Job Placement Agencies in an Agent-based Model of the Local Labor Market with the Long-term Unemployed and on-the-job Flows

Marcin Wozniak

Abstract

In this paper, an agent-based search model of the labor market with heterogeneous agents and an on-the-job search is developed, i.e. the long-term unemployed and other job seekers compete for vacancies which differ in skills demands and in the sector of the economy. Job placement agencies help both types of unemployed persons find the proper vacant job by improving their search effectiveness and by sharing leveraged job advertisements. The agents' interactions take place in an artificial world drawn from labor market search theory. Six global model parameters were calibrated with the Latin hypercube sampling technique for one of the largest urban areas in Poland. To investigate the impact of parameters on model output, two global sensitivity analysis methods were used, i.e. Morris screening and Sobol indices. The results show that both programs considerably influence unemployment and long-term unemployment ratios as well as the level of wages, duration of unemployment, skills demand and worker turnover. Moreover, strong cross-effects were detected: programs aimed at one group of job seekers affect other job seekers and the whole economy. This impact is sometimes positive and sometimes it is negative.

Authors

Marcin Wozniak, ✉ Poznan University of Economics, Department of Labor and Social Policy, Al. Niepodleglosci 10, 61875 Poznan, Poland, wozniac@gmail.com

The model and supplementary files can be found at: https://www.openabm.org/model/4640/version/3/view

Citation   Marcin Wozniak (2016). Job Placement Agencies in an Agent-based Model of the Local Labor Market with the Long-term Unemployed and on-the-job Flows. Economics Discussion Papers, No 2016-24, Kiel Institute for the World Economy. http://www.economics-ejournal.org/economics/discussionpapers/2016-24

1. Introduction

Long-term unemployment (LTU) has become a significant social, psychological and economic problem, even in rich, Western economies. In EU-28, the long-term unemployment ratio rose from 33.5 in 2009 to 44.5 in 2013 (Eurostat). Although there has been a heated debate regarding unemployment and an active labor market policy, the LTU problem has been much less emphasized.

For the unemployed, extension of job-search duration increases the probability of being rejected during the recruitment procedure because employers are not likely to choose applications with gaps in the potential employees' CVs (Winter-Ember 1991). Search intensity decreases as the time and skills' depreciation proceeds, which worsens even more the situation of long-term unemployed persons on the labor market. Some research studies indicate that LTU persons often have health, social and economic problems which, as a result, exclude them from society (e.g. Machin, Manning 1998). The more long-term unemployed persons there are, the more social expenses are paid for unemployment benefits, insurance and activation programs, which further charge the budget.

Empirical studies point out that the effective reintegration of the long-term unemployed is a challenging issue of social policy (e.g., Davidson 2002, OECD 2013). It has been argued that programs targeted at specific groups of the unemployed are more effective (Meager, Evans 1998), based on job-search assistance (Breuning, Cobb-Clark, Dunlop, Terril, 2002) and long-term support (Barnow, Gubits 2002). As a result, LTU-oriented, youth-oriented or disabled-oriented active labor market programs arose in EU-28 which support the unemployed for even several years.

The significant growth of active labor market programs (ALMPs) and the persistence of unemployment both imply increasing social expenses[1] and cause a great need for a reliable and innovative evaluation strategy of the social policy. The paper presented here tries to meet these demands. The local labor market with the long-term unemployed and an on-the-job search was developed based on Agent-Based Modeling (ABM). In turn, the agents' interactions and the active labor market program introduced in this economy derive directly from search theory by Mortensen and Pissarides (1994, 2000, 2007).

Some studies claim that ABM is a more accurate scientific method for the applied social sciences than aggregate macro models because the whole system works here as an output of decisions of autonomous individuals, which, in fact, is closer to reality (Lengnick, Krug, and Wohltmann 2013). As a consequence, agent-based models simulate micro behaviors and work closer to the real world (Borrill, Tesfatsion 2010).

The main research purpose of this paper was to evaluate the active labor market program that was directed at two groups of agents, i.e. the unemployed and the long-term unemployed. In order to conduct the research tasks I used global sensitivity analysis as well as other statistical techniques. The *NetLogo* environment was used to develop the model; the *R* programming language was used with suitable packages for simulations analysis (*RNetLogo*, *lhs* and *sensitivity*).

---

[1] Expenditures on the labor market policy in 2012 amounted to: 1.68% of GDP in Germany; 2.35% of GDP in France; 2.07% of GDP in Italy; 0.72% of GDP in Poland; and 1.15% of GDP in Hungary (OECD). Social protection expenses varied between 18.1% of GDP in Poland to 34.2% of GDP in France (Eurostat).

The paper is structured as follows: Section Two deals with the most important literature concerning labor market search theory and agent-based modeling. Section Three presents the theoretical assumptions and the developed model. Section Four deals with the calibration: Latin hypercube sampling is used to calibrate the global parameters of the model. Section Five presents model performance: simulated time series are plotted and discussed. Section Six develops two global sensitivity analysis techniques; Morris screening is used to investigate the general influence of all global parameters and the Sobol technique is used for a more in-depth analysis of the impact of the six ALMP parameters on the developed economy.

2. Literature review

The canonical theoretical framework for frictional labor markets analysis was developed by P. Diamond, D. Mortensen and Ch. Pissarides in several influential papers (Pissarides 1985; Mortensen and Pissarides 1994; Mortensen and Pissarides 1999; Pissarides 2000, Mortensen 2012). The literature review section first presents some crucial mainstream papers, then articcles that exploit agent-based techniques, labor market analysis and policy evaluations are reviewed.

Stavrunova (2007) built an equilibrium search model to examine the impact of subsidized employment on US labor market outcomes. Her model was characterized by heterogeneity of the unemployed with respect to skill level and heterogeneity of firms with respect to skill requirements. She also incorporated an on-the-job search. Stavrunova calibrated structural model parameters with the empirical data and Bayes techniques and ran numerical simulations and experiments for different labor market policy scenarios. Stavrunova's model was strongly inspired by a paper by Albrecht and Vromann (2003), in which two-stage skill heterogeneity was implemented. What is noteworthy in Stavrunova's paper (2007) is the sophisticated and precise calibration procedure based on empirical data and Bayes techniques. The author also provides a clear summary and conclusions of the ALMP evaluations.

Another paper that is similar to the Albrecht and Vromann (2003) paper is the one by Dolado, Jansen, and Jimeno (2008), which deals with skilled and unskilled jobs as well as highly and less educated workers. What distinguishes the paper from the prototype are on-the-job flows which are treated with particular attention. The authors prove that on-the-job flows improve the search model's ability to replicate some stylized empirical facts as opposed to models without an on-the-job search (Hornstein et al. (2006)). However, the aggregate specification of the model implies some inaccuracies (e.g. workers of the same type employed in jobs of a given type have equal wages).

One of the rare papers that have used search models to evaluate the labor market policy in Europe is Cahuc and Le Barbanchon (2010). They developed a dynamic version of the search and matching model and calibrated the model to the French economy. The authors examined the impact of counseling policies on the unemployment rate in equilibrium and during the transitory period. The conclusions presented in the paper are not clear and can be summed as a statement that counseling can lower the unemployment rate, however, its true effect could be the opposite. The provided model does not distinguish the unemployed according to skills, search duration or productivity level, and introduces heterogeneity through wages dispersion. Besides, it is not clear how the authors estimated the aggregate efficiency parameter, which gives a constant search advantage to counseled job seekers.

It is easy to notice that an agent-based evaluation of the policy has enormous potential and can be used extensively in the field of labor economics. Interesting studies pertaining to search theory of the labor market in an agent-based framework can also be mentioned.

Gabriele (2002) developed an evolutionary agent-based model of the labor market. The model has the possibility of upgrading both the technology and productivity level. The author applied a mechanism that is similar to the Nash bargaining solution for wage determination. She proved that the model replicates series of empirical facts: the Beveridge curve, job destruction and job creation processes and wage stickiness. The model allows to analyze dynamic micro-interaction between agents in an institutional environment. Gabriele's (2002) model was calibrated to look at the stability of the results, thus it is difficult to conclude if results replication would be possible regarding calibration based on empirical facts.

Neugart (2004) adopted the concept of the matching function in a multi-agent environment. He programed an artificial labor market which endogenously sets the main variables (unemployment, reservation wage and vacancies). The simulations suggest that the validity of the labor market policy evaluation with usual flow models can be biased. Neugart's model is an implementation of the matching-function mechanism in an agent-based framework. Contrary to the paper by Gabriele (2002), it does not adopt the Nash solution for wage determination. In fact, the paper does not show how wage dispersion is generated.

Baruffini (2014) evaluated the labor market policy in Switzerland. He tried to implement sector-specific skills requirements and a whole range of passive and active labor market programs. Until then subsidized training had been implemented as one of the active labor market policies. The author underlined the preliminaries of the model; also, the paper provides no calibration procedure, no quantitative results and no in-depth model analysis. The author also did not state whether the preliminary results were based on a single model run. Similarly, we do not know which techniques he used to compute the impact of subsidies training on the employment rate.

Gaudet, Kant and Ballot (2014) investigated the impact of Fixed Duration Contracts (FDCs) on unemployment with an agent-based model of the French labor market. The model simulates gross worker flows among five different states. In the paper the authors focused on an experiment concerning diminishing FDCs. The obtained results indicate that decreasing FDCs leads to a substantial fall in the unemployment rate for all age groups. On the other hand, a labor market with FDCs is characterized by high worker turnover, especially among young people. Although some formal aspects were ignored in the paper, the developed model supports the results of the aggregate labor market model as presented by Bentolila, Cahuc, Dolado, and Barbanchon (2010). The latter paper proves that suppressing FDCs leads to an inward shift of the Beveridge Curve, which is a result of a worker turnover decrease.

Among the other papers, an inspiring paper by Zhang and Lie (2014) shed light on adopting search theory assumptions to conduct an analysis of the resale housing market in Beijing. The authors performed a local sensitivity analysis which allowed them to investigate relations between parameters of the model and endogenous series. Table 1 sums up selected papers concerning search theory, which are related to the present study.

Table 1. *Juxtaposition of selected labor market search theory application papers*

Author	Model	ALMP evaluation	On-the-job flows	Agents' heterogeneity
Albrecht and Vromann (2002)	Continuous time equilibrium search model	No	No	Low-skilled and high-skilled jobs; skilled and unskilled workers; wages dispersion
Gabriele (2002)	Disaggregate agent-based search model with technical change	No	No	Agents' wages dispersion
Neugart (2004)	Disaggregate agent-based model capturing the matching function mechanism	Firm subsidies and money transfer to job seeker	No	Agents' wages dispersion
Stavrunova 2007	Continuous time equilibrium search model calibrated for the U.S. economy	Two kinds of subsidies and job destruction taxes	If the high-skilled person is employed below qualifications, he or she seeks a better job	Low-skilled and high-skilled workers; simple and complex jobs; wages and productivity
Dolado, Jansen, Jimeno 2008	Continuous time equilibrium search model calibrated for the U.S. and E.U. economy	No	Mismatched workers can move to a better job	Skilled and unskilled jobs; Highly and less educated workers
Cahuc and Le Barbanchon (2010)	Continuous time equilibrium and dynamic search model calibrated for the French economy	Job counseling	No	Agents' wages dispersion
Baruffini (2014)	Disaggregate agent-based search model calibrated for the Swiss economy	Subsidized training	Not precise	Skills and sectors heterogeneity
Gaudet, Kant and Ballot (2014)	Disaggregate agent-based search model calibrated for the French economy	No	If employed on FDC, can search for open-ended contract	Job contracts heterogeneity: Fix Duration and Open Duration; Workers heterogeneity: different age groups

3. Model
a. General assumptions

The model developed in this paper is a search and matching agent-based model with skills and jobs heterogeneity, on-the-job search and ALMP programs. Implementing the job-to-job transition and endogenous skill heterogeneity ensures that the outlined model will be more realistic and consistent with the empirical data (Hagedorn, Manovskii, Bocola 2010).

