0.78	-	-	i = 4	0.02	0.21	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	0.75	0.78	0.79	i = 1	0.59	0.67	0.72
i = 2	1.00	1.00	1.00	i = 2	0.92	1.00	1.00
i = 3	0.82	0.86	0.90	i = 3	0.64	0.74	0.82
i = 4	0.28	0.35	0.38	i = 4	0.15	0.25	0.33

Table 7: Search intensities in the four model economies

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	0.85	-	-	i = 1	0.66	0.75	-
i = 2	0.85	-	-	i = 2	0.76	0.85	-
i = 3	0.85	-	-	i = 3	0.65	0.76	-
i = 4	0.79	-	-	i = 4	0.26	0.53	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	0.78	0.79	0.79	i = 1	0.73	0.75	0.77
i = 2	0.85	0.85	0.85	i = 2	0.83	0.85	0.85
i = 3	0.80	0.81	0.82	i = 3	0.74	0.78	0.80
i = 4	0.58	0.62	0.64	i = 4	0.48	0.56	0.61

Table 8: Matching probabilities in the four model economies, given the optimal search intensities.

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	0.21	-	-	i = 1	1.65	0.43	-
i = 2	0.21	-	-	i = 2	3.77	0.36	-
i = 3	0.21	-	-	i = 3	29.92	1.19	-
i = 4	0.34	-	-	i = 4	>40	3.83	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	0.38	0.33	0.32	i = 1	0.62	0.41	0.37
i = 2	0.27	0.26	0.25	i = 2	0.40	0.30	0.25
i = 3	0.59	0.50	0.41	i = 3	1.29	0.78	0.46
i = 4	1.69	1.10	0.91	i = 4	4.56	1.96	1.05

Table 9: Unconditional expected average duration of the unemployment spell in the four model economies

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	0.00	-	-	i = 1	0.03	0.00	-
i = 2	0.00	-	-	i = 2	0.03	0.01	-
i = 3	0.00	-	-	i = 3	0.19	0.03	-
i = 4	0.00	-	-	i = 4	0.72	0.13	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	0.00	0.00	0.00	i = 1	0.00	0.00	0.00
i = 2	0.00	0.00	0.00	i = 2	0.01	0.00	0.00
i = 3	0.01	0.01	0.00	i = 3	0.03	0.01	0.01
i = 4	0.05	0.02	0.02	i = 4	0.17	0.06	0.02

Table 10: Unconditional probability of becoming long-term unemployed (> 4 periods)

Model Economy 1							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	92.87	-	-	i = 1	3.18	-	-
i = 2	3.18	-	-	i = 2	0.22	-	-
i = 3	0.50	-	-	i = 3	0.02	-	-
i = 4	0.02	-	-	i = 4	0.00	-	-
Model Economy 2							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	82.73	0.23	-	i = 1	6.59	0.02	-
i = 2	6.29	0.34	-	i = 2	0.86	0.01	-
i = 3	0.50	1.53	-	i = 3	0.20	0.10	-
i = 4	0.06	0.24	-	i = 4	0.26	0.04	-
Model Economy 3							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	84.48	0.07	5.99	i = 1	3.58	0.01	0.53
i = 2	2.51	0.12	1.38	i = 2	0.17	0.00	0.18
i = 3	0.04	0.57	0.22	i = 3	0.01	0.03	0.03
i = 4	0.00	0.04	0.02	i = 4	0.00	0.00	0.00
Model Economy 4							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	84.38	0.11	3.79	i = 1	4.50	0.02	0.40
i = 2	3.70	0.19	0.96	i = 2	0.36	0.01	0.14
i = 3	0.14	0.84	0.21	i = 3	0.03	0.05	0.03
i = 4	0.00	0.09	0.02	i = 4	0.00	0.01	0.00

Table 11: Steady-state population distribution in the four model economies

	Model 1	Model 2	Model 3	Model 4
output per capita	2.411	2.356	2.409	2.401
average productivity of employed	2.496	2.591	2.527	2.568
average wage of employed	2.170	2.147	2.172	2.148
unemployment rate (%)	3.42	9.07	4.66	6.50
share of high-skilled workers (%)	99.45	96.21	98.89	98.17
total tax revenues	0.193	0.312	0.244	0.293
total transfers	0.000	0.116	0.052	0.086
$\overline{\tau}$	0.08	0.08	0.05	0.07
τ^p	0.00	0.20	0.20	0.20
average utility (employed)	210.40	210.22	213.22	211.05
average utility (unemployed)	206.70	208.04	211.46	209.63
average utility (total)	210.27	210.03	213.14	210.95

Table 12: Steady-state values for the four model economies with $\chi = 0.2$

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	1.801	-	-	i = 1	2.201	1.819	-
i = 2	1.000	-	-	i = 2	1.497	1.010	-
i = 3	1.002	-	-	i = 3	1.707	1.354	-
i = 4	1.000	-	-	i = 4	1.866	1.309	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	2.053	1.927	1.840	i = 1	2.151	1.929	1.762
i = 2	1.260	1.147	1.005	i = 2	1.359	1.155	1.000
i = 3	1.328	1.261	1.153	i = 3	1.464	1.353	1.147
i = 4	1.262	1.152	1.013	i = 4	1.455	1.257	1.000

Table 13: Reservation productivities in the four model economies with $\chi = 0.2$

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	1.00	-	-	i = 1	0.38	0.57	-
i = 2	1.00	-	-	i = 2	0.59	0.87	-
i = 3	1.00	-	-	i = 3	0.30	0.59	-
i = 4	0.73	-	-	i = 4	0.01	0.16	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	0.68	0.72	0.72	i = 1	0.51	0.59	0.65
i = 2	1.00	1.00	1.00	i = 2	0.81	0.91	1.00
i = 3	0.75	0.79	0.82	i = 3	0.55	0.64	0.73
i = 4	0.24	0.31	0.34	i = 4	0.11	0.20	0.27

Table 14: Search intensities in the four model economies with $\chi = 0.2$

Model Economy 1							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	92.87	-	-	i = 1	3.18	-	-
i = 2	3.18	-	-	i = 2	0.22	-	-
i = 3	0.50	-	-	i = 3	0.02	-	-
i = 4	0.02	-	-	i = 4	0.00	-	-
Model Economy 2							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	81.56	0.24	-	i = 1	6.71	0.02	-
i = 2	6.33	0.35	-	i = 2	0.98	0.01	-
i = 3	0.54	1.60	-	i = 3	0.28	0.11	-
i = 4	0.06	0.24	-	i = 4	0.90	0.05	-
Model Economy 3							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	84.12	0.08	6.01	i = 1	3.60	0.01	0.58
i = 2	2.54	0.14	1.42	i = 2	0.19	0.00	0.20
i = 3	0.05	0.65	0.24	i = 3	0.01	0.04	0.03
i = 4	0.00	0.06	0.03	i = 4	0.00	0.01	0.00
Model Economy 4							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	81.84	0.14	4.32	i = 1	5.14	0.02	0.50
i = 2	4.20	0.23	1.13	i = 2	0.45	0.01	0.18
i = 3	0.17	1.04	0.27	i = 3	0.05	0.07	0.04
i = 4	0.01	0.12	0.04	i = 4	0.01	0.02	0.01

Table 15: Steady-state population distribution in the four model economies with $\chi = 0.2$

	Model 1	Model 2	Model 3	Model 4
output per capita	2.370	2.277	2.376	2.370
average productivity of employed	2.457	2.552	2.494	2.514
average wage of employed	2.183	2.194	2.189	2.179
unemployment rate (%)	3.56	10.76	4.72	5.75
share of high-skilled workers (%)	94.12	88.18	93.37	92.67
total tax revenues	0.095	0.196	0.155	0.179
total transfers	0.000	0.142	0.052	0.075
$\overline{\tau}$	0.04	0.06	0.04	0.05
τ^p	0.00	0.10	0.10	0.10
average utility (employed)	213.35	216.39	216.16	215.35
average utility (unemployed)	207.70	211.23	213.04	212.21
average utility (total)	213.15	215.84	216.49	215.17

