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Job Placement Agencies in an Artificial Labor Market

Marcin Wozniak

Abstract
In this paper, an agent-based search and matching (ABSAM) model of a local labor market with heterogeneous agents and an on-the-job search is developed, i.e. job seekers who vary in unemployment duration, skills levels and preferences compete for vacancies which differ for skills demands and the sector of the economy. Job placement agencies help unemployed persons find appropriate job vacancies by improving their search effectiveness and by sharing job advertisements. These agents cooperate in an artificial labor market where the key economic conditions are imposed. The interactions between the participants are drawn directly from labor market search theory. The main research task was to measure the direct and indirect impacts of labor market policies on labor market outcomes. The global parameters of the ABSAM model were calibrated with the Latin hypercube sampling technique for one of the largest urban areas in Poland. To study 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 the job placement agencies' services, as well as minimum wage and unemployment benefits, considerably interact with and influence unemployment and long-term unemployment ratios, wage levels, duration of periods of unemployment, skills demand, and worker turnover. Moreover, strong indirect effects were detected, e.g. programs aimed at one group of job seekers affected other job seekers and the whole economy. This impacts are sometimes positive and sometimes negative.

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Keywords Agent-based search and matching model; skills heterogeneity; long-term unemployment; on-the-job search; ALMP evaluation; sensitivity analysis

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

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1 Introduction

The past two decades have been a time of persistent unemployment, particularly in European countries, and the duration of time out of work in the EU-28 has grown gradually lately. As a consequence, the share of the long-term unemployed (LTU) in relation to total unemployment rose from 32.7% in 2002 to 43.6% in 2015 (Eurostat). LTU has become a permanent social, psychological, and economic problem, even in rich, Western economies. Currently, the reality of the labor market is highly uncertain and volatile, which further impedes the successful transition from unemployment to work and negatively influences the duration of unemployment.

Long-term unemployment and negative duration dependence have been studied in several papers that have looked at these issues from a few different perspectives (e.g. Heckman et al. 1999; Breunig et al. 2003; Card et al. 2010; Kroft et al. 2016). Some researchers have highlighted the fact that extending the job-search duration increases the probability of being rejected during the recruitment procedure (e.g. Winter-Ember 1991). Furthermore, skills depreciation continues, search intensity decreases and the unemployment exit rate falls (Cockx and Dejemeppe 2005). Other issues are lower income and a decline in re-employment wages, which proceeds along with the duration of the unemployment spell (Johnson and Feng 2013). In turn, other studies have showed that LTU persons often have health, social, and economic problems which, as a result, exclude them from society (e.g. Machin and Manning 1999). Junankar (2011) highlights the social consequences of LTU which can be very serious, e.g. growth of nationalism, riots, divorces and family breakdowns. Nichols et al. (2013) added to this blacklist the devastation to local communities which is reflected in behavioral changes and erosion of social networks.

Given the above, the effective reintegration of LTU persons is a challenging but essential issue of social policy (e.g. Davidson 2002; OECD 2013). In the European Union, the most important labor market policies that improve the probability of the successful transition of unemployed persons to the labor market are job-search assistance, job counseling, training schemes and job subsidies

(Vlandas 2013). The state usually also provides unemployment benefits[1] which should help one subsist when out-of-work and assure a means for seeking a job and a modest lifestyle (Schuster 2010). However, despite the significant growth in the number of active labor market programs (ALMPs) and increases in social expenditure,[2] a high unemployment rate and LTU are both an immutable part of Europe's labor markets. This situation means there is great need for a reliable and innovative design and evaluation strategy for labor market policies.