The evaluated institutions that were implemented in the model are local job placement agencies that provide ALMPs to the local labor market. The job placement agencies' effects are twofold: first, they provide job search support (counseling); second, they share job advertisements gathered from the local labor market with the programs' participants. The programs are directed at two groups of the unemployed: i.e. regular (non-LTU) job seekers and the long-term unemployed (LTU).

The number of participants in both programs is endogenous, with the maximum determined to be 40% of the fraction of job seekers in a specific group. Any job seeker who wants to can participate in the ALMP, and none of the participants is forced to take part and can resign at any given period.

In general, there are four types of agents in the economy: firms, job seekers, vacancies and job placement agencies. The firms can create vacancies in three general sectors of the economy, which are represented on a Poznan agglomeration: production (*prod*), services (*ser*) and agriculture (*agr*). The distribution of vacancies is random, however, the probability that the firm will open up new jobs in a more numerous sector of the economy (e.g. services) is higher[2]. The vacancies also differ with respect to skill requirements and offered wages. The higher the skills requirements, the more favorable the offered wage and the bigger the productivity.

The job seekers can be in one of three different states: the unemployed (*un*), the long-term unemployed (*ltu*) or the employed (*emp*). Job seekers can seek a job in the three general sectors of the economy, the choice of which depends on their individual preferences. The unemployed are heterogeneous in their skill levels; similarly to the vacancies, they are characterized by 5 skill levels. Job seekers employed under their qualifications may search on the job. Job seekers face the problem of human capital depreciation: the probability of skills loss rises along with the duration of unemployment, as was proven in Meager and Metcalf (1999). In turn, while employed, workers can improve their qualifications due to training and gaining professional experience. If job seekers search without success, they can change their job preferences every fixed period. This change is based on individual identification of labor market needs.

Agents are characterized by their position on a two-dimensional square grid of 20 patches. At the beginning of the simulation they are randomly assigned to the grid in such a way that two agents cannot share the same *x, y* position. The initial position of the job seekers and firms determines the chances of finding a potential trading partner. If there are many firms-agents in neighborhood patches, the probability of matching a proper vacancy is higher. The matching algorithm is described in detail in the next section.

The initial position of the job-placement agencies determines the number and distribution of the job offers they share with the job seekers, because agencies have better access to vacancies situated in neighboring firms. Time is discrete and each agent in every time step is allowed to make decisions according to the programmed set of algorithms. The agent-based model programmed in *NetLogo* is presented on figure 1.

---

[2] The probabilities were tuned on the basis of empirical distribution of jobs on a Poznan agglomeration as extracted from www.stat.gov.pl. More details in the calibration section.
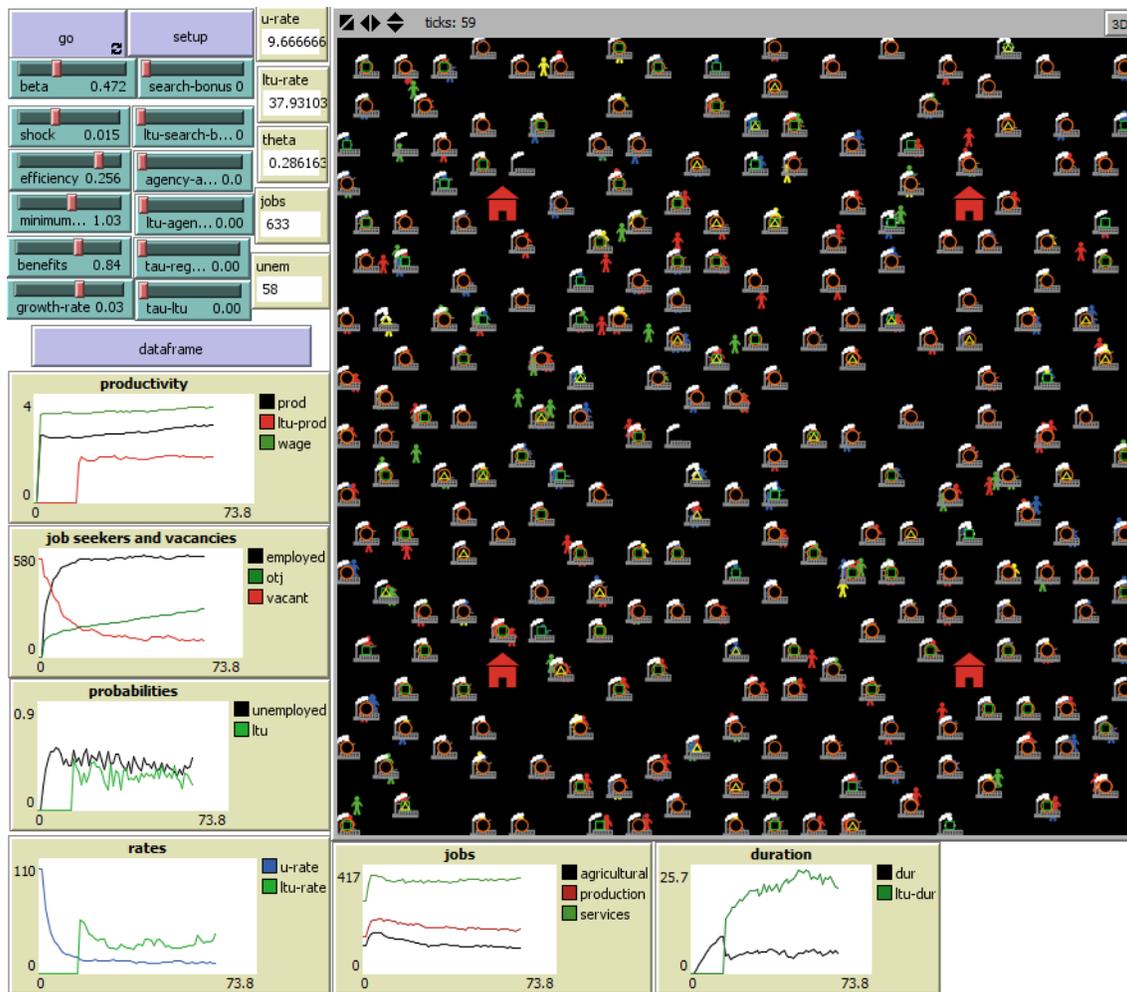
Figure 1. Agent-based model of local labor market – sample simulation

b. Labor market – the setup

Job seekers roam the local labor market and seek a job with or without the support of local job placement agencies. The choice of a vacant position depends on individual preferences, skill level and the distance to go. In general, job seekers try to maximize their expected income through the implemented dynamic programming algorithm (Section 3.4). When employed they can work in the services sector, in production or in agriculture, then they can earn suitable wages, produce and search for work while on-the-job.

Job seekers' activities in the economy are costly, as each of the unemployed person's agent has an individual number of search units which can be perceived as the number of steps he or she can make at each turn. Each job seeker must decide how to spend owned search units. He or she can roam the world seeking a vacancy or visiting a job-placement agency. He or she can also give up a turn and do nothing. The higher the number of individual search units, the more applications can be made at every period because each move on the grid costs one unit. Each job seeker has his/her own CV, which contains information about that job seeker's individual productivity level, job preferences, skill level, employment and unemployment duration. The CV is updated every period. Generally, job seekers with a higher skill

level have greater individual productivity. When job seekers are unemployed, they receive social care benefits b_t^i, enjoy leisure l_t^i and seek a job[3].

When an unemployed person seeks a job for more than 12 months, he or she becomes a long-term unemployed person and suitable information appear in the individual CV. As a consequence, employers will reject offers from the LTU more often and will consider them to be worse – the probability of finding a job in the LTU group is smaller because these job seekers search with less intensity and suffer from skills depreciation (Budd, Levine and Smith (1988)). The number of job seekers is set to 600.

A job can be either filled or vacant. When empty, every period it pays the cost of maintaining the vacancy c_t^i. Costs are connected with recruitment procedures in firms, e.g. screening applications or interviews. When the job seeker and the vacancy match and a real wage is negotiated, production starts. Production is the resultant of the individual productivity of the job seeker p_t^i and the productivity component of vacancy x_t^i. In general, high-skilled unemployed persons who match vacancies with the highest skills demand are the most productive, however, exceptions to this rule are possible because individual productivity is a random number drawn from normal distribution. After the match the production follows the AR1 process of the general form: $x_t^i p_t^i = \varphi x_t^i p_{t-1}^i + \varepsilon_t$, where φ is *the growth-rate* parameter and ε is white noise. If unemployed, job seekers face depreciation of individual productivity at an exogenous rate of φ per month; p_t^i and x_t^i cannot fall below the exogenous reservation threshold.

The initial number of firms-agents is 200. Each firm spreads job offers characterized by the sector of the economy, offered wage and skill requirements. At the beginning of the simulation the number of vacant jobs is randomly drawn from the [1, 2, 3] vector. As a consequence, each firm can have a maximum of 3 and a minimum of 1 vacancy/ies of each type, which implies that total vacancies are in the range of 200–600 at t=0. Furthermore, each job seeker and vacancy is characterized by individual skill level, which is drawn from a vector [1,2,3,4,5][4] at the beginning of simulation and then endogenously evolves in given intervals. During each of the simulation periods the firms make decisions about creating vacancies of each type based on identifying the needs of the local labor market and on the potential profit they can gain. The job destruction process continues with the exogenous rate *lambda*. The minimum number of vacancies is not specified, so if it is not profitable then the firm is not obligated to employ any workers.

c. Match creation

We derive the algorithm that links the agents on the local labor market from modifications of the urn-ball matching model, which was described in the economic literature several times (Gerard Butters 1977; Robert Hall 1979; Pissarides 1979; Kevin Lang 1991; James Montgomery 1991; and Blanchard and Diamond 1994). In the economic adaptation of such a model, firms or vacancies play the role of the urn and the job seekers act as the balls. When a job seeker encounters a vacant position, production starts. The search strategies depend on individual search intensity, which in this case is defined as the number of search units supplied by each agent (Petrolongo, Pissarides 2001). The general mechanism that describes the agents' behavior is a matching function which presents the number of new matches as a

---

[3] Where *i* is the individual index and *t* is the time index.
[4] The 5 skills levels may be equate with 5 educational stages in Poland.

result of vacancies and the unemployed (Pissarides 2000, Shimmer 2005, Rogerson, Shimmer, Wright 2005). For a modeled economy with three general sectors and three groups of job seekers varying in search effectiveness, the aggregate matching function can be written as:

$$M_t = m(sJ_t^i, V_t^i) \quad (1),$$

The number of matches in a given time M_t is the result of the behavior of all job seekers sJ_t^i in the economy as well as vacancies V_t^i. Note that in the skills and preferences heterogeneous group of job seekers we can extract: the unemployed $J_t^{i,un}$; the long-term unemployed $J_t^{i,ltu}$, and the employed seeking on the job $J_t^{i,emp}$. Similarly, in the skills heterogeneous group of vacancies we can extract: services vacancies $V_t^{i,ser}$; production vacancies $V_t^{i,prod}$, and agricultural vacancies $V_t^{i,agr}$. I assumed, conventionally, that the matching function is Cobb-Douglas, has increasing returns to scale and decreasing marginal productivity. M is a homogeneous function of degree 1.

Given (1), we can define the individual meeting probability for each agent. If a single job seeker in a given time interval chooses a search intensity of s_t^i, then his or her individual hazard rate could be written as:
$h_t^i = s_t^i m(sJ_t^i, V_t^i)/sJ_t^i$. Thus, a representative free vacancy is filled with the individual rate: $r_t^i = s_t^i m(sJ_t^i, V_t^i)/V_t^i$. Now let us define aggregate labor market tightness as the ratio of the total number of vacancies to the total number of job seekers: $\theta_t = \frac{V_t^{i,ser} + V_t^{i,pro} + V_t^{i,agr}}{J_t^{i,un} + J_t^{i,ltu} + J_t^{i,em}}$, however, for a single agent who samples from preferred job offers in a maximum distance, individual labor market tightness would be $\theta_t^i = \frac{V_t^i}{J_t^i}$. In that case, the meeting probability for a representative firm would be $q(\theta)_t^i = r_t^i$, and for a job seeker: $\theta q(\theta)_t^i = h_t^i$.