Table 16: Steady-state values for the four model economies with $\gamma = 0.5$

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	1.801	-	-	i = 1	2.201	1.855	-
i = 2	1.000	-	-	i = 2	1.453	1.000	-
i = 3	1.027	-	-	i = 3	1.717	1.358	-
i = 4	1.000	-	-	i = 4	1.848	1.266	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	2.052	1.930	1.854	i = 1	2.118	1.931	1.791
i = 2	1.228	1.112	1.000	i = 2	1.318	1.127	1.000
i = 3	1.356	1.302	1.187	i = 3	1.473	1.362	1.172
i = 4	1.254	1.136	1.009	i = 4	1.421	1.231	1.004

Table 17: Reservation productivities in the four model economies with $\gamma = 0.5$

Model 1	j = 1	j = 2	j = 3	*Model 2*	j = 1	j = 2	j = 3
i = 1	1.00	-	-	i = 1	0.43	0.67	-
i = 2	1.00	-	-	i = 2	0.67	1.00	-
i = 3	1.00	-	-	i = 3	0.33	0.65	-
i = 4	0.75	-	-	i = 4	0.01	0.18	-
Model 3	j = 1	j = 2	j = 3	*Model 4*	j = 1	j = 2	j = 3
i = 1	0.75	0.79	0.79	i = 1	0.59	0.68	0.73
i = 2	1.00	1.00	1.00	i = 2	0.92	1.00	1.00
i = 3	0.78	0.81	0.85	i = 3	0.60	0.69	0.78
i = 4	0.26	0.33	0.36	i = 4	0.13	0.23	0.30

Table 18: Search intensities in the four model economies with $\gamma = 0.5$

Model Economy 1							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	84.19	-	-	i = 1	1.58	-	-
i = 2	6.73	-	-	i = 2	1.62	-	-
i = 3	4.64	-	-	i = 3	0.24	-	-
i = 4	0.89	-	-	i = 4	0.12	-	-
Model Economy 2							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	72.20	0.62	-	i = 1	4.39	0.05	-
i = 2	7.96	0.95	-	i = 2	1.98	0.03	-
i = 3	1.33	4.42	-	i = 3	0.75	0.24	-
i = 4	0.26	1.49	-	i = 4	2.93	0.40	-
Model Economy 3							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	77.27	0.39	4.31	i = 1	2.05	0.05	0.28
i = 2	4.48	0.72	2.15	i = 2	1.40	0.02	0.26
i = 3	0.39	3.36	1.08	i = 3	0.13	0.16	0.16
i = 4	0.02	0.79	0.32	i = 4	0.01	0.13	0.08
Model Economy 4							
Employed (%)	j = 1	j = 2	j = 3	*Unemployed (%)*	j = 1	j = 2	j = 3
i = 1	76.66	0.47	2.79	i = 1	2.78	0.06	0.23
i = 2	5.81	0.80	1.31	i = 2	1.56	0.02	0.18
i = 3	0.70	3.69	0.73	i = 3	0.25	0.21	0.11
i = 4	0.05	0.98	0.27	i = 4	0.04	0.22	0.08

Table 19: Steady-state population distribution in the four model economies with $\gamma = 0.5$