Some influential papers (e.g. Calmfors 1994; Kluve 2010; Kroft et al. 2013) have underlined that meaningful, indirect effects should be considered to fully understand and appropriately measure the impact of policies on labor market outcomes. Brown and Koettl (2015) provided a clear and comprehensive description of labor market policy side-effects. The authors enumerated the following potential side-effects: the dead-weight effect – when we do not know whether or not employment was the result of participation in a given program; the substitution effect – when hiring a program participant was preceded by firing another employee; the replacement effect – when we do not know if hiring a program participant will not cause the firing of another employee in the future; the wage effect – when the ALMP induces wages and, as a result, firms do not create new employment; the stigmatizing effect – when the ALMP prevents the employment of an employee, because of the potential low productivity of the program participant. It can easily be noticed that the indirect policy effects are quite extensive and differentiated, and influence the overall performance of the labor market in a complex manner and from various economic perspectives.

There are several other issues which arise in this context. An important task is to identify the effects of labor market policies which can vary in time, e.g. an

[1]In some countries, unemployment benefits are significantly reduced if the unemployed person becomes an LTU. In turn, expiration of unemployment benefits may result in a short spike in the unemployment exit rate. This is probably the result of the less selective search behavior of those unemployed facing a loss of income (Caliendo et al. 2009). One of the consequences may be a reduction in match quality, e.g. the job seeker starts a less well-paid job or agrees to work in a worse position, which might imply a decrease in employment duration.

[2] Expenditure 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 security expenditure varied between 18.1% of GDP in Poland to 34.2% of GDP in France (Eurostat).

initial positive effect can turn into a neutral or negative one over time (Card et al. 2015). Furthermore, one must consider which program addresses which participant, as some programs may be efficient for one group and inefficient for another (e.g. training courses addressed to young people may be more efficient than training courses addressed to the long-term unemployed (Meager and Evans 1997). Subsidies may increase the wages and productivity levels of the treated groups, thus in some way affecting the non-treated agents (Neumark 2009).

The paper presented here tries to meet these demands and to contribute to the literature on ALMP evaluation and long-term unemployment. The assessed ALMPs are job counseling and job advertisement postings which are provided by job-placement agencies operating within an artificial local labor market. The programs are directed at two groups of job seekers varying in unemployment duration, i.e. the unemployed and the long-term unemployed. The analysis is focused on an evaluation of the policies' cross-effects (the impact on those non-treated) as well as the direct and indirect impacts of the policies on unemployment, long-term unemployment, worker turnover, skills demand, real wages, and the durations of unemployment spells.

To achieve the research task, agent-based modeling (ABM) was used in conjunction with labor market search theory. A complex artificial local labor market with strongly heterogeneous agents and an on-the-job search was developed. In turn, the agents' interactions in the simulated economy derive directly from the highly respected framework designed by Mortensen and Pissarides (1985, 2000, 2009). The developed model is called agent-based search and matching (ABSAM). The ABSAM model tries to link the strengths of both worlds. A rigorous, well-founded but rigid theory meets the freedom and flexibility of agent-based modeling, which in turn may appear to be too flexible.[3]

The existing literature highlights the fact that the ABM approach allows for a larger level of complexity and diversity, because the routines for the agents' behavior are created instead of requiring a burdensome search for the numerical solutions to equations (Lengnick et al. 2013). The whole system works here

[3] This is probably one of the weakest points of the ABM. Flexibility and the absence of the need to obey strict theoretical assumptions lead to very different models (e.g. Parker, and Epstein 2011). In the present paper, the theoretical framework of search theory should help to overcome this disadvantage.

dynamically as the output of the memory, decisions, and cooperation of autonomous individuals (Helbing 2012). As a result, ABM improves the realism of the simulation (Borril and Tesfatsion 2010) and possibly provides more accurate results when investigating social phenomena (Tesfatsion and Judd 2006). Recently, it has also increasingly been pointed out that agent-based models are a promising tool for economic modeling and policy-making (e.g. Villamor et al. 2012; Erlingsson et al. 2014), as they allow for an evaluation of ex-ante policy effects (Vermeulen and Pyka 2016).