The AB implementation of the search and match algorithm for a representative agent can be described as follows: when a job seeker wakes up in the artificial world, he or she looks around and makes a list of potential trading partners. On the list are firms which correspond to the job seeker's preferences in a distance equal to the maximum number of search units he or she owns given turn. Then the job seeker chooses a firm which can be achieved at a lower cost of search units s_t^i and moves in this direction. When he or she meets a firm, an application is presented to the potential employer. If the vacancy has other skill requirements, the job seeker removes the firm from the list and goes on the search as long as $s_t^i > 0$. When all of the job seekers utilize their search units, the turn ends. If the job seeker's preferences and skill level are convergent with the met vacancy, wage negotiation begins according to the Nash solution as described in the next subsection.

The number of search units is assigned to each of the job seekers at the beginning of the period from the distribution that depends on two aspects:

- The duration of unemployment: the higher the duration, the lower the maximum number of search units. The long-term unemployed draw from the distribution with a lower maximum.
- Participation in a job-search assistance program: if the unemployed person participates in the ALMP, he or she receives a few extra search units *(bonus)*.

The above assumptions are compatible with search theory, in which the search intensity falls with time (Shimmer 2004), and job-search assistance programs improve the search intensity (Kluve 2006; Card, Kluve, Weber 2009). In other words: when job seekers search for a job unsuccessfully, their motivation falls and they search with lower intensity. On the other hand, if job seekers participate in a job-search assistance program they gain some knowledge about the labor market and the methods of searching for a job, thus some increase in the search intensity is justified.

Besides, job placement agencies gather and share information about newly opened vacancies. Job advertisements may be utilized by unemployed participants every period with a given probability (*util*). In that case the assumption is that the job advertisements that are available in agencies are more fitted to an individual's skill level than those found on the job seeker's own. The inflow of non-LTU job seekers to the ALMP is at an exogenous rate tau_{un}; the inflow of LTU to the ALMP is at a rate tau_{ltu}. Program participants resign from ALMP support at some exogenous rate $sigma$.

d. The value functions

The next step is to define the value functions for workers and firms which can be implemented in the agent-based framework on the basis of the well-known 'stopping problem', which is regarded as a dynamic programming issue (McCall (1970), Mortensen (1970); Rogerson, Shimmer, Wright 2005). In this case the job seeker who visits a given firm with the preferred type of vacancy considers whether he or she wants to continue search for better work conditions in the next round or to accept the current work proposal. If he or she finds that the potential future gain from continuing the search is less than the gain from the current job offer, then he or she stops the search process and moves on to wage negotiations.

We use the following notations for unemployed job seekers $- U$, for the employed $- E$, for a vacant position $- V$, and for an occupied and producing job $- F$. Let us first consider an unemployed person i in time t who wants to maximize his or her earnings. His or her future payoffs are then equal to:

$$U_t^i = b_i + l_i + h_t^i[E(w)_t^i - U_{t+1}^i] \quad (2),$$

where $E(w)_t^i$ is the gain from accepting the current job offer and U_{t+1}^i is the potential gain from rejecting the offer and sampling again with some known probability h_t^i the next period in the range of maximum distance[5]. Worth mentioning here is that the unemployed person, besides receiving money from the social care system b_i, has additional benefits from being unemployed, e.g. free time, no stressful situations. From this point of view it is suitable to increase the unemployment benefits by the value of leisure l_i (e.g. Mortensen, Pissarides 1999; Hagedorn, Manovskii 2008).

Analogously, payoff from a given vacancy would be:

$$V_t^i = -c_i + r_t^i[F(v)_t^i - V_{t+1}^i] \quad (3).$$

---

[5] The maximum distance is the variable which captures the maximum number of search units in the economy for each period; for example, if the maximum number of search units is 8, the agent will draw from the distribution in the range of 8 patches. As an implication, such a distribution would be different for any agent who resides in another patch.

Firms try to maximize the profit from filling the vacancy, which is equal to $v_t^i = p_t^i x_t^i - w_t^i$: the firm gains the rest, v_t^i, from production of a given vacancy $p_t^i x_t^i$ after paying the wage w_t^i to the worker. The employer also faces the costs of recruiting the worker c_i and compares the gain from filling the vacancy now $F(v)_t^i$ with potential (r_t^i) future trading partners' distribution in the maximum distance V_{t+1}^i. Thus, when a job seeker is employed, the value equation turns into:

$$E(w)_t^i = w_t^i - lambda(E(w)_t^i - U_t^i) \quad (4),$$

where w_t^i is the individual wage of a job seeker of each type that he or she receives when employed in a given vacancy of each type; $lambda$ is the exogenous probability of losing a job of each type. The value function for the employed person consists of the wage he or she receives minus the probability of losing the profit and becoming unemployed in case of the job destruction process $lambda(E(w)_t^i - U_t^i)$.

For job seekers employed under their qualifications who are able to search on the job, the equation turns into:

$$\overline{E(w)}_t^i = \overline{w_t^i} - lambda(E(w)_t^i - U_t^i) + h_t^i[E(w)_{t+1}^i - E(w)_t^i] \quad (5).$$

The value of being employed consists of the wage minus the probability of losing the job in case of exogenous shock, plus the probability of receiving the profit in case of on-the-job search success. When the job is occupied and productive, the value function is:

$$F(v)_t^i = p_t^i x_t^i - w_t^i - lambda(F(v)_t^i - V_t^i) \quad (6).$$

The value consists of the production of each job reduced by the wage the employer must pay to the worker $p_t^i x_t^i - w_t^i$ and the probability of profit loss in case of the job destruction process. If a worker with an inappropriate skill level fills the given job, the Bellman equation must be rewritten as:

$$\overline{F(v)}_t^i = \bar{p}_t^i \bar{x}_t^i - \overline{w}_t^i - lambda(\overline{F(v)}_t^i - V_t^i) - h_t^i[F(v)_t^i - V_{t+1}^i] \quad (7).$$

The value of a vacancy filled by an overqualified worker consists of the firm's current payoff from production $\bar{p}_t^i \bar{x}_t^i - \overline{w}_t^i$, the probability of capital loss in the case of the job destruction process $lambda(\overline{F(v)}_t^i - V_t^i)$, and the probability of a job seeker's outflow to another job and the necessity of maintaining the vacancy for the next period at cost V_{t+1}^i. Note that in that case the matches terminate for two reasons.

e. Wages

In search theory, the standard mechanism of wage determination is through the symmetric Nash bargaining solution. Assuming that the job seeker and firm have equal negotiation power means that $\beta = 0.5$, which determines the equal fraction of surplus which the agent receives in the negotiation process[6]. The surplus cannot be negative, so $E(w)_t^i - U_t^i > 0$ as well as $F(v)_t^i - V_t^i > 0$, as both types of agents must have a profit in the cooperation. To start the job the worker resigns from U_t^i and receives

---

[6] The equal negotiation power of workers and employers is not confirmed and an uncertain fact on the real labor market (Mortensen, Nagypal 2008).

$E(w)_t^i$, thus when the firm hires the job seeker it resigns from V_t^i and receives $F(v)_t^i$. The Nash solution implies

$$w_t^i = argmax(E(w)_t^i - U_t^i)^\beta (F(v)_t^i - V_t^i)^{1-\beta} \quad (8).$$

Applying the first-order condition, the general surplus S equation for a representative pair in the bargaining process can be written as:

$$S(w,v)_t^i = E(w)_t^i - U_t^i + F(v)_t^i - V_t^i \quad (9).$$

Note that according to the Nash solution the total surplus is shared between the pair of agents with share parameter β, then substitute $F(v)_t^i$ and $W(w)_t^i$ from (9) to get the following wage equation:

$$w_t^i = \beta S_t^i \rightarrow U_t^i(1-\beta) + \beta(p_t^i x_t^i - V_t^i) \quad (10).$$

Applying the free-entry condition determines that the wage equation simplifies to:

$$w_t^i = U_t^i(1-\beta) + \beta p_t^i x_t^i \quad (11).$$

Finally, the job creation condition can be derived by substituting (6) in (3) and by applying the free-entry conditions:

$$c_t^i \frac{1}{r_t^i} < r_{t+1}^i (p_t^i x_t^i - w_t^i) \quad (12).$$

The cost of maintaining the vacancy of each type c_t^i multiplied by the expected time of waiting for filling the vacancy $\frac{1}{r_t^i}$ is compared in every period with the possible gain from finding a trading partner and starting production in the next period (the right-hand side of the equation). If LHS < RHS, a new vacancy is created.

The job creation algorithm starts when firms with fewer than 3 opened jobs calculate the potential time needed to fill the vacancy (the inverse of individual probability) and multiply it by the mean recruiting cost $c_t^i \frac{1}{r_t^i}$. Then the firm scans the neighborhood in search of job seekers with $s_t^i > 0$ and calculates the maximum profit from filling the new vacancy in the next period $r_{t+1}^i (p_t^i x_t^i - w_t^i)$. If the profit is more than or equal to the predicted costs, the firm creates a new vacancy of a random type and skill requirements. In other cases the firm does nothing and the job destruction process continues with exogenous frequency $lambda$.

f. Calibration procedure

The model will be calibrated for the local labor market of the Poznan agglomeration, which is one of the largest urban areas in the Wielkopolska region – it is situated in north-western Poland. Almost 1 million citizens reside within this area of 13 125 square miles. The region is known for its good situation on the labor market and it belongs to one of the richest regions in Poland.

The local labor market is characterized by various empirical statistics which will be exploited in order to calibrate the key parameters of the model. Unfortunately, free data concerning low levels of

aggregation are unavailable in the Polish public statistical system. Therefore, the NUTS2 time series for the Wielkopolska region are used as a proxy of the labor market of the Poznan agglomeration.

The model consists of a large number of parameters, some of which are unobservable (e.g. worker bargaining power, labor market efficiency parameter). There are also some problematic parameters whose exact value is unknown (e.g. shock frequency estimates provide different results, as was shown in Wozniak 2015a). In these cases the parameters will be calibrated according to the developed calibration criteria and statistical methods.

Three calibration criteria which are crucial to model performance were developed. The ranges for these were computed based on empirical data for the Wielkopolska region extracted from the Public Employment Service and the Central Statistical Office (http://psz.praca.gov.pl/; www.stat.gov.pl).

The *unemployment density* criterion indicates the ranges of the mean unemployment rate on the local labor market in the years 2005–2013. The *long-term unemployment density* criterion indicates the ranges of the mean long-term unemployed ratio[7] in the years 2005–2013. The *tightness fluctuation criterion* points to the variation in the θ. The large variability of θ is a peculiarity of the economies: the co-movements of vacancies and unemployment are known in the theory as the Beveridge curve (Shimmer 2005). Empirical fluctuations of θ were measured through the coefficient of variation of seasonally adjusted, registered unemployment monthly time series[8]. The seasonal component was removed with the Hodrick-Prescott filter, with the smoothing parameter set to 129600. The minimal coefficient of variation of θ were 0.15, thus the maximal fluctuations were little more than 0.34. Finally, the three developed calibration criteria can be recapped as:

1) *Unemployment density criterion (ud) = 0.159 > ud > 0.064*
2) *Tightness fluctuations criterion= (tf) 0.15 > tf > 0.34*
3) *Long term unemployment density criterion (ltud) = 0.197 < ltud < 0.484*

The global parameters with uncertain values are calibrated to keep the three criteria in the selected ranges. The Latin hypercube sampling (LHS) technique was used for this task as a relatively simple and effective technique. The method was first described by McKay, Beckman and Conover in 1979, and is now one of the most popular ways of developing and analyzing computer experiments. In the LHS technique, the experimental design is written as a matrix, where columns represent the variables and rows represent the samples. The random algorithm draws samples for each variable. If the point matches, a parameter value is found which fulfills the experimental criteria. The dimensions of the matrix constitute the number of variables (Viana, Venter, Balabanov 2010). In fact, some portion of luck is desirable to match all criteria at one point.