A Appendix: MATLAB code

```
% steady_main.m
% This is the main file for the calculation of the steady-state decision rules.

economy = 2;                    % 1 : laissez-faire (no taxes, no benefits)
                                % 2 : 65% replacement, indefinite duration
                                % 3 : 50% replacement, finite duration (~ 2 periods)
                                % 4 : 70% replacement, finite duration (~ 4 periods)

steady_param;                   % calls the script steady_param.m in which the relevant
                                % parameters for the upcoming calculations are set
steady_init;                    % calls the script steady_init.m in which a whole bunch of
                                % things are initialised
disp(' ');
disp(sprintf('Model economy: %1.0f       Benefits   :  %4.2f (j = 1)',economy,benefit(1)));
disp(sprintf('                                     %4.2f (j = 2)', benefit(2)));
disp(sprintf('                                     %4.2f (j = 3)', benefit(3)));
disp(' ');
disp(sprintf('                        Turbulence :  %4.2f', gamma));

max_iter  = 250;                % number of iterations to calculate the steady state
next_show = 10;                 % auxiliary variable: the calculation status shall be
                                % displayed not more than ~ times
disp(' ');
for n_iter = 1 : (max_iter - 1),
    perc_iter = fix(n_iter/max_iter*10)*10;
    if (perc_iter >= next_show),
        disp(sprintf('   Calculation Status: %4.0f%% ...',perc_iter));
        next_show = perc_iter + 10;
    end;
    steady_step;                % performs one iteration of the steady-state calculation
end;
disp('   Calculation Status:  100% ... completed.');

steady_convcheck;               % calls the script steady_convcheck.m in which the
                                % convergence quality of the solution is checked

for i_ind = 1 : i_max,          % equations (9)-(10)   (calculation of wages)
for j_ind = 1 : j_max,
for z_ind = 1 : z_ind_max,
    Option_value = 0;
    for i_prime_ind = 1 : i_max,
    for j_prime_ind = 1 : j_max,
        Option_value = Option_value + betta * ( Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                        ( U(i_prime_ind,j_prime_ind) - U(i_ind,j_ind) ) );
    end;
    end;
    Option(i_ind,j_ind) = Option_value;
    w(i_ind,j_ind,z_ind) = pi * ( (1-tau(z_ind))*z_grid(z_ind) - (1-betta)*V ) + ...
```

```
                          (1 - pi)* ( (1-betta)*U(i_ind,j_ind) - Option_value);
end; % z_ind
end; % j_ind
end; % i_ind

lambda_value = lambda_coeff.*(s_grid(searchint).^lambda_exp);
                                  % calculates matching probabilities under optimal search
                                  % intensities; required for distribution calculations

disp('                              ');
disp('Optimal search intensities:    '); disp(s_grid(searchint));
disp('Threshold productivity values: '); disp(zbar_val);

save steady_results.mat

-----------------------------------------------------------------------------------------------------

% steady_param.m   (called in steady_main.m)
% In this file various parameters are set. A period is a quarter.

i_max = 4;                     % no. skill levels (1: robust high, 2: fragile high, 3: medium, 4: low)
j_max = 3;                     % no. unemployment benefit levels (1: high benefits, 2: low
                               % benefits, 3: social assistance)

betta  = 0.99;                 % discount rate between two consecutive periods
sigma  = 0.03;                 % exogenous job separation rate
kappa  = 0.07;                 % probability of getting a new productivity draw while employed

xi = 0.1;                      % per capita value of government purchases of other commodities
V  = 0;                        % value of a vacant job for the firm
pi = 0.5;                      % relative bargaining power of worker; 0 <= pi <= 1

s_minval = 0;                  % minimum search intensity for unemployed workers
s_maxval = 1;                  % maximum --------------  "  --------------------
s_step   = 0.01;               % defines interval between grid points for the search intensity
                               % use small value relative to (s_maxval - s_minval) (e.g. 1/50*(.))

c_coeff      = 0.7;            % coefficient '^c^' in search cost function:   c(s) = ^c^ * s
lambda_coeff = 0.85;           % coefficient 'a' in matching function: lambda(s) = a * s^b
lambda_exp   = 0.3;            % exponent    'b' in matching function: lambda(s) = a * s^b

l_leisval = 0.7;               % extra value of unemployment (leisure, shadow market activities, ...);
                               % here: equals cost of maximum search intensity

gamma = 0;                    % degree of 'turbulence': probability of losing one skill level after
                               % an exogenous (!) breakup

%  Transition probabilites while UNEMPLOYED (will be used to initialise array P):
   p_rob_frag = 0.25;          % from robust high skill to fragile high skill --> on avg 4 periods
   p_frag_med = 0.20;          % from fragile high skill to medium skill --> on avg 5 periods
   p_med_low  = 0.10;          % from medium skill to low skill --> on average 10 periods
```

```
%  Transition probabilites while EMPLOYED (will be used to initialise array Q):
   q_frag_rob    = 0.25;       % from fragile high skill to robust high skill --> on average 4 periods
   q_med_frag    = 0.0875;     % from medium to fragile high skill --> on average 12 periods (3 years)
   q_low_med     = 0.10;       % from low to medium skill --> on average 10 periods

   q_lowb_highb  = 0.25;       % from low to high benefits while being either robust high-skilled or
                               % fragile high-skilled (= high productivity) --> on average 4 periods
   q_highb_lowb  = 0.25;       % from high to low benefits while being low-skilled (situation:
                               % high-skilled person gets unemployed, transits to low skill while
                               % receiving high benefits and then finds a new job) --> after an
                               % average of 4 periods of working his benefit entitlements change

% tax scheme:                  % define: tau(z) = tau_flat + tau_prog * z   --->
  tau_prog = 0.01;             % check steady_init for tax scheme initialisation!

startval = 0;                  % initial values for U and G;
                               % 'good' values can be used to increase the convergence

switch economy
case 1                            % LAISSEZ-FAIRE ECONOMY
   benefit = [ 0 0 0 ];           % no benefits, taxes just to finance commodity purchases
   p_vlowb = 0;
   q_vlowb_lowb  = 1;
   q_vlowb_highb = 1;
   q_lowb_highb  = 1;
   q_highb_lowb  = 0;
   tau_flat = 0.04;               % (xi = 0.1, tau_flat = 0.04); (xi = 0.2, tau_flat = 0.08)
   tau_prog = 0;
   startval = 200;
case 2                            % 65% REPLACEMENT, INDEFINITE DURATION
   benefit = [ 1.28  1  0 ];
   p_vlowb  = 0;
   q_vlowb_lowb  = 1;
   q_vlowb_highb = 1;
   tau_flat = 0.06;               % (xi = 0.1,tau_flat = 0.06);(xi = 0.2/gamma = 0.5,tau_flat = 0.08)
   startval = 205;
case 3
   benefit = [ 1.2  0.95  0.7 ];  % 50% REPLACEMENT, FINITE (CA. 2 PERIODS = 0.5 YEARS)
   p_vlowb = 0.5;                 % while unempl: from high/low benefits to social assistance
   q_vlowb_lowb  = 0.25;          % while empl: from social assistance to low benefits  (avg 1 year)
   q_vlowb_highb = 0.25;          % while empl: from social assistance to high benefits (avg 1 year)
   tau_flat = 0.04;               % (xi = 0.1, tau_flat = 0.04); (xi = 0.2, tau_flat = 0.05)
   startval = 220;
case 4
   benefit = [ 1.4  1.1  0.8 ];   % 70% REPLACEMENT, FINITE (CA. 4 PERIODS = 1.0 YEARS)
   p_vlowb  = 0.25;               % while unempl: from high/low benefits to social assistance
   q_vlowb_lowb  = 0.25;          % while empl: from social assistance to low benefits  (avg 1 year)
   q_vlowb_highb = 0.25;          % while empl: from social assistance to high benefits (avg 1 year)
   tau_flat = 0.05;               % (xi = 0.1, tau_flat = 0.05); (xi = 0.2, tau_flat = 0.07)
   startval = 200;
```

```
otherwise
    disp('WARNING!!! No valid economy chosen! Check steady_main.m!');
end;

z_low_left   = 1;             % LOWER limit of productivity distribution for LOW-skilled workers;
z_low_right  = 2;             % UPPER limit of productivity distribution for LOW-skilled workers
                              % Condition: z_low_left < z_low_right

z_med_left   = 1;             % LOWER limit of productivity distribution for MEDIUM-skilled workers;
z_med_right  = 3;             % UPPER limit of productivity distribution for MEDIUM-skilled workers;