I used global sensitivity analysis and other statistical techniques to quantitatively evaluate the impact of labor market policies on the economy. The *NetLogo* environment was used to develop the model; the *R* programming language with suitable packages was used for simulation analysis (*RNetLogo*, *NetLogo-R*, *lhs* and *sensitivity*). As can be observed, the complexity of the ABSAM model simulation results far exceeds the possibilities of classic equilibrium or dynamic search models. What is more, the ABSAM framework can easily be extended or modified according to given needs.

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, the developed ABSAM model and calibration procedure: Latin hypercube sampling is used to calibrate the global parameters of the model; section four presents general model performance: simulated time series are plotted and discussed; section five develops two global sensitivity analysis techniques: Morris screening is used to study 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; section six concludes and presents main findings.

2 Literature review

It is necessary to start with the theoretical frictional labor market framework which lies at the heart of the analysis. This was developed by D. Mortensen and C. Pissarides in several influential papers (e.g. Pissarides 1985; Mortensen and Pissarides 1994; Mortensen and Pissarides 1999b; Pissarides 2000). Mortensen and Pissarides' partial equilibrium search model becomes a workhorse in the analysis of labor markets with search frictions and has inspired many researchers who have developed the framework in a few directions. Those most related to the paper are the search and matching models designed for an evaluation of labor market policy and emphasizing heterogeneity. The comparison of the papers related to the developed ABSAM model can be found in Table 1.

*Table 1:*Comparison of the most relevant papers

SEARCH AND MATCHING MODELS				
Author	**Model**	**ALMP evaluation**	**On-the-job flows**	**Agents' heterogeneity**
Ljungqvist and Sargent (1998)	Equilibrium search model	Unemployment benefits	No	Two skill levels
Birk (2001)	Equilibrium search model with neoclassical growth process	Search subsidies for employers (steady-state evaluation)	No	Short-term and long-term unemployed
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 et al. 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
AGENT-BASED MODELS				
Author	**Model**	**ALMP evaluation**	**On-the-job flows**	**Agents' heterogeneity**
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 seekers	No	Agents' wages dispersion
Baruffini (2014)	Disaggregate agent-based search model calibrated for the Swiss economy	Subsidized training	Not precise	Skills and economic sectors heterogeneity
Gaudet et al., (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

Nonetheless, to my knowledge, Ljungqvist and Sargent (1998) were the first to discuss the issue of policy evaluation within a search framework in the European environment. They developed a model with identical individuals who lose their skills as the duration of unemployment increases. Among the main findings the authors pointed out that a generous welfare state may increase long-term unemployment in an uncertain economic reality. In turn, Birk (2001) presents a model with the long-term unemployed and introduces search subsidies for employers. Although Birk did not conduct numerical simulations, his steady state analysis suggests that search subsidies may reduce the duration of unemployment and decrease LTU.

Another related analysis is the thesis by Stavrunova (2007), who built an equilibrium search model to examine the impact of subsidized employment on US labor market outcomes. The model was characterized by heterogeneity of the unemployed with respect to skill level and heterogeneity of firms with respect to skill requirements. Stavrunova's model was strongly inspired by a paper by Albrecht and Vroman (2002), in which two-stage skill heterogeneity was implemented. The results show that an employment subsidy for a low-skilled worker may reduce the unemployment rate and increase wages. In turn, the same subsidy for a skilled worker entails a rise in the number of the low-skilled unemployed.

Dolado et al. (2009) prove that on-the-job flows improve the search model's ability to replicate stylized facts regarding wage dispersion as opposed to models without an on-the-job search (Hornstein et al. 2011). 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 labor market policy in Europe is Cahuc and Le Barbanchon (2010). The authors calibrated the model to the French economy and examined the impact of counseling policies on the unemployment rate both in equilibrium and during the transitory period. However, the model does not distinguish the unemployed according to skills, search duration, or productivity level. Besides, it is not clear how the aggregate efficiency parameter, which gives a constant search advantage to counseled job seekers, was estimated. However, the authors proved that policies enhancing search efficiency may have an ambiguous effect on the unemployment rate.