---

[7] The long-term unemployment ratio was computed as the relation of the long-term unemployed to all those unemployed in the economy.

[8] The coefficient of variation was used to make simulated and empirical time series comparable. The v/u computed from the empirical series has a very low value with a mean of 0.012, while the mean-simulated v/u was about 0.6. The low value of the empirical v/u results mostly from the slight number of vacancies registered by the Public Employment Service in Poland (Wozniak 2011, Kabaj 2005, Krynska 2009).

The efficiency parameter of the matching function[9] has a significant impact on the job-finding probabilities and vacancy-filling probabilities, but there is no obvious way to set it due to the lack of a clear economic interpretation. Therefore, the parameter allows for freedom in adjustment. A reasonable range between 0.10 and 0.30 is assumed in this case. The job destruction rate was also problematic because different data lead to different estimates. The aggregate job destruction rate[10] was estimated from the Labor Force Survey data to 0.011–0.036, thus the calibrated destruction rate was set in that range for the LHS experiment.

Another ambiguous feature are the values of beta, which is the so-called worker bargaining power in wage negotiations. The parameter beta is usually set to 0.5, thus implying the same negotiation power of both the job seeker and employer (e.g. Shimmer 2005, Hagedorn and Manovskii 2008). However, such a value is not supported by empirical facts, and in the real labor market numerous situations are known in which either the job seeker or the employer has an advantage in the wage negotiation process (Mortensen, Nagypal 2008). Having this in mind, I set the beta in the range of 0.4–0.6 for calibration.

The next parameter with an uncertain value was the rate of productivity growth. Poland belonged to countries known for their poor labor productivity, however, during the last decade a dynamic rise of this indicator could be noticed. Eurostat noted that the productivity rate for Poland in the years 2005–2012 rose between 0.008 and 0.072 quarterly; rare falls oscillated between 0.003 and 0.016. In the model, the monthly productivity growth rate range for the Poznan agglomeration was set at 0.002–0.03 for the calibration procedure.

The minimum wage parameter, which is apparently easy to set, was another problematic issue. In Poland, the legally set minimum wage in the economy is 1700 PLN (GUS 2015), however, it concerns only full-time employment contracts. Many employees work based on other contracts which are not affected by labor law regulations. Thus, in fact the real minimum wage in the whole economy is probably lower than that declared by government adjustments. Having in mind these facts, we set the parameter's range at 1–1.7.

The last ambiguous variable is the height of unemployment benefits in the economy. Depending on the duration of unemployment, previous earnings, and marital and family status, the height of the unemployment benefits visibly differs. The replacement ratio was estimated as 0.4–0.6 in the case of a family with two children, with previous earnings equal to 67% of the mean wage, while for a single, long-term unemployed person the replacement ratio was estimated as 0.2–0.3 (OECD 2012, OECD 2013). For the calibration procedure I assumed the average height of the parameter to be somewhere between 0.3 and 1.2, while the mean wage was 3.29.

---

[9] The Cobb-Douglas shape of the matching function with constant returns to scale is assumed: $M = Au^\alpha v^{1-\alpha}$, where A is the so-called 'efficiency parameter' of the labor market. A higher A implies more efficient matching of workers and vacancies; α is the elasticity of the function with respect to unemployment.

[10] The job destruction rate for the whole economy in the years 2000–2014 was estimated based on Shimmer's (2005) slightly modified formula: $S_t = \frac{u_{t+1}^{short}}{e_t(1-0.2F_t)}$, where u_{t+1} is the number of unemployed persons in the next period, u_{t+1}^{short} is the number of short-term unemployed persons, and F_t is the probability of finding a job in a given period $\left(F_t = 1 - \frac{u_{t+1}-u_{t+1}^{short}}{u_t}\right)$. Equations S_t and F_t are a linear approximation for the differential equations describing probabilities (see Becker, Clerc 2012 for details).

The uniform distribution with border values [0,1] was chosen for sampling with 10 repetitions and 120 samples for each parameter. The first 12 months of the simulation were deleted from the LHS analysis as the start-up period. Benchmark simulations start in the 13th month and end in the 156th month, which implies 12 years of the model run. For the benchmark calibration, six ALMP parameters were set to 0 in order to estimate the economy without support for the unemployed. . Figure 2 presents the results of the LHS for the six global parameters of the model.
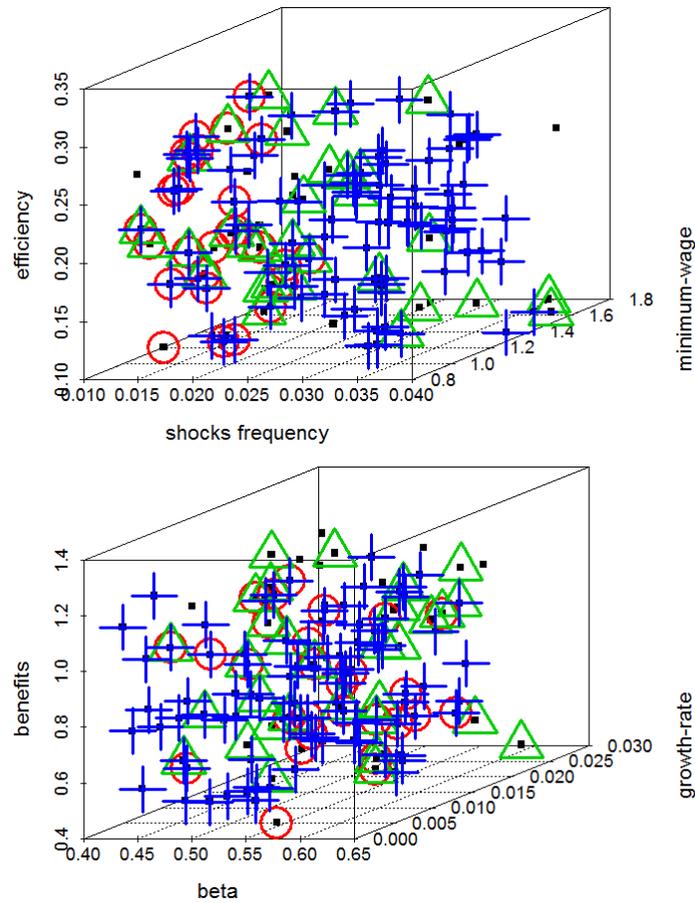
Figure 2. *Results of calibration of the job destruction rate (shock frequency), matching efficiency parameter, height of the unemployment benefits, beta – worker bargaining power and the growth rate of productivity. Black points are algorithm sampled. The red circle is the unemployment density criterion, the triangle is the tightness fluctuation criterion and the cross is the long-term unemployment density criterion.*

The LHS algorithm managed to pin down a few vectors of the matching points that fulfill the calibration criteria. The jobs shock probability was set to 0.0111; the efficiency parameter of labor was set to 0.213. Worker bargaining power was set to 0.458, which means that employers had an advantage in the negotiations process (beta < 0.5); the growth rate of productivity was set to 0.013. The height of the unemployment benefits was set to 0.88, while the minimum wage was 1.02.

The local parameters were set as follows: initial job seekers' productivity mean value is set at 1.7 – 2.7 and depends on an individual's skill level, then the AR(1) process followed. The individual value of leisure was randomly drawn from the 0–0.5 interval. The wages offered for jobs depend on the skill requirements and were set between minimum-wage and minimum-wage + 1.5. Thus, if a minimum wage parameter was equal to 1, the offered wages distribution in the economy was 1 – 2.5.

The recruitment costs also depend on the kind of vacancies, and their mean value was set at 50% – 90% of minimum wage. The higher the skill requirements, the higher the recruitment costs. The summary of parameter calibration is described in Table 2.

Table 2. *Model parameters, values and calibration techniques*

no	name	value	calibration method
	Global parameters		
1	efficiency of labor market (A)	**0.213**	Latin hypercube sampling
2	worker bargaining power (β)	**0.458**	Latin hypercube sampling
3	unemployment benefits (b_i)	**0.884**	Latin hypercube sampling
4	jobs shocks ($lambda$)	**0.011**	Latin hypercube sampling
5	minimum wage $\min(w_i)$	**1.03**	Latin hypercube sampling
6	productivity growth rate (φ)	**0.013**	Latin hypercube sampling
	Local parameters		
7	value of leisure (l_i)	**max. 0.5**	random float
8	initial productivity ($p_{t=1}^i$)	**1.7 - 2.7**	draw from normal distribution *(std. = 0.2)*
9	firm offered wage (w_t^i)	**minimum wage + max. 1.5**	global parameter + random float
10	jobs recruiting costs (c_t^i)	**0.5 - 0.9**	draw from normal distribution *(std. = 0.2)*
11	number of search units (s_t^i)	**max. 12**	random float
12	minimum productivity $min(p_t^i)$	**1**	arbitrary set
	ALMP parameters		
13	ALMP inflow rate ($tau_{un,ltu}$)	**0 - 0.5**	different values are tested for evaluation
14	ALMP resign rate ($sigma$)	**0.05**	arbitrary set
15	ALMP search unit bonus *(bonus)*	**max. 5**	different values are tested for evaluation
16	ALMP job advertisement utilization (*util*)	**max. 0.4**	different values are tested for evaluation

The 'ALMP inflow rate' means the monthly frequency at which job seekers start participating in the ALMP program; the 'ALMP resign rate' means the monthly frequency at which job seekers resign from ALMP participation; 'ALMP search unit bonus' means the monthly additional number of search units gained by job seekers who participate in the ALMP; 'ALMP job advertisement utilization' means the frequency with which the job seekers visit the job-placement agencies to sample their job advertisements. Each ALMP parameter was implemented separately to two groups of job seekers: LTU and non-LTU, which implies six ALMP parameters in the model.

4. Simulation results

The following subsection presents the results of the initial model simulations. The first 12 months of the model run were cut off as the start-up period. The whole simulation ran for 156 months, which implied 12 years of a clear model run. The values plotted in Figures 3–8 are the means of 20 model runs without ALMP support (solid lines) and 10 model runs with ALMP support[11] (dotted lines).