                              % Condition: z_med_left < z_med_right

z_high_left  = 2;             % LOWER limit of productivity distribution for HIGH-skilled workers
z_high_right = 3;             % UPPER limit of productivity distribution for HIGH-skilled workers
                              % Condition: z_high_left < z_high_right

z_step  = 0.05;               % defines interval between grid points
                              % use small value relative to domain size (e.g. 1/20 * domain size)

status_max = 2;               % status = 1: unemployed, status = 2: employed

-------------------------------------------------------------------------------------------------------

% steady_init.m   (called in steady_main.m)
% In this file a bunch of things are initialised. steady_param has to be executed before.

init_PQ;                      % calls the script init_PQ.m in which the transition probability
                              % arrays P and Q are initialised

s_grid    = [ s_minval : s_step : s_maxval ];    % creates a grid over the range of possible
                                                 % search intensities
s_ind_max = length(s_grid);                      % length of grid (no. of index points)

z_minval = z_low_left   - z_step;                % defines lower limit of grid
z_maxval = z_high_right + z_step;                % defines upper limit of grid

z_grid = [ z_minval : z_step : z_maxval ];       % creates grid

z_ind_max = length(z_grid);                      % length of grid (no. of index points)

z_ind_left  = [find(abs(z_grid - z_high_left) < 0.001),find(abs(z_grid - z_high_left) < 0.001),...
               find(abs(z_grid - z_med_left)  < 0.001),find(abs(z_grid - z_low_left)  < 0.001)];
z_ind_right = [find(abs(z_grid - z_high_right)< 0.001),find(abs(z_grid - z_high_right)< 0.001),...
               find(abs(z_grid - z_med_right) < 0.001),find(abs(z_grid - z_low_right) < 0.001)];
                % creates index vectors of left and right domain limits; here: four skill levels

z_val_left  = [ z_high_left , z_high_left , z_med_left , z_low_left  ]';  % lower domain limits
z_val_right = [ z_high_right, z_high_right, z_med_right, z_low_right ]';  % upper domain limits

nu_dens = zeros(i_max,z_ind_max);                % provides the probability densities nu(i)
```

```
% The following loop fills nu_dens with probability densities for the different skill levels.
% Note that a continuous uniform distribution is assumed and approximated by discretisation.
% Furthermore, a quick calculation checks whether the generated distribution is valid in the
% sense that its density function integrates to one!

for i_ind = 1 : i_max,
    nu_dens(i_ind, z_ind_left(i_ind) : z_ind_right) = 1/(z_val_right(i_ind) - z_val_left(i_ind));
    integ = [ z_grid( z_ind_left(i_ind) : z_ind_right(i_ind) ) ];
    nu_densint = [ nu_dens(i_ind, z_ind_left(i_ind) : z_ind_right(i_ind) ) ];
    integval = trapz(integ, nu_densint);
    if (abs(1 - integval) > 0.001),
        disp('WARNING: Invalid density function! Integral does not sum up to one.');
    end;
end;

S = zeros(i_ind,j_max,z_ind_max+1);     % S denotes the matrix of surpluses; initial values are
for i_ind = 1 : i_max,                  % set to zero; the 'z_ind_max+1'-entry guarantees a
    for j_ind = 1 : j_max,              % positive entry for z_bar and is filled in this loop!
        S(i_ind,j_ind,z_ind_max+1) = 1;
    end;
end;

zbar_ind  = zeros(i_max,j_max);
zbar_frac = zeros(i_max,j_max);
zbar_val  = zeros(i_max,j_max);

tau = ones(1,z_ind_max);                % initialises tax scheme
for z_ind = 1 : z_ind_max,
    tau(1,z_ind) = tau_flat + tau_prog * z_grid(z_ind);
end;

U = startval*ones(i_max,j_max);
G = startval*ones(i_max,j_max,z_ind_max);

E = zeros(i_max,j_max);

F_1 = ones(i_max,j_max,z_ind_max);
F_2 = ones(i_max,j_max);
F_3 = ones(i_max,j_max);

U_value      = zeros(s_ind_max,1);
searchint    = zeros(i_max,j_max);
lambda_value = zeros(i_max,j_max);

Option = zeros(i_max,j_max);
w      = zeros(i_max,j_max,z_ind_max);

-----------------------------------------------------------------------------------------------------

% init_PQ.m   (called in steady_init.m)
% In this file the transition probability arrays P and Q are initialised.
```

```
P = zeros(i_max,j_max,i_max,j_max);             % initialises array P (transition probabilities
                                                % while unemployed)

P(1,1,1,1) = (1 - p_rob_frag) * (1 - p_vlowb);    % current status:
P(1,3,1,1) = (1 - p_rob_frag) *      p_vlowb ;    % --------------
P(2,1,1,1) =      p_rob_frag  * (1 - p_vlowb);    % robust high skill and
P(2,3,1,1) =      p_rob_frag  *      p_vlowb ;    % high benefits

P(2,1,2,1) = (1 - p_frag_med) * (1 - p_vlowb);    % current status:
P(2,3,2,1) = (1 - p_frag_med) *      p_vlowb ;    % --------------
P(3,1,2,1) =      p_frag_med  * (1 - p_vlowb);    % fragile high skill and
P(3,3,2,1) =      p_frag_med  *      p_vlowb ;    % high benefits

P(1,2,1,2) = (1 - p_rob_frag) * (1 - p_vlowb);    % current status:
P(1,3,1,2) = (1 - p_rob_frag) *      p_vlowb ;    % --------------
P(2,2,1,2) =      p_rob_frag  * (1 - p_vlowb);    % robust high skill and
P(2,3,1,2) =      p_rob_frag  *      p_vlowb ;    % low benefits

P(2,2,2,2) = (1 - p_frag_med) * (1 - p_vlowb);    % current status:
P(2,3,2,2) = (1 - p_frag_med) *      p_vlowb ;    % --------------
P(3,2,2,2) =      p_frag_med  * (1 - p_vlowb);    % fragile high skill and
P(3,3,2,2) =      p_frag_med  *      p_vlowb ;    % low benefits

P(3,1,3,1) = (1 - p_med_low)  * (1 - p_vlowb);    % current status:
P(3,3,3,1) = (1 - p_med_low)  *      p_vlowb ;    % --------------
P(4,1,3,1) =      p_med_low   * (1 - p_vlowb);    % medium skill and
P(4,3,3,1) =      p_med_low   *      p_vlowb ;    % high benefits

P(3,2,3,2) = (1 - p_med_low)  * (1 - p_vlowb);    % current status:
P(3,3,3,2) = (1 - p_med_low)  *      p_vlowb ;    % --------------
P(4,2,3,2) =      p_med_low   * (1 - p_vlowb);    % medium skill and
P(4,3,3,2) =      p_med_low   *      p_vlowb ;    % low benefits

P(1,3,1,3) = (1 - p_frag_med)                ;    % current status:
P(2,3,1,3) =      p_frag_med                 ;    % robust high skill and very low benefits

P(2,3,2,3) = (1 - p_frag_med)                ;    % current status:
P(3,3,2,3) =      p_frag_med                 ;    % fragile high skill and very low benefits

P(3,3,3,3) = (1 - p_med_low)                 ;    % current status:
P(4,3,3,3) =      p_med_low                  ;    % medium skill and very low benefits

P(4,1,4,1) =                    (1 - p_vlowb);    % current status:
P(4,2,4,1) =                         p_vlowb ;    % low skill and high benefits

P(4,2,4,2) =                    (1 - p_vlowb);    % current status:
P(4,3,4,2) =                         p_vlowb ;    % low skill and low benefits

P(4,3,4,3) = 1                               ;    % current status: low skill & very low benefits
```

```
% ----------------------------------------------------------------------------------------------

Q = zeros(i_max,j_max,i_max,j_max);              % initialises array Q (transition probabilities
                                                 % while employed)

Q(4,3,4,3) = (1 - q_low_med)  * (1 - q_vlowb_lowb) ;  % current status:
Q(4,2,4,3) = (1 - q_low_med)  *      q_vlowb_lowb  ;  % --------------
Q(3,3,4,3) =      q_low_med   * (1 - q_vlowb_lowb) ;  % low skill and
Q(3,2,4,3) =      q_low_med   *      q_vlowb_lowb  ;  % very low benefits

Q(3,3,3,3) = (1 - q_med_frag) * (1 - q_vlowb_lowb) ;  % current status:
Q(3,2,3,3) = (1 - q_med_frag) *      q_vlowb_lowb  ;  % --------------
Q(2,3,3,3) =      q_med_frag  * (1 - q_vlowb_lowb) ;  % medium skill and
Q(2,2,3,3) =      q_med_frag  *      q_vlowb_lowb  ;  % very low benefits

Q(2,3,2,3) = (1 - q_frag_rob) * (1 - q_vlowb_highb);  % current status:
Q(2,1,2,3) = (1 - q_frag_rob) *      q_vlowb_highb ;  % --------------
Q(1,3,2,3) =      q_frag_rob  * (1 - q_vlowb_highb);  % fragile high skill and
Q(1,1,2,3) =      q_frag_rob  *      q_vlowb_highb ;  % very low benefits

Q(1,3,1,3) =                    (1 - q_vlowb_highb);  % current status:
Q(1,1,1,3) =                         q_vlowb_highb ;  % robust high skill and very low benefits

Q(4,2,4,2) = (1 - q_low_med)                       ;  % current status:
Q(3,2,4,2) =      q_low_med                        ;  % low skill and low benefits

Q(3,2,3,2) = (1 - q_med_frag)                      ;  % current status:
Q(2,2,3,2) =      q_med_frag                       ;  % medium skill and low benefits

Q(2,2,2,2) = (1 - q_frag_rob) * (1 - q_lowb_highb) ;  % current status:
Q(2,1,2,2) = (1 - q_frag_rob) *      q_lowb_highb  ;  % --------------
Q(1,2,2,2) =      q_frag_rob  * (1 - q_lowb_highb) ;  % fragile high skill and