By contrast, agent-based modeling is much less popular than classic computational equilibrium or dynamic search models. However, this promising technique has been extensively used in labor economics (e.g. Neugart and Richiardi 2012; Hamil and Gilbert 2016).

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 a series of empirical facts: the Beveridge curve, job destruction and job creation processes, and wage stickiness. The model allows the analysis of 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 the results could be replicated regarding calibration based on empirical facts.

Neugart (2004), on the other hand, adopted the concept of the matching function in a multi-agent environment. He programmed an artificial labor market which endogenously sets unemployment, reservation wage, and vacancies. The simulations suggest that the validity of 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. Unlike 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 labor market policy in Switzerland. The author tried to implement sector-specific skills requirements and a whole range of passive and active labor market programs. Until this time, subsidized training had been implemented as one of the active labor market policies. The author underlined the preliminaries of the model; however, 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 or multiple model run. Similarly, we do not know which techniques he used to compute the impact of subsidized training on the employment rate.

Gaudet et al. (2014) studied 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 between five different states. In the paper, the authors focused on an experiment concerning diminishing FDCs. The results indicate that decreasing the use of 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 classic aggregate labor market model as presented by Bentolila et al. (2010). The latter paper proves that suppressing FDCs leads to an inward shift of the Beveridge Curve, which is a result of a decrease in worker turnover.

3 ABSAM model

3.1 General assumptions

The model developed in this paper is an agent-based search and matching (ABSAM) model with skills and jobs heterogeneity, long-term unemployed, on-the-job search and labor market policies. There are four types of agents in the artificial labor market: firms, vacancies, job seekers and job placement agencies.

The firms can create vacancies in three general sectors of the economy which are represented on a local labor market: production (*prod),* services (*ser*), and agriculture (*agr*). The distribution of vacancies is random; however, the probability that the firm will create new jobs in a more vibrant sector of the economy (e.g. services) is higher.[4] The vacancies also differ with respect to skill requirements, productivity, and wages offered. The higher the skills requirements, the more favorable the wage and the larger the productivity.

Job seekers can be in one of three different states: unemployed (un), long-term unemployed (ltu), or employed (emp). Job seekers can seek a job in three general sectors of the economy, the choice of which depends on their individual preferences. The unemployed are heterogeneous in their skill levels; similar to the

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[4] The probabilities were tuned on the basis of the empirical distribution of jobs in economic sectors in the Poznan agglomeration as extracted from www.stat.gov.pl. More details are in the Calibration section.

vacancies, they are characterized by 5 skill levels.[5] Underemployed job seekers may search for a job. Job seekers face the problem of human capital depreciation: the probability of skills and individual productivity loss rises along with the duration of unemployment and is updated every period. In turn, while employed, workers can improve their qualifications via 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.

Job placement agencies provide ALMPs to the local labor market. The job placement agencies' effects are twofold: first, they provide job search support to unemployed persons (counseling); second, they share job advertisements gathered from the local labor market with the program participants. The programs are directed at two groups of unemployed: i.e. regular (non-LTU) job seekers and the long-term unemployed (LTU). Any job seeker who wants to can participate in the ALMP, and none of the participants are forced to take part and can resign at any given period.

Agents are characterized by their position on a two-dimensional square grid. 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 neighboring patches, the probability of matching a proper vacancy is higher (the spatial matching algorithm is described in detail in the Match Creation 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. Each agent at every time step is allowed to make decisions according to the programmed set of algorithms. The ABSAM model is presented in the Appendix as Pseudocode.

[5] The 5 skills levels correspond to the 5 education stages in Poland, which were distinguished on the basis of the International Standard Classification of Education. We can then write Level 1 as Elementary School; Level 2 as Middle School; Level 3 as Vocational School; Level 4 as High School and Level 5 as Higher Education.