---

[11] In the simulations with support for the unemployed, the ALMP inflow rates were set to 0.15; the search unit bonus for both groups of job seekers was a random float with max = 3; the probabilities of visiting the agency were

The main model-generated series were plotted in the figures, i.e. unemployment rate and the long-term unemployment rate[12] (Figure 3), number of jobs and employers' skills requirements (Figure 4), jobs productivity and wages (Figure 5), labor market transition probabilities (Figure 6), number of on-the-job seekers and labor market tightness (Figure 7), duration of unemployment in the group of LTU and non-LTU job seekers (Figure 8).
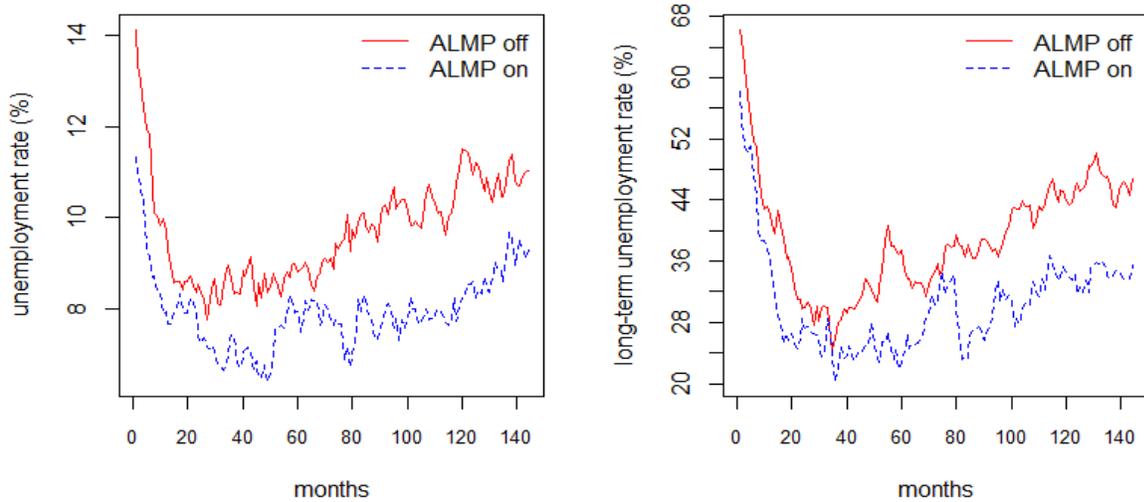
Figure 3. *Unemployment and long-term unemployment ratios*
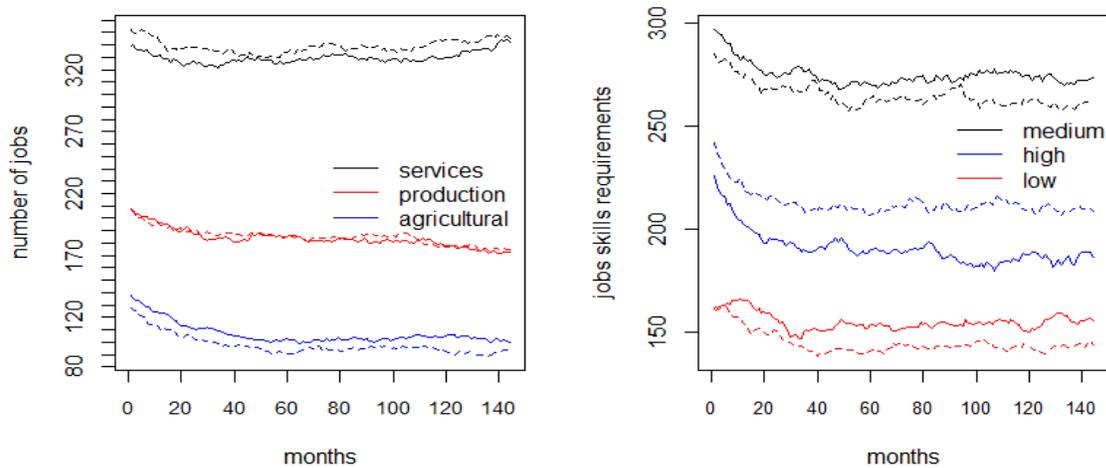
Figure 4. *Number of jobs in the three sectors of the economy and distribution of job skill requirements*

---

set to 0.25. The ALMP resign rate was set to 0.05. Detailed analysis of the ALMP contribution is considered in the next section.

[12] The long-term unemployment rate was computed as the share of the long-term unemployed in the stock of all the unemployed.
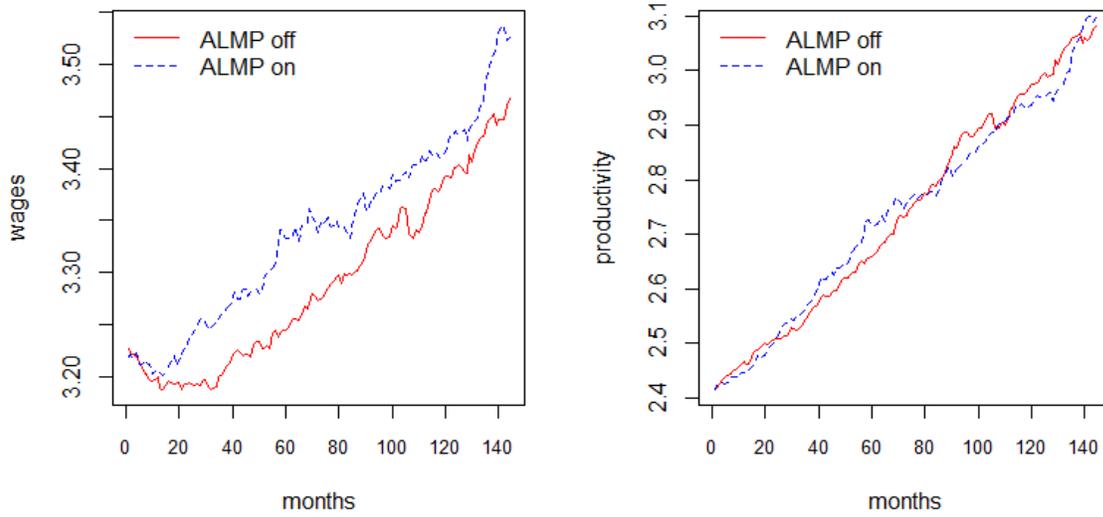
Figure 5. *Wages and productivity. The dotted lines are the results with ALMP support*
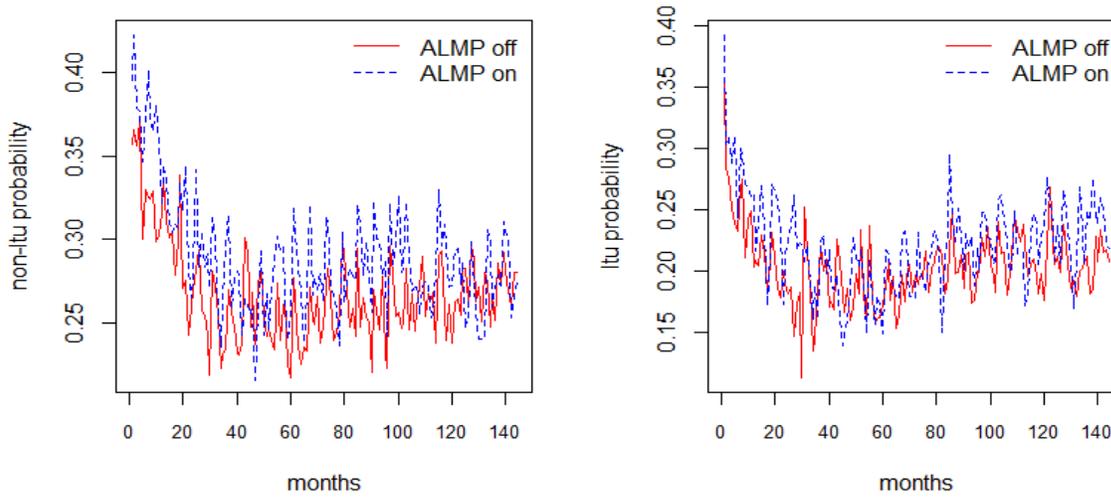
Figure 6. *Probabilities of finding a job*
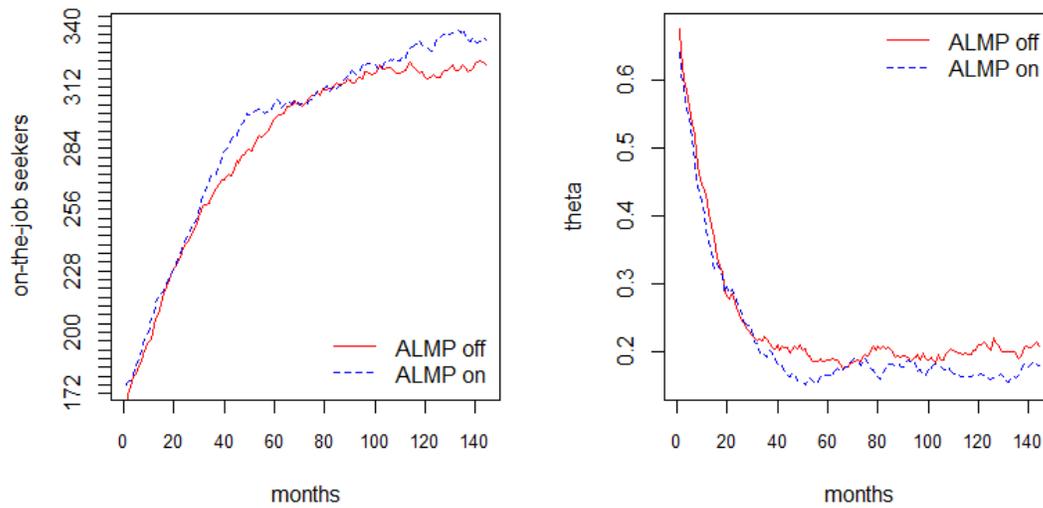
Figure 7. *On-the-job seekers and labor market tightness*
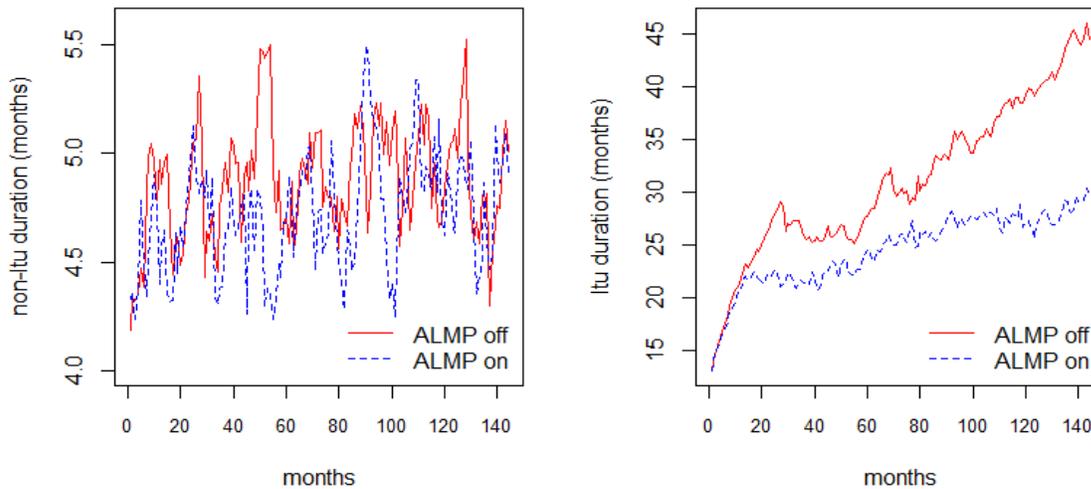
Figure 8. *Duration of the unemployment spell in the two groups of job seekers*

Ten model runs showed that the unemployment rate in the economy without ALMP support covered the range 7.76–14.13% (9.71% mean); the long-term unemployment rate fluctuated between 24.34 and 66.32% (39% mean) (Figure 3). Another ten repetitions of simulations with ALMP support showed that the mean unemployment rate decreased by almost 2% (7.94% mean) and fluctuated between 6.4 and 11.33%. The long-term unemployment rate fell even more significantly, ranging from 20.2 to 58.1% and with a mean value of 30.38%.

Some changes in the number of jobs in the given three sectors of the economy are visible if we turn on the ALMP parameters (Figure 4): a 3% increase in the number of services jobs was observed, while the

number of agricultural jobs decreased by 8.5%. The mean number for all jobs was 620, including 97 jobs in the agricultural sector, 185 in production and 339 in services. Next, with ALMP support, changes in the skill demand distribution can be noticed. A 10% increase in high-skill level jobs and a decline in the number of medium-skilled and non-skilled jobs can be noticed (respectively, by 3.7% and 6.4%). This is the consequence of changes in the unemployed persons' behaviors. Employers adjust the skill requirements to the job seekers: in an economy with ALMP support it is easier to find the proper worker, thus firms do not have to lower their demands to fill the vacancy in a reasonable period of time. Wages paid for jobs were, on average, 2% higher in the economy with ALMP support (a rise from 3.28% to 3.34%), while productivity did not change substantially (Figure 5). A rise in wages can be perceived as an effect of the changed skill demand distribution. Firms filled vacancies with more productive workers and did not have to wait until a less skilled worker took the job.

The transition probabilities were permanently higher in the economy with ALMP support (Figure 6). The job-finding probability of the non-LTU rose from 0.26 to 0.29; LTU rose from 0.20 to 0.22. Job seekers who participated in ALMP programs received extra search units and the possibility of utilizing an extra job advertisement gathered by an agency. This implied a higher probability of encountering the vacancy. Note that the meeting probability in an economy with ALMP support is the mean of all job seekers, i.e. those who take part in the ALMP and those who do not.