Q(1,1,2,2) =      q_frag_rob  *      q_lowb_highb  ;  % low benefits

Q(1,2,1,2) =                    (1 - q_lowb_highb) ;  % current status:
Q(1,1,1,2) =                         q_lowb_highb  ;  % robust high skill and low benefits

Q(4,1,4,1) = (1 - q_low_med) * (1 - q_highb_lowb)  ;  % current status:
Q(4,2,4,1) = (1 - q_low_med) *      q_highb_lowb   ;  % --------------
Q(3,1,4,1) =      q_low_med  * (1 - q_highb_lowb)  ;  % low skill and
Q(3,2,4,1) =      q_low_med  *      q_highb_lowb   ;  % high benefits

Q(3,1,3,1) = (1 - q_med_frag) * (1 - q_highb_lowb) ;  % current status:
Q(3,2,3,1) = (1 - q_med_frag) *      q_highb_lowb  ;  % --------------
Q(2,1,3,1) =      q_med_frag  * (1 - q_highb_lowb) ;  % medium skill and
Q(2,2,3,1) =      q_med_frag  *      q_highb_lowb  ;  % high benefits

Q(2,1,2,1) = (1 - q_frag_rob)                      ;  % current status:
Q(1,1,2,1) =      q_frag_rob                       ;  % fragile high skill and high benefits
```

```
Q(1,1,1,1) = 1                                      ;  % status: robust high skill and high benefits


% For debugging:

for i_ind = 1 : i_max,                                 % checks whether transition arrays are
    for j_ind = 1 : j_max,                             % initialised properly
        P_sum(i_ind,j_ind) = sum(sum(P(:,:,i_ind,j_ind)));
        Q_sum(i_ind,j_ind) = sum(sum(Q(:,:,i_ind,j_ind)));
        if ( P_sum(i_ind,j_ind) - 1  >  0.001),        % checks whether P is properly initialised
            disp('        ');
            disp('WARNING: Probabilities in matrix P do not sum up to 1. Check file "init_PQ"!');
            disp('        ');
            disp('Press any key to continue.')
            pause
        end;
        if ( Q_sum(i_ind,j_ind) - 1  >  0.001),        % checks whether Q is properly initialised
            disp('        ');
            disp('WARNING: Probabilities in matrix Q do not sum up to 1. Check file "init_PQ"!');
            disp('        ');
            disp('Press any key to continue.')
            pause
        end;
    end;
end;

-----------------------------------------------------------------------------------------------------

% steady_step.m   (called in steady_main.m)
% In this script one step of the iteration procedure to calculate the steady-state values
% for various variables is performed. The input variables are U(i_ind,j_ind) and
% G(i_ind,j_ind,z_ind) denoting the values of different unemployment and employment states.

for i_ind = 1 : i_max,                 % equations (1)-(6)
for j_ind = 1 : j_max,

   for z_ind = 1 : z_ind_max,          % calculate S(i,j,z)
       S(i_ind,j_ind,z_ind) = (1- tau(z_ind)) * z_grid(z_ind) + G(i_ind,j_ind,z_ind) - ...
                               V - U(i_ind,j_ind);
   end;

   zbar_ind_here = min(find(S(i_ind,j_ind,:)>0)) - 1;
                                       % zbar_ind_here is an integer value, giving the highest
                                       % grid point index, for which NO S value is POSITIVE
                                       % until and INCLUDING this grid point.
   % ---------------------------------------------------------------------------------------
   % The following part approximates the true value of z_bar:
   if (zbar_ind_here >= 1) & (zbar_ind_here < z_ind_max),      % interior solution!
       S_left  = S(i_ind,j_ind,zbar_ind_here  );
       S_right = S(i_ind,j_ind,zbar_ind_here+1);
       zbar_frac_here = max(min(1,S_left/(S_left-S_right)),0);
```

```
        % zbar_frac_here = 0 if S_left = 0, and = 1 if S_right = 0!
    else
        zbar_frac_here = 0;
    end;
    zbar_ind_here = max(1,zbar_ind_here);
    zbar_ind (i_ind,j_ind) = zbar_ind_here;
    zbar_frac(i_ind,j_ind) = zbar_frac_here;
    zbar_val (i_ind,j_ind) = (1- zbar_frac_here) * z_grid(zbar_ind_here) + ...
           zbar_frac_here * z_grid(min( zbar_ind_here+1,z_ind_max ));

    % -------------------------------------------------------------------------------------
    % In the following part the value of E(i_ind,j_ind) is calculated:
    integrand = zeros(z_ind_max,1);
    for z_prime_ind = 1 : z_ind_max,
        integrand(z_prime_ind) = S(i_ind,j_ind,z_prime_ind) * nu_dens(i_ind,z_prime_ind);
    end;
    Int_val = 0;
    if zbar_ind(i_ind,j_ind) < z_ind_left(i_ind),          % accept all job offers
        z_left_ind = z_ind_left(i_ind);
        z_right_ind = z_ind_right(i_ind);
    else                                                    % only accept jobs above zbar -
        zbar_here = zbar_ind(i_ind,j_ind);                  % the usual case!!
        z_left_ind = zbar_here + 1;
        z_right_ind = z_ind_right(i_ind);
        Int_val = 0.5*(1-zbar_frac(i_ind))* ...             % calculate size of initial triangle
            ( z_grid(min(zbar_here+1,z_ind_max))-z_grid(zbar_here) ) * ...
            integrand(min(zbar_here+1,z_ind_max));
    end;
    for z_prime_ind = z_left_ind : (z_right_ind-1),         % add the remaining trapezes
       Int_val = Int_val + ...
           0.5*(integrand(z_prime_ind+1) + integrand(z_prime_ind))*...
               (    z_grid(z_prime_ind+1) -     z_grid(z_prime_ind));
    end;
    E(i_ind,j_ind) = Int_val;
    % ------------------------------------------------------------------------------------
    for z_ind = 1 : z_ind_max,
        F_1(i_ind,j_ind,z_ind) = max( S(i_ind,j_ind,z_ind),0 ) + V + U(i_ind,j_ind);
    end;
    F_2(i_ind,j_ind) = E(i_ind,j_ind) + V + U(i_ind,j_ind);
    F_3(i_ind,j_ind) = V + (1-gamma)*U(i_ind,j_ind) + gamma*U(min(i_ind+1,4),j_ind);

end;  % j_ind
end;  % i_ind                                       % equations (1)-(6)


for i_ind = 1 : i_max,                              % equation (7)
for j_ind = 1 : j_max,
   for s_ind = 1 : s_ind_max,
      U_value(s_ind) = l_leisval + benefit(j_ind) - c_coeff*(s_grid(s_ind));
      for i_prime_ind = 1 : i_max,
      for j_prime_ind = 1 : j_max,
```

```
         U_value(s_ind) = U_value(s_ind)+P(i_prime_ind,j_prime_ind,i_ind,j_ind)*...
                          betta * (lambda_coeff*s_grid(s_ind)^lambda_exp * pi * ...
                          E(i_prime_ind,j_prime_ind) + U(i_prime_ind,j_prime_ind));
      end;
      end;
   end;
   [U(i_ind,j_ind), searchint(i_ind,j_ind)] = max(U_value);
end;
end;


for i_ind = 1 : i_max,                              % equation (8)
for j_ind = 1 : j_max,
   for z_ind = 1 : z_ind_max,
      G_value = 0;
      for i_prime_ind = 1 : i_max,
      for j_prime_ind = 1 : j_max,
         G_value = G_value + betta * ...
                   ( (1-kappa-sigma) * Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                                       F_1(i_prime_ind,j_prime_ind,z_ind) + ...
                               kappa * Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                                       F_2(i_prime_ind,j_prime_ind) + ...
                               sigma * Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                                       F_3(i_prime_ind,j_prime_ind) );
      end;
      end;
      G(i_ind,j_ind,z_ind) = G_value;
    end;
end;
end;

-----------------------------------------------------------------------------------------------------

% steady_convcheck.m   (called in steady_main.m)
% In this file the convergence quality of the solution is checked. If the relative change of
% the current solution values over the next iteration step exceeds a critical value (e.g.
% 0.01 percent), a warning message is displayed.

U_old = U;                        % saves matrix U before final iteration step
G_old = G;                        % saves matrix G before final iteration step

steady_step;                      % do final iteration step

conv_crit = 0.01;                 % critical value which shall not be exceeded (e.g. 0.01 percent)

reldiff_U = 100 * abs(U - U_old)./U;   % relative differences in the values of U and G compared
reldiff_G = 100 * abs(G - G_old)./G;   % to previous the previous step are calculated here

if (max(reldiff_U) > conv_crit),
   disp(' ');
   disp(sprintf('WARNING!!! The convergence criterion of %5.3g%% is not fulfilled! You might'...
```

```
                                                                                    ,conv_crit));
   disp('consider increasing the no. of iterations or choosing better starting values!');
elseif (max(max(max(reldiff_G))) > conv_crit),
   disp(' ');
   disp(sprintf('WARNING!!! The convergence criterion of %5.3g%% is not fulfilled! You might'...
                                                                                    ,conv_crit));
   disp('consider increasing the no. of iterations or choosing better starting values!');
end;
```

```
----------------------------------------------------------------------------------------------------

% distr_main.m
% This is the main file for the calculation of the steady-state population distribution.

distr_init;                     % calls the script distr_init.m in which a bunch of things are
                                % initialised and various parameters are set

distr_max_iter = 20;            % number of iterations to calculate the steady-state distribution

%sigma = 0.06;                           % change parameters here e.g. for a one-period shock
%lambda_value = lambda_value * 5/7;      % transition; note: more than 1 transition usually does
                                         % not make sense since agents modify decision rules

disp(' ');

for distr_iter = 1 : distr_max_iter,
    disp(sprintf('Calculation Status: %4.0f%% ...', distr_iter/distr_max_iter*100));
    distr_step;
end;


save distrib_new.mat mu         % saves the distribution matrix mu to a file named distrib_new.mat;
                                % if you want to use this result as an initial distribution another
                                % time, rename the file distrib_new.mat and modify distr_init.m

save dist_results               % saves all variables in the workspace to a file named dist_results;
                                % to reload the results quickly, type 'load dist_results'!

distr_results;                  % calls the script distr_results.m which analyses the results of the
                                % population distribution calculation

----------------------------------------------------------------------------------------------------

% distr_init.m   (called in distr_main.m)
% In this file the steady-state results are loaded and matrices mu and nu are initialised/loaded.

LOAD_STEADY_STATE         = 1;

if LOAD_STEADY_STATE,           % loads data file which contains all relevant variables
   load steady_turb_2.mat       % and values
end;
```

```
LOAD_INITIAL_DISTRIBUTION = 1;  % e.g. use an initial distribution to get to good results faster

if LOAD_INITIAL_DISTRIBUTION,
    load distr_mu_turb_2.mat         % should contain ONLY the distribution matrix mu
else
    mu = zeros(i_max,j_max,status_max,z_ind_max);  % starting distribution: all people unemployed
    mu(1:i_max,j_max,1) = 1/i_max;                 % and with the lowest productivity level
                                                   % equally distributed across all skills
end;

mu_old = mu;

init_nu;                        % calls the script init_nu.m in which the matrices of acceptance
                                % probability masses and rejection probability masses are
                                % calculated based on the steady-state decision rules

-----------------------------------------------------------------------------------------------------

% init_nu.m   (called in distr_main.m)
% In this file the matrices of acceptance probability masses and rejection probability masses
% are calculated based on the steady state decision rules.

nu_acc_mass = zeros(i_max,j_max,z_ind_max);
nu_rej_mass = zeros(i_max,j_max,z_ind_max);

for i_ind = 1 : i_max,
for j_ind = 1 : j_max,
for z_ind = 1 : z_ind_max,

   if ( z_ind >= z_ind_left(i_ind) ) & ( z_ind <= z_ind_right(i_ind) ),    % within domain

      % ---------------------------------------------------------------------------------------

      if (z_ind == zbar_ind(i_ind,j_ind)),              % FIRST CASE

         if ( zbar_frac(i_ind,j_ind) < 0.5 ) & ( z_ind < z_ind_right(i_ind) ),
                                                        % a fraction is in acceptance part!
             nu_acc_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                         max(0,0.5-zbar_frac(i_ind,j_ind)) * (z_grid(z_ind+1) - z_grid(z_ind));
                                                        % this fraction is calculated here
         end;

         if ( z_ind == z_ind_left(i_ind) ),             % prob mass only to the right
             nu_rej_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                         (z_grid(z_ind+1) - z_grid(z_ind)) * min (0.5, zbar_frac(i_ind,j_ind));
                                                        % remaining fraction goes to rej_mass
         elseif ( z_ind == z_ind_right(i_ind) ),        % prob mass only to the left
             nu_rej_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                         (z_grid(z_ind) - z_grid(z_ind-1))*0.5;
                                                        % full rej mass to the left
```

```
   else                                           % prob mass to both sides
       nu_rej_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
           ( 0.5*(z_grid(z_ind) - z_grid(z_ind-1)) + ...
                   min(0.5,zbar_frac(i_ind,j_ind))*(z_grid(z_ind+1) - z_grid(z_ind)) );
   end;

% ---------------------------------------------------------------------------------------

elseif (z_ind == zbar_ind(i_ind,j_ind) + 1),      % SECOND CASE

   if (z_ind == z_ind_left(i_ind)),               % prob mass only to the right
       nu_acc_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                   ( z_grid(z_ind+1) - z_grid(z_ind) ) * 0.5;
                                                  % full acc mass to the right
   elseif (z_ind == z_ind_right(i_ind)),          % prob mass only to the left
       nu_acc_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                   ( z_grid(z_ind) - z_grid(z_ind-1) ) * min(0.5, 1 - zbar_frac(i_ind,j_ind));
                                                  % full or fraction of acc mass to the left
   else
       nu_acc_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                   ( ( z_grid(z_ind) - z_grid(z_ind-1) ) * ...
                   min(0.5, 1 - zbar_frac(i_ind,j_ind)) + (z_grid(z_ind+1) - ...
                   z_grid(z_ind))*0.5 );         % full acc mass to the right and full OR
                                                 % fraction of acc to the left
   end;
   if ( (zbar_frac(i_ind,j_ind) > 0.5) & (z_ind > z_ind_left(i_ind)) ),  % fraction is rej part!
       nu_rej_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                   max(0,zbar_frac(i_ind,j_ind)-0.5) * (z_grid(z_ind) - z_grid(z_ind-1));
   end;

% ---------------------------------------------------------------------------------------

elseif ( z_ind > zbar_ind(i_ind,j_ind) + 1 ),     % THIRD CASE (only acceptance mass)

   if (z_ind == z_ind_left(i_ind)),              % full acc mass to the right
       nu_acc_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                   ( z_grid(z_ind+1) - z_grid(z_ind) ) * 0.5;
   elseif (z_ind == z_ind_right(i_ind)),         % full acc mass to the left
       nu_acc_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                   ( z_grid(z_ind) - z_grid(z_ind-1) ) * 0.5;
   else                                          % full acc mass to both sides
       nu_acc_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                   ( z_grid(z_ind+1) - z_grid(z_ind-1)) * 0.5;
   end;

% ---------------------------------------------------------------------------------------

else % ( z_ind < zbar_ind(i_ind,j_ind) )         % FOURTH CASE (only rejection mass)

   if (z_ind == z_ind_left(i_ind)),              % full rej mass to the right
       nu_rej_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
```

```
                         ( z_grid(z_ind+1) - z_grid(z_ind) ) * 0.5;
         elseif (z_ind == z_ind_right(i_ind)),          % full rej mass to the left
             nu_rej_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                         ( z_grid(z_ind) - z_grid(z_ind-1) ) * 0.5;
         else                                           % full rej mass to both sides
             nu_rej_mass(i_ind,j_ind,z_ind) = nu_dens(i_ind,z_ind) * ...
                         ( z_grid(z_ind+1) - z_grid(z_ind-1)) * 0.5;
         end;

      % ---------------------------------------------------------------------------------------

      end; % relate z_ind to zbar_ind (four cases)

   end;   % if within domain

end;   % for z_ind
end;   % for j_ind
end;   % for i_ind

nu_acc_sum = sum(nu_acc_mass,3);
nu_rej_sum = sum(nu_rej_mass,3);
nu_tot_sum = nu_acc_sum + nu_rej_sum;

if (nu_tot_sum - ones(i_max,j_max) > 0.001)
    disp('WARNING: Probabilities in matrix nu do not sum up to 1!!!')
end;

---------------------------------------------------------------------------------------------------

% distr_step.m   (called in distr_main.m)
% In this script one step of the iteration procedure to calculate the steady state
% population distribution is performed. The input variable is mu_old(:,:,:,:) denoting
% the current population shares.

% e = 1 (the now unemployed):