The number of on-the-job seekers ranged from 166 and 325 workers with a mean of 285. This means that, on average, 47% of workers were employed below their skill level and sought a better job (Figure 7). In the economy with ALMP support the number of on-the job seekers increased by 4%. Labor market tightness (theta) tended to be lower in the economy with ALMP support: a lower theta is the result of a more effective matching process in the labor market. Agents find preferable trading partners more quickly, which implies a decrease in a job–worker mismatch.

Figure 8 shows that the mean duration of the unemployment spell in the non-LTU group was about 4.9 months. ALMP support did not significantly influence these results, and the average period of seeking employment during 20 simulations was 4.7 months. The LTU duration changed much more significantly, from 31.2 months to 24.5 months with ALMP support.

5. Sensitivity analysis

For the purpose of sensitivity analysis, besides the three calibration criteria (unemployment density, long-term unemployment density and tightness fluctuations), four other criteria were added:
1) *wages paid to LTU who find a job,*
2) *wages paid to non-LTU who find a job,*
3) *non-LTU unemployment duration,*
4) *LTU unemployment duration.*

This extension allows to investigate the detailed impact of parameters on real wages and unemployment duration in the two groups of job seekers.

Sensitivity analysis methods are numerous and can be divided into local and global analyses (Frey, Patil 2002). Local analysis is based on single point estimates. It investigates the effects of change in one

parameter while the other parameters are fixed (Saltelli et al. 2004). Global analysis focuses on the contribution of particular parameters to the model responses. Global sensitivity analysis also provides some information about the importance of and interactions between parameters (Zhan et al. 2013). Two techniques of global sensitivity analysis were developed in this paper: the Morris screening method was used initially to provide a general overview of the relevance of all parameters. In the more in-depth analysis the Sobol method was used to focus on the importance of the job-search assistance program and of the unemployment benefits parameters.

a. Morris method results

The Morris screening method performed a global sensitivity analysis by making r changes in k number of parameters. The algorithm samples some initial values in given parameter ranges, then the value for one of the parameters is changed and the model response is calculated. In the next step the value of another parameter is changed. The procedure continues until all sampled values for all parameters are investigated, which implies $r(k+1)$ of model runs (Saltelli et al. 2008).

The Morris method is easy to implement and is not demanding as regards computing power (Wallach et al. 2006). Morris (1991) proposed two sensitivity measures: mean value μ, which captures the overall influence of the parameter, and standard deviation σ, which estimates the non-linear effects. However, in the case of more complex models, Campolongo, Cariboni and Saltelli (2007) proposed using μ^*, which is the absolute mean value of the distribution of elementary effects. Such a modification prevents cancelling the overall parameter influence by the effect of opposite signs.

The Morris screening was divided into two separate experiments: in the first experiment the impact of the six global parameters was investigated (Figure 9), while in the second the focus was on the six ALMP parameters (Figure 10). A division of the experiments allowed for a more accurate investigation of parameter influence and to avoid the situation where a very strong parameter, e.g. matching efficiency or beta, is compared with a relatively weak one, e.g. search unit bonus. The parameters of the Morris function were *levels = 6* and *grid.jump=3* (Morris suggests *grid.jump=levels/2*).
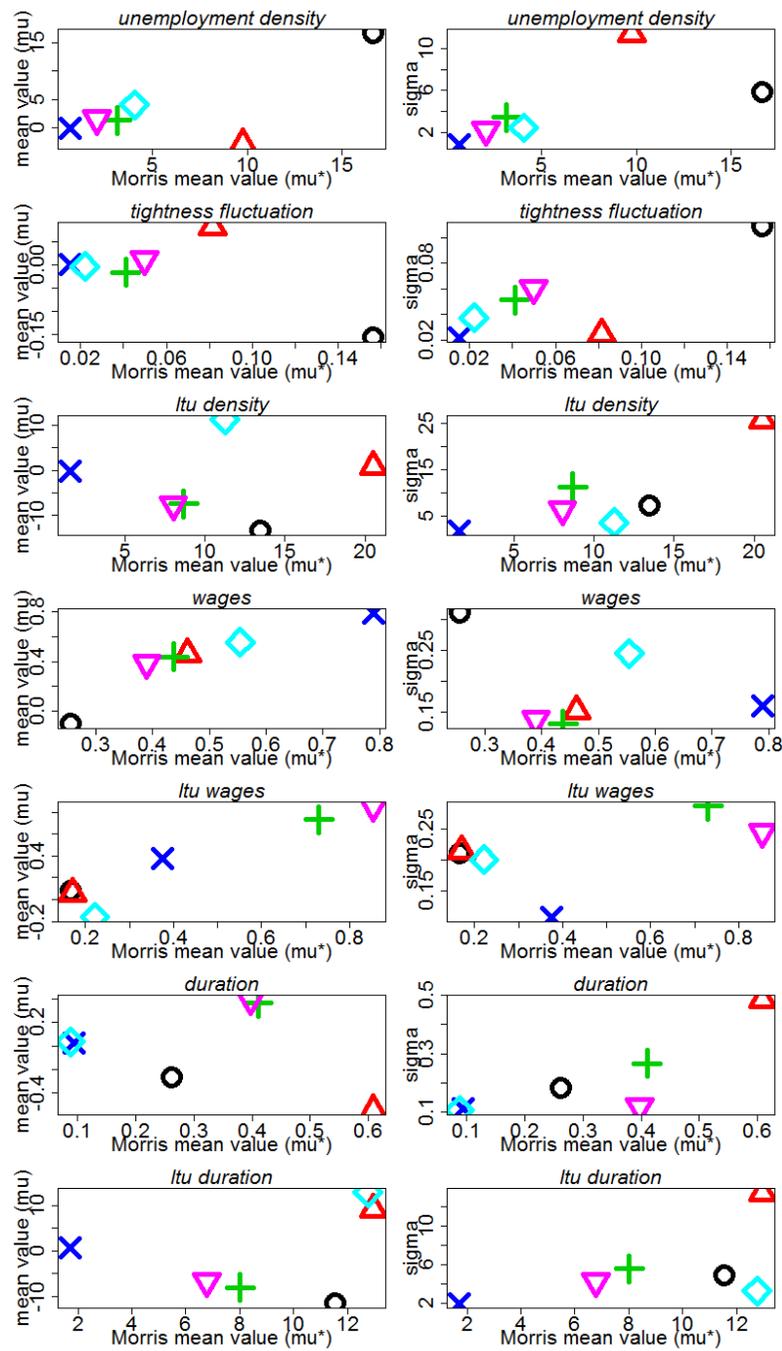
Figure 9. *Results of the Morris screening method for 6 global model parameters. Plots in the first column show the general importance of the parameters (mu - mu*); plots in the second column show the parameter interactions and non-linear effects (mu* - sigma). The circle is the job destruction rate; the red triangle is the level of minimum wage, the green cross is the efficiency parameter; the blue star is the worker bargaining power (beta); the rhombus is the growth rate of productivity; the purple triangle is the height of the unemployment benefits.*

The left column shows the general importance of the parameters and the right column shows the interdependencies among the parameters. The analysis of general impact on the unemployment density criterion (mu, mu*) shows that the most significant of the global parameters are the job destruction rate and the level of minimum wage. In the second group are parameters which are still relevant, but their effect on criterion variation is not as strong. These parameters are: efficiency of the labor market, the height of unemployment benefits and the growth rate of productivity. A strong, positive, first-order and monotonic effect of the job destruction rate on the first criterion is observed. A rising job destruction rate raises the unemployment rate. Minimum wage can affect the criterion negatively, however, the influence on the unemployment rate is non-monotonic (high mu*) and strongly depends on other parameter values (high sigma). A rising growth rate of productivity, the height of the unemployment benefits or the efficiency parameter contributes to an increase in the unemployment rate – this influence is relatively low and non-monotonic.

Labor market tightness fluctuations are affected mostly by the job destruction rate and minimum wage. Other parameters that influence the criterion are the efficiency parameter and unemployment benefits. Increasing the job destruction rate lowers the fluctuations of theta, however, this influence depends on other parameters. Minimum wage affects the criterion positively and monotonically. The other two parameters' impact is low and highly depends on the other inputs' values.

The LTU rate is affected mostly by minimum wage, the job destruction rate and the growth rate of productivity. Minimum wage raises the criterion but the effect is relatively slight and non-linear, while rising unemployment benefits may lead to a slight fall in the LTU rate. An increase in the job destruction rate also lowers the criterion monotonically. The jobs become vacant more frequently, the turnover is higher and LTU is more likely to match the jobs.

The strongest parameter regarding non-LTU wages is worker bargaining power: it raises mean wages in the economy monotonically. The higher the beta, the bigger the part of the surplus from the Nash negotiation gets to the worker. The growth rate of productivity, minimum wage and unemployment benefits also raise wages linearly, but their impact is not as strong. Contrarily, the LTU wages are affected mostly by the main effects of the unemployment benefits parameter, which raises wages monotonically. The growth rate of productivity affects the criterion negatively. Its influence also depends on the values of other parameters.

LTU and non-LTU unemployment duration analysis comes with interesting results. The rising minimum wage can potentially lower the non-LTU duration of unemployment. If the LTU parameter has an opposite effect, it may raise the LTU duration of unemployment. Analyzing the impact of unemployment benefits comes with a similar conclusion: rising benefits shorten the non-LTU duration but prolong the LTU time of the job search. Job destruction contributes to a decrease in the durations, however, in the case of the LTU it has twice the effect.
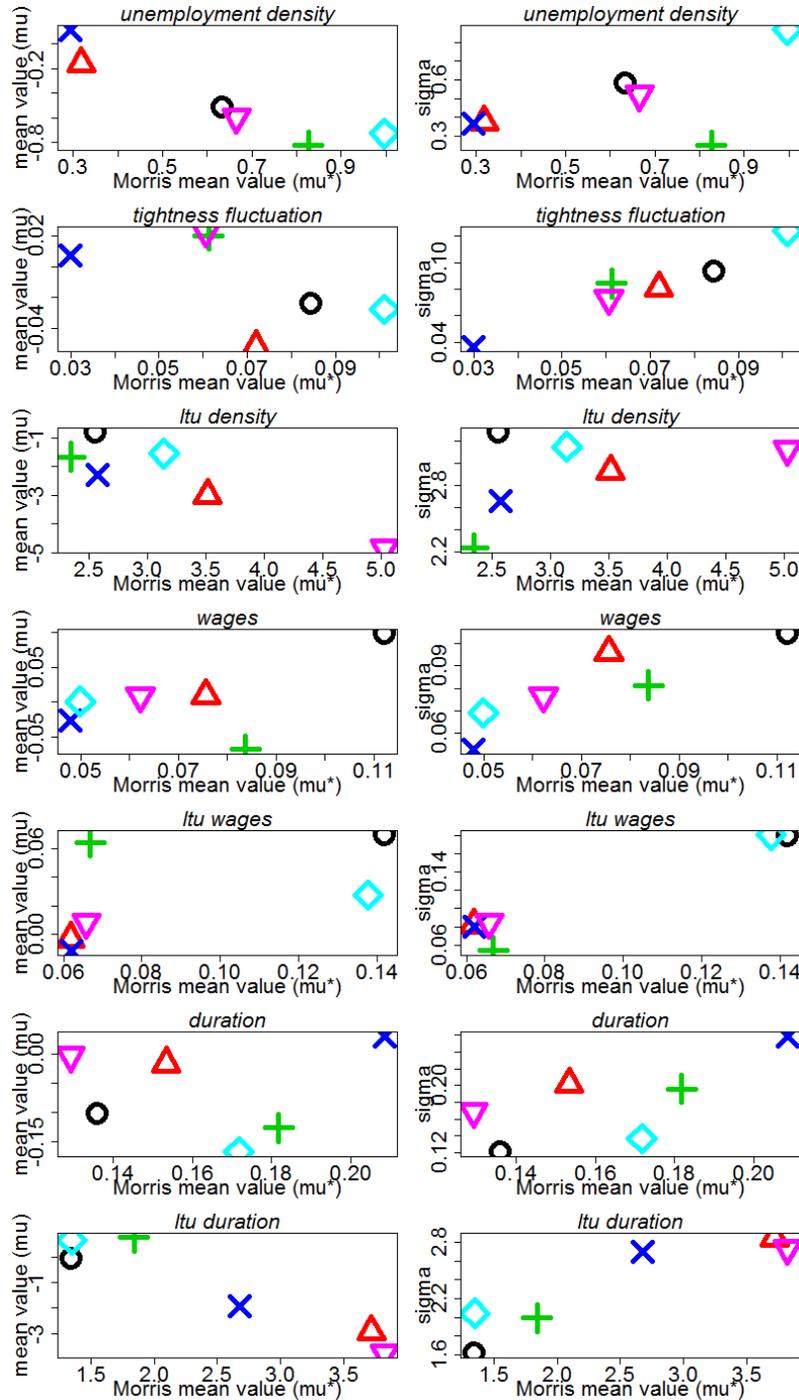
Figure 10. *Results of the Morris screening method for 6 ALMP model parameters. Plots in the first column show the general importance of the parameters (mu - mu*); plots in the second column show the parameter interactions and non-linear effects (mu* - sigma). The circle is the non-LTU search unit bonus; the red triangle is the LTU search unit bonus, the green cross is the non-LTU probability of job agency advertisement utilization; the blue star is the LTU probability of job agency advertisement utilization; the rhombus is the non-LTU inflow rate to ALMP; the purple triangle is the LTU inflow rate to ALMP.*