for i_prime_ind = 1 : i_max,
for j_prime_ind = 1 : j_max,

  mu_val = 0;

  for i_ind = 1 : i_max,
  for j_ind = 1 : j_max,

    % PIECE 1:
    % previous status: unemployed  --->   do not get a new job offer
      mu_val = mu_val + mu_old(i_ind,j_ind,1,1) * (1-lambda_value(i_ind,j_ind)) * ...
              P(i_prime_ind,j_prime_ind,i_ind,j_ind);
    % ---------------------------------------------------------------------------------
    % PIECE 2:
    % previous status: unemployed  --->   get a job offer but reject it
```

```
      for z_prime_ind = 1 : z_ind_max,
         mu_val = mu_val + mu_old(i_ind,j_ind,1,1) * lambda_value(i_ind,j_ind) * ...
                  P(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                  nu_rej_mass(i_prime_ind,j_prime_ind,z_prime_ind);
      end;
    % ------------------------------------------------------------------------------------
    % PIECE 3: (a)
    % previous status: employed    --->   exogenous separation
      for z_ind = 1 : z_ind_max,
         mu_val = mu_val + mu_old(i_ind,j_ind,2,z_ind) * sigma * ...
                  Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * (1-gamma);
      end;
    % PIECE 3: (b)
    % previous status: employed    --->   exogenous separation and skill loss (turbulence)
      if (i_prime_ind > 1),
         for z_ind = 1 : z_ind_max,
            mu_val = mu_val + mu_old(i_ind,j_ind,2,z_ind) * sigma * ...
                     Q(i_prime_ind-1,j_prime_ind,i_ind,j_ind) * gamma;
         end;
         if (i_prime_ind == 4),
            for z_ind = 1 : z_ind_max,
               mu_val = mu_val + mu_old(i_ind,j_ind,2,z_ind) * sigma * ...
                        Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * (1-gamma);
            end;
         end;
      end;
    % ------------------------------------------------------------------------------------
    % PIECE 4:
    % previous status: employed   --->   new productivity draw, reject it
      for z_ind = 1 : z_ind_max,
         for z_prime_ind = 1 : z_ind_max,
            mu_val = mu_val + mu_old(i_ind,j_ind,2,z_ind) * kappa * ...
                     Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                     nu_rej_mass(i_prime_ind,j_prime_ind,z_prime_ind);
         end;
      end;
    % ------------------------------------------------------------------------------------
    % PIECE 5:
    % previous status: employed    --->   no new productivity draw, voluntary separation
      for z_ind = 1 : z_ind_max,
         mu_val = mu_val + mu_old(i_ind,j_ind,2,z_ind) * (1 - kappa - sigma) * ...
                  Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                  (z_grid(z_ind) < zbar_val(i_prime_ind,j_prime_ind));
      end;

  end; % j_ind
  end; % i_ind

  mu(i_prime_ind,j_prime_ind,1,1) = mu_val;

end; % j_prime_ind
```

```
end; % i_prime_ind

% -------------------------------------------------------------------------------------

% e = 2 (the now employed):

for i_prime_ind = 1 : i_max,
for j_prime_ind = 1 : j_max,
for z_prime_ind = 1 : z_ind_max,

  mu_val = 0;

  for i_ind = 1 : i_max,
  for j_ind = 1 : j_max,

    % PIECE 1:
    % previous status: unemployed   --->   get a job offer and accept it
      mu_val = mu_val + mu_old(i_ind,j_ind,1,1) * ...
               P(i_prime_ind,j_prime_ind,i_ind,j_ind) * lambda_value(i_ind,j_ind) * ...
               nu_acc_mass(i_prime_ind,j_prime_ind,z_prime_ind);
    % ---------------------------------------------------------------------------------
    % PIECE 2:
    % previous status: employed    --->   new productivity draw (n = 2), accept it
      for z_ind = 1 : z_ind_max,
         mu_val = mu_val + mu_old(i_ind,j_ind,2,z_ind) * kappa * ...
                  Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
                  nu_acc_mass(i_prime_ind,j_prime_ind,z_prime_ind);
      end;
    % ---------------------------------------------------------------------------------
    % PIECE 3:
    % previous status: employed    --->   no new productivity draw (n = 3), stay in the job
      mu_val = mu_val + mu_old(i_ind,j_ind,2,z_prime_ind) * (1 - sigma - kappa) * ...
               Q(i_prime_ind,j_prime_ind,i_ind,j_ind) * ...
               (z_grid(z_prime_ind) >= zbar_val(i_prime_ind,j_prime_ind));

   end; % j_ind
   end; % i_ind

   mu(i_prime_ind,j_prime_ind,2,z_prime_ind) = mu_val;

end; % z_prime_ind
end; % j_prime_ind
end; % i_prime_ind

mu_sum = sum(sum(sum(sum(mu))));

if (abs(mu_sum - 1) > 0.001),
    disp('WARNING: The distribution array mu might be corrupt. Population shares');
    disp('         do not add up to 1. Please check distr_step.m.');
end;
```

```
mu_old = mu;

------------------------------------------------------------------------------------------------------

% distr_results.m   (called in distr_main.m)
% In this file results of the distribution calculations are calculated and shown.

AA = sum(mu_old,4);                % aggregation over productivity; basis for the followings
BB = sum(AA);                      % aggregation over productivity and skill level
CC = sum(sum(AA,3)');              % aggregation over employment status and benefit levels to
                                   % calculate shares of skill levels in the population
DD = sum(BB);                      % aggregate over productivity and all states to calculate
                                   % the total shares of e=1 (unemployed) and e=2 (employed)

format bank                        % output with two decimal places

disp('- - - - - - - - - - - - - - - - - - - - - - - - - - - -');
disp('             Calculations finished!                    ');
disp('                                                       ');
disp('Mass of employed people (in percent):');
disp(100*AA(:,:,2));
disp('Mass of unemployed people (in percent):');
disp(100*AA(:,:,1));
disp(sprintf('   The total share of   employed people is:  %5.2f%%',DD(2)*100));
disp(sprintf('   The total share of unemployed people is:  %5.2f%%',DD(1)*100));
disp('                                                       ');

format short                       % default format

% In this part the following values are calculated: total output per capita, average
% productivity of employed workers, average wage rate of employed workers, total
% tax revenues, total transfers, average expected discounted utility

output    = 0;                         avgprod  = 0;
avgwage   = 0;                         avgutil  = 0;
avgutile  = 0;                         avgutilu = 0;
revenues  = 0;                         benefits = 0;
transfers = 0;

for i_ind = 1 : i_max,
   for j_ind = 1 : j_max,
      for z_ind = 1 : z_ind_max,
          output   = output   + mu(i_ind,j_ind,2,z_ind) * z_grid(z_ind);
          revenues = revenues + mu(i_ind,j_ind,2,z_ind) * tau(z_ind) * z_grid(z_ind);
          avgwage  = avgwage  + mu(i_ind,j_ind,2,z_ind) * w(i_ind,j_ind,z_ind);
          avgutil  = avgutil  + mu(i_ind,j_ind,2,z_ind) * G(i_ind,j_ind,z_ind);
          avgutile = avgutile + mu(i_ind,j_ind,2,z_ind) * G(i_ind,j_ind,z_ind);
      end;
      avgutilu = avgutilu + mu(i_ind,j_ind,1,1) * U(i_ind,j_ind);
      avgutil  = avgutil  + mu(i_ind,j_ind,1,1) * U(i_ind,j_ind);
   end;
```

```
end;

avgprod =  output / DD(2);                  % divide over total employment rate
avgwage = avgwage / DD(2);                  % divide over total employment rate

transfers = benefit * BB(:,:,1)';
balance   = revenues - transfers - xi;

avgutile = avgutile / DD(2);
avgutilu = avgutilu / DD(1);

disp('- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -');
disp('                                                          ');
disp(sprintf('   output per capita    :    %5.3f',output));
disp(sprintf('   average productivity :    %5.3f',avgprod));
disp(sprintf('   average wage rate    :    %5.3f',avgwage));
disp(sprintf('   total tax revenues   :    %5.3f',revenues));
disp(sprintf('   total transfers      :    %5.3f',transfers));
disp(sprintf('   other purchases      :    %5.3f',xi));
disp(sprintf('   fiscal balance       :   %+5.3f',balance));
disp('   -----------------------------------------------------');
disp(sprintf('   avg expected discounted utility when   employed :   %5.2f',avgutile));
disp(sprintf('   avg expected discounted utility when unemployed :   %5.2f',avgutilu));
disp(sprintf('   avg expected discounted utility                 :   %5.2f',avgutil));

disp('                                                          ');

----------------------------------------------------------------------------------------------------

% trans_main.m
% This is the main file for population transition calculations. Required are the steady-state
% decision rules, the steady-state population distribution (or any other initial distribution)