Almost all ALMP parameters affect the criterion negatively, so we can conclude that, in general, ALMP decreases the unemployment rate on the local labor market. Both inflow rates are among the most influential parameters, which decreases the criterion, but comparing the sigma value shows that their influence is associated with other inputs. The next influential parameter is non-LTU job agency advertisement utilization, which negatively impacts the unemployment rate. The non-LTU search unit bonus is also likely to decrease the criterion, however, with less strength.

Labor market tightness fluctuations depend on: the non-LTU probability of job agency advertisement utilization and LTU ALMP inflow rate. Both parameters affect the criterion positively and mostly monotonic. The non-LTU ALMP inflow rate and the LTU probability of job agency advertisement utilization negatively influence the fluctuations of theta.

The LTU rate is most affected by the following parameters: LTU inflow rate to ALMP and LTU search unit bonus. The influence of these parameters is negative and mostly monotonic, however, it relies on the values of other inputs. What is interesting among the most influential parameters decreasing the LTU rate is the non-LTU ALMP inflow rate. This phenomenon can be interpreted as the prevention effect of such a program which protects non-LTU from extending unemployment duration and the possibility of replenishing the LTU group in the future.

ALMP may affect wages in both groups of unemployed persons. The strongest parameter that has a positive impact on non-LTU wages is the search unit bonus, as it also influences the wage level in the group of the LTU. In turn, the non-LTU probability of job agency advertisement utilization and the LTU probability of job agency advertisement utilization have a slight negative impact on wages. This may be explained by agencies providing more skill-fitted vacancies and by job seekers more likely accepting such proposals even if the wage might sometimes be smaller.

Regarding the non-LTU duration criterion, the strongest parameters are: the non-LTU probability of job advertisement utilization and the LTU probability of job advertisement utilization. The former parameter affects the criterion monotonically and negatively, while the latter influences it monotonically and positively. The other parameter which may decrease the criterion is the non-LTU search unit bonus.

The LTU inflow rate to ALMP is a parameter which most affects the LTU duration criterion and decreases it monotonically. The LTU search unit bonus influences the criterion negatively and slightly less significantly. The non-LTU inflow rate to ALMP and the non-LTU probability of job advertisement utilization can influence the criterion positively and monotonously, thus implying an extension of unemployment duration of the LTU.

5.2 Sobol method

The method of Sobol has become popular due to precision, robustness and successful application in complex models (Glenn, Isaacs 2012). The method distinguishes two sensitivity measures which can be between 0 and 1. The first-order effect sensitivity index S_j shows the model response when one of the parameters changes. The total sensitivity index ST_j summarizes all interactions to model input, thus by assumption: $ST_j > S_j$ (Chan, Saltelli, Tarantola 1997). Let us consider the vector of model parameters:

$Y = \{X_1, X_2, \ldots, X_n\}$. The key idea is to capture how the difference in the variance of input parameters influences the variance of model outputs (Lamboni et al. 2013). The first-order and total sensitivity indices are the contributions to the model output. For the *i* parameter they can be written as:

$$S_i = \frac{V_{X_i}\big(E(Y|X_i)\big)}{V(Y)} \quad ST_{i,j} = \frac{V_{X_i,X_j}\big(E\big(Y|X_iX_j\big)\big)}{V(Y)}$$

Where $ST_{i,j}$ is the total model sensitivity to interactions between parameters X_i and X_j.

The general importance of $ST_{i,j}$ is higher as it captures first-order and higher-order effects. The method demands substantial computing power due to the large amount of iterations with total cost (k+1)N, where N is the recommended sample size and k are the impact factors. Saltelli (2008) suggested that this should be about 500–1000 samples, implying at least 2000 model runs in a single experiment. The model single run time is about 2.5 minutes, which implies 833 hours of total simulation time, which is unacceptable.

To reduce the computing costs, a modification of the Sobol method as proposed by Saltelli (1999) was used. The extended Fourier amplitude sensitivity test based on the multidimensional Fourier transform is one of the ways to decrease the number of necessary iterations. In this case we receive the main effects and interaction effects without higher-order interactions and confidence intervals as in the classical Sobol method. A total of 750 calls of the algorithm provide the results as presented in Figure 11.
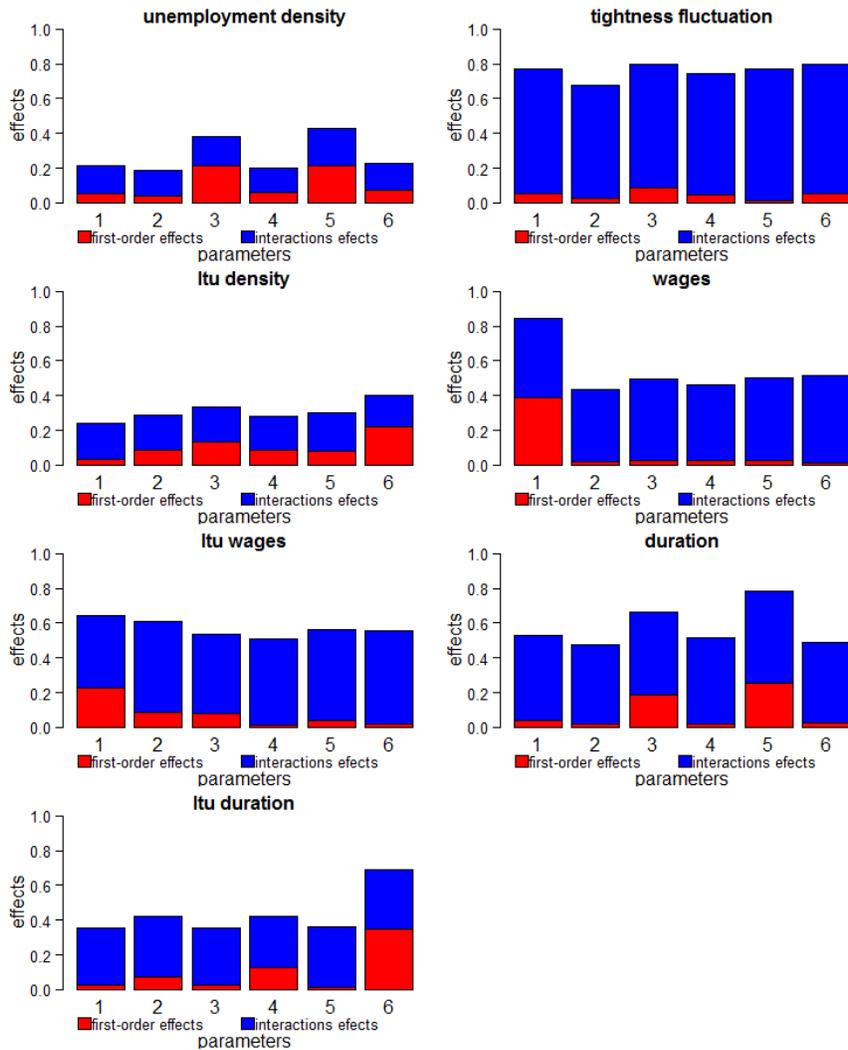
Figure 11. *Results of estimation of the main effects and interaction effects with the extended Fourier amplitude sensitivity test. 1: Non-LTU search unit bonus; 2: LTU search unit bonus, 3: non-LTU probability of job agency advertisement utilization; 4: LTU probability of job agency advertisement utilization; 5: non-LTU inflow rate to ALMP; 6: LTU inflow rate to ALMP. The red color are the first-order or main effects, the blue color are the interaction effects. Total effects are the sum of first-order and interaction effects (blue and red bars).*

A cursory overview of the Sobol indices show that large interactions occur between the parameters. Worth noticing is that all of the ALMP parameters somehow affect the criteria variances. A detailed analysis of the contribution of the ALMP to the variance of the unemployment rate shows that there are two most influential parameters (3 and 5). Both of them are responsible for variation above 21% of the output (main effects) and, respectively, 43% and 38% variation of the output when it comes to total effects. Thus we can conclude that the most straightforward way to decrease the non-LTU rate is to focus on providing and improving employment agencies for this group of unemployed persons.

Besides the LTU inflow rate to the ALMP, which in total affects almost 41% of variation in the LTU rate, the other parameters which have the strongest impact on its fluctuations are: 2 and 4 (both parameters have contribution equal to 28%). Estimation of the Sobol indices shows that strong cross-effect occurs: parameter 3 is responsible for 33% variation of the criterion.

The contribution of parameter 1, which affects wages positively, is definitely the strongest (38% of the main effects and 84% of total effects contribution), however, we must remember that the next influential parameters, 3 and 4 (respectively 49% and 45% contribution), can affect wages negatively. Strictly speaking, programs enhancing search effectiveness impact wages in the economy, but in combination with employment agencies an offsetting effect was observed. A cross-effect was also detected between the LTU wages criterion and the ALMP program for the non-LTU: parameter 1 is likely to affect LTU wages somehow and is responsible for 22% of main effects and 64% of total effects. Unemployed persons participating in a program enhancing search effectiveness find a more profitable job earlier (thus a positive wage effect) and are protected from the prolonged unemployment spell and flow into the LTU group (prevention effect).

Parameter 5 has the biggest contribution to the variation of unemployment duration (it is responsible for 25% of the main effects and 78% of the total effects of changes in the criterion). The next influential parameter is 3, with total impact explaining 66% of the fluctuations and parameter 1 which affects 53% of criterion variation: both parameters decrease the duration. However, the positive effect of parameter 2 and 4 is also significant and explains 47% and 51%, respectively, of the fluctuations in criterion variance.

The LTU duration criterion is strongly influenced by parameter 6, which explains 34% of the main effects' and 68% of the total effects' changes in the criterion. Parameters 2 and 4 affect the variation with 42% of total effects contributions. This time the counteracting impact of parameters 1 and 3 explains 35% of variation of the criterion.

6. Conclusions

In this paper, an agent-based model of the local labor market with the long-term unemployed, on-the-job flows and ALMP support was developed and calibrated for the Poznan agglomeration, which is one of the largest urban areas in Poland. Global sensitivity analysis methods allowed to evaluate the contribution of each of the parameters to the model output, with particular emphasis on six ALMP parameters.

Regarding the evaluation of ALMP programs addressed at two groups of job seekers, some key findings can be enumerated here:

1) ALMP programs significantly affect the local labor market when it comes to the duration of unemployment, level of wages, unemployment rate, and LTU rate as well as skill demand distribution and worker turnover.

2) In general, the LTU group has more gain from participating in programs enhancing search effectiveness, while the non-LTU group benefits more from improving job adverts sharing by the employment agencies.

3) ALMP may induce endogenous wage growth in the economy, thus calculations of expenditures in the labor market policy should be re-estimated by the positive wage effect.

28

4) The prevention effect of job search assistance programs for the non-LTU was identified: such programs protect the unemployed from the prolonged unemployment spell and decrease the probability of flow into the LTU group.

5) Programs for the LTU may increase non-LTU unemployment duration. An LTU participant takes a job that would normally be filled by a non-LTU more quickly.

6) Programs for the non-LTU may increase LTU unemployment duration. In that case, non-LTU ALMP participants are much more competitive than the LTU. This may lead to a permanent push of some part of the LTU group from the labor market and may deepen unemployment persistence among these individuals.

7) A rising minimum wage can potentially decrease non-LTU unemployment duration and the unemployment rate, but it simultaneously leads to an extension of LTU unemployment duration and an increase in the LTU rate.

8) The computations show that raising unemployment benefits does not radically influence the LTU rate and can even lower it. In turn, raising benefits among the non-LTU implies an increase in the unemployment rate and a prolongation of non-LTU unemployment duration.

9) Programs for the unemployed affect skill demand distribution. In an economy with ALMP support, employers profit more from opening up high-skilled jobs.

10) The ALMP boosts flows on-the-job and increases workers' turnover.

It is necessary to emphasize that ALMP programs should be developed complementarily and holistically. This means that complex cross-effects and interdependencies should be taken into account when designing labor market policies.

Summing up, search a theory can be easily adopted into an agent-based framework and used to evaluate the labor market policy. The overall performance of an agent-based search model converges on the canonical search theory framework. Flexibility of the agent-based model allows to easily modify, add, enable and disable other ALMPs into the model code. The model presented here can also be enriched by business cycle fluctuations, bank institutions, elements of the social policy or sectors of the economy.

References

BARNOW, B. S., Gubits, D. B. (2003). Review of recent pilot, demonstration, research, and evaluation initiatives to assist in the implementation of programs under the Workforce Investment Act. Washington, D.C: U.S. Dept. of Labor, Employment and Training Administration. Employment and Training Administration Occasional Paper 2003-10.
https://wdr.doleta.gov/research/FullText_Documents/ETAOP%202003-10%20Review%20of%20Recent%20Pilot,%20Demonostration,%20Research,%20and%20Evaluation%20Initiatives.pdf

BORRILL, P. L., Tesfatsion, L. (2010). *Agent-Based Modeling: The Right Mathematics for the Social Sciences?* Working Paper No. 10023, Iowa State University.
http://www2.econ.iastate.edu/tesfatsi/ABMRightMath.PBLTWP.pdf

BREUNIG, R., Deborah A. Cobb-Clark & Yvonne Dunlop & Marion Terrill. (2003). Assisting the Long-Term Unemployed: Results from a Randomised Trial. *The Economic Record*, 79(244), 84-102.

CHAN, K., Saltelli, A., Tarantola S. (1997). *Sensitivity analysis of model output: variance-based methods make the difference.* Proceedings of the 29th conference on Winter simulation, IEEE Computer Society Washington. http://www.informs-sim.org/wsc97papers/0261.PDF

CAHUC, P., Le Barbanchon T. (2010). Labor market policy evaluation in equilibrium: Some lessons of the job search and matching model. *Labour Economics*, 17(1), 196-205.
https://ideas.repec.org/a/eee/labeco/v17y2010i1p196-205.html

CAMPOLONGO, F., Cariboni J., Saltelli A. (2007). An effective screening design for sensitivity analysis of large models, Environmental Modelling & Software, 22(10), 1509 – 1518.
http://www.sciencedirect.com/science/article/pii/S1364815206002805

BARUFFINI, M. (2014). *An agent-based simulation of the Swiss labour market: an alternative for policy evaluation.* Institute for Economic Research (IRE), University of Lugano, Switzerland.
http://www.ire.eco.usi.ch/tesi-baruffini-248016.pdf

DOLADO, J., Jansen M., Jimeno J.F. (2009). On-the-Job Search in a Matching Model with Heterogeneous Jobs and Workers. *The Economic Journal*, 119(534), 200–228.
http://onlinelibrary.wiley.com/doi/10.1111/j.1468-0297.2008.02210.x/abstract

DAVIDSON, P. (2002). *Employment assistance for long-term unemployed people: time for a re-think*, In T. Eardley and B. Bradbury (Eds.), *Competing Visions: Refereed Proceedings of the National Social Policy Conference* (pp. 107-125), Social Policy Research Centre, University of New South Wales, Sydney.

FREEMAN, R. B. (1998). War of the models: Which labour market institutions for the 21st century? *Labour Economics*, 5(1), 1–24.
http://users.nber.org/~freeman/Papers%20on%20RBF%20website/War%20of%20the%20Models%20-%20Labour%20Economics%205%20-%201998.pdf

FREY, Ch., Sumeet, R. P. (2002). Identification and Review of Sensitivity Analysis Methods. *Risk Analysis* 22(3), 553–578. http://onlinelibrary.wiley.com/doi/10.1111/0272-4332.00039/abstract

GABRIELE, R. (2002). Labor Market Dynamics and Institutions. An Evolutionary Approach. *LEM Working Paper Series 2002/07*. http://www.lem.sssup.it/WPLem/files/2002-07.pdf

GLEN, G., Isaacs K. (2012). Estimating Sobol sensitivity indices using correlations. *Environmental Modelling & Software*, 37, 157–166. https://www.semanticscholar.org/paper/Estimating-Sobol-sensitivity-indices-using-Glen-Isaacs/c301722da482f174e80a576bc799e904756049f9/pdf

HAGEDORN, M. Manovskii, I. Bocola, L. (2010). The Dynamic Effects of Aggregate Demand and Supply Disturbances in Models with Heterogeneous Inputs. *Society for Economic Dynamics*, Meeting Papers 1125.

MEAGER, N. Evans, C. (1997). The evaluation of active labour market measures for the long-term unemployed, Employment and Training Department. International Labour Office Geneva. http://ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_120317.pdf

MACHIN S., Manning A. (1999). The causes and consequences of long-term unemployment in Europe. In: Stephen Machin and Alan Manning (Eds.), *Handbook of Labor Economics*, Elsevier.

MARKS, R.E. Vriend, N.J. (2012). The Special Issue: Agent-based Computational Economics - Overview. *The Knowledge Engineering Review*, 27 (2), 115-122.

MCKAY M. D. Beckman, R. J. Conover, W. J. (1979). *A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code*. Technometrics, 21(2), 239-245. http://www.jstor.org/stable/1268522?seq=1#page_scan_tab_contents

MORTENSEN, D. Pissarides, Ch. (1994). Job Creation and Job Destruction in the Theory of Unemployment. *Review of Economic Studies*, 61(3), 397-415. http://restud.oxfordjournals.org/content/61/3/397.abstract

MORTENSEN, D. Pissarides, Ch. (1999). New developments in models of search in the labour market. Handbook of Labour Economics, In: Ashenfelter O., Card D. (Ed.), *Handbook of Labour Economics*, Elsevier.

MORTENSEN, D. Pissarides, Ch. (1999). *Job reallocation, employment fluctuations and unemployment*, Handbook of Macroeconomics. In: J. B. Taylor & M. Woodford (Eds.), Handbook of Macroeconomics (pp. 1171-1228), Elsevier.

MORTENSEN, D. (2010). Wage Dispersion in the Search and Matching Model with Intra-Firm Bargaining. *American Economic Review*, 100(2), 338-342. http://search.proquest.com/docview/855255303?pq-origsite=gscholar

MORTENSEN, D. Nagypal, E. (2007). More on Unemployment and Vacancy Fluctuations. *Review of Economic Dynamics*, Elsevier for the Society for Economic Dynamics, 10(3), 327-347. http://www.sciencedirect.com/science/article/pii/S1094202507000038

NEUGART, M. (2004). Endogenous matching functions: an agent-based computational approach. *Advances in Complex Systems*, 07(02), 187-201. http://www.worldscientific.com/doi/abs/10.1142/S0219525904000147

PISSARIDES, Ch. (1985). Short-run Equilibrium Dynamics of Unemployment Vacancies and Real Wages. *American Economic Review*, 75(4), 676-90.
https://www.jstor.org/stable/1821347?seq=1#page_scan_tab_contents

PISSARIDES, Ch. (2000). *Equilibrium Unemployment Theory. 2nd Edition*. Cambridge, Massachussets, London, ME: The MIT Press.

POLLAK, A. (2007). *Optimal Unemployment Insurance*. Mohr Siebeck, Germany.

SALTELLI A., Ratto, M. Andres, T. Campolongo, F. Cariboni, J. Gatelli, D. Saisana, M. Tarantola, S. (2008). *Global Sensitivity Analysis: The Primer*, John Wiley & Sons.

SALTELLI, A. Tarantola, S. Campolongo, F. Ratto, M. (2008). *Sensitivity Analysis in Practice: A Guide to Assessing Scientific Models*. John Wiley & Sons.

SALTELLI, A. Saisana M. (2008). Settings and Methods for Global Sensitivity Analysis: A Short Guide. *Proceedings in Applied Mathematics and Mechanics*, 7(1), 2140013 – 2140014.
http://onlinelibrary.wiley.com/doi/10.1002/pamm.200700986/abstract

SHIMER, R. (2005). The Cyclical Behavior of Equilibrium Unemployment and Vacancies. *American Economic Review*, 95(1), 25-49. https://www.aeaweb.org/articles?id=10.1257/0002828053828572

STAVRUNOVA, O. 2007. *Labour market policies in an equilibrium matching model with heterogeneous agents and on-the-job search*. PhD thesis: University of Iowa.
http://ir.uiowa.edu/cgi/viewcontent.cgi?article=1335&context=etd.

TESFATSION L., Kenneth, L. J. (2006). (Eds.) *Handbook of Computational Economics, Volume II: Agent-Based Computational Economics*. Elsevier/North-Holland: Amsterdam.

THIELE, J. C., Kurth, W. Grimm, V. (2014). Facilitating Parameter Estimation and Sensitivity Analysis of Agent-Based Models: A Cookbook Using NetLogo and 'R'. *Journal of Artificial Societies and Social Simulation*, 17 (3) 11. http://jasss.soc.surrey.ac.uk/17/3/11.html

OECD (2013), Tackling Long-Term Unemployment Amongst Vulnerable Groups.
http://www.oecd.org/cfe/leed/Tackling%20Long_Term%20unemployment_%20WP_covers.pdf

VIANA, F. A. C. Venter, G. Balabanov, V. (2010). An algorithm for fast optimal Latin hypercube design of experiments. *International Journal for Numerical Methods in Engineering*, 82(2), 135–156.
http://onlinelibrary.wiley.com/doi/10.1002/nme.2750/abstract

WINTER-EBMER, R. (1991). Some Micro Evidence on Unemployment Persistence. *Oxford Bulletin of Economics and Statistics*, 53(1), 27-43.
http://onlinelibrary.wiley.com/doi/10.1111/j.1468-0084.1991.mp53001003.x/abstract

CHE-SHENG, Z., Xiao-Meng, S., Jun, X. and Tong, Ch. (2013). An efficient integrated approach for global sensitivity analysis of hydrological model parameters. *Environmental Modelling & Software*, 41, 39-52.
http://www.sciencedirect.com/science/article/pii/S1364815212002563

ZHANG, H. Li, Y. (2014). Agent-Based Simulation of the Search Behavior in China's Resale Housing Market: Evidence from Beijing. *Journal of Artificial Societies and Social Simulation*, 17 (1) 18
http://jasss.soc.surrey.ac.uk/17/1/18.html

Please note:

You are most sincerely encouraged to participate in the open assessment of this discussion paper. You can do so by either recommending the paper or by posting your comments.

Please go to:

The Editor