% and the population distribution after the arrival of the shock (can be calculated in
% distr_main or, with some modifications, here).

load steady4.mat                  % loads the steady-state decision rules; choose e.g. steady_1,
                                  % steady_2, steady_3 or steady_4 (benchmark case)!

trans_periods = 20;               % number of transition periods

mu_store = zeros(i_max,j_max,status_max,z_ind_max,trans_periods+2);

load distr_mu_4.mat               % loads steady-state population distribution ( will be t = -1 );
mu_store(:,:,:,:,1) = mu;         % choose e.g. distr_mu_x.mat  with x = #economy (benchmark case)
clear mu
load postshock_4.mat              % loads after-shock population distribution ( will be t = 0 )
mu_store(:,:,:,:,2) = mu;
mu_old = mu;

init_nu;                          % calls the script init_nu.m in which the matrices of acceptance
                                  % probability masses and rejection probability masses are
```

```
                                 % calculated based on the steady-state decision rules
disp(' ');

for trans_iter = 1 : trans_periods,
    disp(sprintf('Calculation Status:   period %1.0f / %1.0f ...', trans_iter,trans_periods));
    distr_step;                  % performs one iteration step of the transition calculations
    mu_store(:,:,:,:,trans_iter+2) = mu_old;
end;

trans_results;                   % calls the script trans_results.m in which the results of the
                                 % transition calculations are analysed
save trans_new.mat mu_store
save trans_result

-----------------------------------------------------------------------------------------------------

% trans_results.m (called in trans_main)
% In this file the results of the transition calulations are analysed.

AA_t = zeros(i_max, j_max, status_max, trans_periods+2);
BB_t = zeros(1,j_max,status_max,trans_periods+2);
CC_t = zeros(1, i_max, trans_periods+2);
DD_t = zeros(1,1,status_max,trans_periods+2);
EE_t = zeros(i_max,1,status_max,trans_periods+2);

for t = 1 : trans_periods + 2,
   AA_t(:,:,:,t) = sum(mu_store(:,:,:,:,t),4);      % aggregate over z
   BB_t(1,:,:,t) = sum(AA_t(:,:,:,t));              % aggregate over i
   CC_t(1,:,t)   = sum(sum(AA_t(:,:,:,t),3)');      % aggregate over j and employment status
   DD_t(1,1,:,t) = sum(BB_t(:,:,:,t));              % aggregate over i and j
   EE_t(:,1,:,t) = sum(AA_t(:,:,:,t),2);            % aggregate over j
end;

output_t    = zeros(1,trans_periods+2);
avgprod_t   = zeros(1,trans_periods+2);
revenues_t  = zeros(1,trans_periods+2);
benefits_t  = zeros(1,trans_periods+2);
transfers_t = zeros(1,trans_periods+2);

for t = 1 : trans_periods + 2,
   for i_ind = 1 : i_max,
   for j_ind = 1 : j_max,
      for z_ind = 1 : z_ind_max,
       output_t(1,t)   = output_t(1,t)   + mu_store(i_ind,j_ind,2,z_ind,t) * z_grid(z_ind);
       revenues_t(1,t) = revenues_t(1,t) + mu_store(i_ind,j_ind,2,z_ind,t)*tau(z_ind)*z_grid(z_ind);
      end;
   end;
   end;
   avgprod_t(1,t)   = output_t(1,t) / DD_t(1,1,2,t);
   transfers_t(1,t) = benefit * BB_t(:,:,1,t)';
   balance_t(1,t)   = revenues_t(1,t) - transfers_t(1,t) - xi;
```

```
end;

SHOW_UNEMPLOYMENT_SHARES   = 1;                   % responses of unemployment shares by skill class

if SHOW_UNEMPLOYMENT_SHARES,
   figure(1);
   for i_ind = 1 : i_max,
      plot(-1:(trans_periods),100*squeeze(EE_t(i_ind,1,1,:) - EE_t(i_ind,1,1,1)),'LineWidth',1.5);
      hold on
      text(0.8,0.08+100*(EE_t(i_ind,1,1,3) - EE_t(i_ind,1,1,1)),...
              sprintf('i=%1.0f',i_ind),'FontSize',14);                     % large scale
      %text(6.2,0.0012+100*(EE_t(i_ind,1,1,8) - EE_t(i_ind,1,1,1)),...
              %sprintf('i=%1.0f',i_ind),'FontSize',12);                    % small scale
   end;
   hold off
   %axis([ -0.5  3 -0.2  3.5 ])                                            % large scale
   %axis([ 3  16  -0.02  0.1 ])                                           % small scale
   set(gca,'FontSize',14);
   grid on
   xlabel('Time in periods')
   ylabel('Deviation in percentage points from steady state')
   title('Impulse responses of unemployment by skill class in model economy 3');
end;

--------------------------------------------------------------------------------------------------------

% trans_plotall.m
% In this file impulse responses of various variables to a transient UNEMPLOYMENT shock are
% plotted. Required are the results of the transition calculations for the four model economies!

SHOW_UNEMPL  = 0;                    % total unemployment
SHOW_OUTPUT  = 0;                    % total output
SHOW_AVGPROD = 1;                    % average productivity of employed workers
SHOW_BALANCE = 0;                    % government balance as % of total steady-state output

font_size = 12;                      % font size of text in plots

if SHOW_UNEMPL,
   figure(1);
   hold on
   load shockunempl_1
   plot1 = plot(-1:(trans_periods), 100*squeeze(DD_t(1,1,1,:) - DD_t(1,1,1,1)), 'm','LineWidth',2);
   text1 = text(0.95,0.35,'1','FontSize',font_size);
   load shockunempl_2
   plot2 = plot(-1:(trans_periods), 100*squeeze(DD_t(1,1,1,:) - DD_t(1,1,1,1)), 'b','LineWidth',2);
   text(1.05,1.5,'2','FontSize',font_size);
   load shockunempl_3
   plot3 = plot(-1:(trans_periods), 100*squeeze(DD_t(1,1,1,:) - DD_t(1,1,1,1)), 'k','LineWidth',2);
   text(1.04,0.78,'3','FontSize',font_size);
   load shockunempl_4
   plot4 = plot(-1:(trans_periods), 100*squeeze(DD_t(1,1,1,:) - DD_t(1,1,1,1)), 'r','LineWidth',2);
```

```
   text(1,1.1,'4','FontSize',font_size);
   axis([ -1  4  -0.2  4.5 ])
   set(gca,'FontSize',12);
   xlabel('Time in periods')
   ylabel('Deviation in percentage points from steady state')
   title('Impulse responses of total unemployment');
   hold off
end;

if SHOW_OUTPUT,
   figure(2);
   hold on
   load shockunempl_1
   plot(-1:(trans_periods), 100*(output_t(1,:)/output_t(1,1) - 1), 'm','LineWidth',2);
   text(1,-0.35,'1','FontSize',font_size);
   load shockunempl_2
   plot(-1:(trans_periods), 100*(output_t(1,:)/output_t(1,1) - 1), 'b','LineWidth',2);
   text(1,-1.7,'2','FontSize',font_size);
   load shockunempl_3
   plot(-1:(trans_periods), 100*(output_t(1,:)/output_t(1,1) - 1), 'k','LineWidth',2);
   text(1,-0.67,'3','FontSize',font_size);
   load shockunempl_4
   plot(-1:(trans_periods), 100*(output_t(1,:)/output_t(1,1) - 1), 'r','LineWidth',2);
   text(1,-1.2,'4','FontSize',font_size);
   axis([ -1  6  -4.5  0.5 ])
   set(gca,'FontSize',12);
   xlabel('Time in periods')
   ylabel('Percentage deviation from steady state')
   title('Impulse responses of total output');
   hold off
end;

if SHOW_AVGPROD,
    figure(3);
    hold on
    load shockunempl_1
    plot(-1:(trans_periods), 100*(avgprod_t(1,:)/avgprod_t(1,1) - 1), 'm','LineWidth',2);
    text(4,-0.017,'1','FontSize',font_size);
    load shockunempl_2
    plot(-1:(trans_periods), 100*(avgprod_t(1,:)/avgprod_t(1,1) - 1), 'b','LineWidth',2);
    text(10,-0.034,'2','FontSize',font_size);
    load shockunempl_3
    plot(-1:(trans_periods), 100*(avgprod_t(1,:)/avgprod_t(1,1) - 1), 'k','LineWidth',2);
    text(3,-0.038,'3','FontSize',font_size);
    load shockunempl_4
    plot(-1:(trans_periods), 100*(avgprod_t(1,:)/avgprod_t(1,1) - 1), 'r','LineWidth',2);
    text(6,-0.036,'4','FontSize',font_size);
    axis([ -1  16  -0.1  0.1 ])
    set(gca,'FontSize',12);
    xlabel('Time in periods')
    ylabel('Percentage deviation from steady state')
```

```
    title('Impulse responses of average productivity');
    hold off
end;

if SHOW_BALANCE,
   figure(4);
   hold on
   load shockunempl_1
   plot(-1:(trans_periods), 100*((balance_t(1,:)-balance_t(1,1))/output_t(1,1)), 'm','LineWidth',2);
   text(1,-0.07,'1','FontSize',font_size);
   load shockunempl_2
   plot(-1:(trans_periods), 100*((balance_t(1,:)-balance_t(1,1))/output_t(1,1)), 'b','LineWidth',2);
   text(1,-1,'2','FontSize',font_size);
   load shockunempl_3
   plot(-1:(trans_periods), 100*((balance_t(1,:)-balance_t(1,1))/output_t(1,1)), 'k','LineWidth',2);
   text(1,-0.37,'3','FontSize',font_size);
   load shockunempl_4
   plot(-1:(trans_periods), 100*((balance_t(1,:)-balance_t(1,1))/output_t(1,1)), 'r','LineWidth',2);
   text(1,-0.65,'4','FontSize',font_size);
   axis([ -1  6  -3  0.2 ])
   set(gca,'FontSize',12);
   xlabel('Time in periods')
   ylabel('Deviation as percentage of steady-state output')
   title('Impulse responses of government balance');
   hold off
end;
```

Declaration of Authorship

I hereby confirm that I have written this master thesis independently and without use of other than the indicated resources. All passages, which are literally or in general matter taken out of publications or other resources, are marked as such.

Nawid Siassi

Berlin, December 15, 2006