3.2 Labor market – The setup

The number of job seekers is set to 600. The number of firm agents is 200.[6] The number of job-placement agencies is 4.[7] There are 20 equal patches to each side from the center of the artificial labor market.[8]

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 travel. In general, job seekers try to maximize their expected income through the implemented dynamic programming algorithm (The value functions Section.). 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 agents 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. Information in the CV is updated every period. If unemployed, job seekers face depreciation of individual productivity p_t^i at an

[6] The number of job seekers and number of firms was set to capture the dependency between the actors in the simulated labor market of the Poznan agglomeration. The empirical proportion is lower (5 job seekers per 1 firm) than the relation in the model. However, in the model, a maximum number of vacancies that the firm can open up is three. In real life, firms can create as many vacancies as they want. Because we have no detailed vacancies statistics at our disposal, I assume that the proportion should be larger in the model.

[7] The number of job-placement agencies was adjusted to cover most of the local labor market. Assuming a maximum number of search units, each agency operates in an area of max. 400 patches. The world is built out of 1600 patches, thus each agency has its own operating area.

[8] The number of patches was adjusted according to two criteria: 1) reasonable time execution of a simulation; 2) accuracy of the results and possibility of free movements of the agents on the grid. A larger world usually needs fewer repetitions and should provide better results, however, the simulation time increases significantly along with the number of patches (Oremland et al. 2014).

exogenous rate of φ per month; p_t^icannot fall below the exogenous reservation threshold. On average, job seekers with a higher skill level and lower unemployment duration have greater individual productivity. When an unemployed person seeks a job for more than 12 months, he or she becomes a long-term unemployed person and suitable information appears in his/her individual CV. From then on, every month the LTU, besides undergoing productivity depreciation, he/she must also face the probability of losing his/her skills.

When job seekers are unemployed, they receive social security benefits b_t^i, enjoy leisure l_t^i and seek a job. Job seekers plan their moves on the grid according to their individual resources as well as information gathered from the local labor market. They make a list of firms they have visited and plan to visit, then they move and update the information for the next turn.

Firms provide job offers that are characterized by the sector of the economy 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 of each type, which implies that total vacancies are in the range of 200–600 at t=0. From then on, the number of vacancies evolves endogenously according to the needs of the local labor market, the potential profit firms can gain and the job destruction process continues at exogenous rate λ. 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. The minimum number of vacancies is not specified, so if it is not profitable then the firm is not obliged to employ any workers and can close all vacant jobs. The maximum number of vacancies remains 3 per firm during the entire simulation period.

An exogenous variable called *wage-offer* is assigned to each vacancy and job seeker. The wage-offer consists of the minimum wage in the economy (global parameter) and the random float variable, whose value depends on the skill demands/skill level of the given vacancy/job seeker. The higher the skill demands/skill level, the higher the upper boundary of the random float variable.[9] Such a solution implies that the wage-offers of more skilled vacancies/job seekers

[9] More details on the wage-offer parameter can be found in the Calibration section on page 19 and in Table 2.

are, on average, higher than those of less skilled agents. Production starts when the job seeker and vacancy match and a real wage is negotiated. Production is the result of the individual productivity of the job seeker p_t^i and the productivity component of vacancy x_t^i. In general, higher-skilled unemployed persons who match vacancies with a higher skills demand are more productive; however, exceptions to this rule are possible, because individual productivity is a random number drawn from normal distribution. After the match, 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.

Job-placement agencies encourage unemployed individuals to start ALMP programs. Non-LTU job seekers begin to participate in ALMPs at an exogenous rate τ_{un} every period; the LTU start the programs at rate τ_{ltu}. If a job seeker decides to enroll, the job placement agency provides him/her with obligatory counseling. The number of individual search units increases by *almp-bonus* in that case. A program participant may also use job advertisements gathered by the agency for every period with a given probability (*util-prob*). In that case, the assumption is that the job advertisements that are available in the agencies are more fitted to an individual's preferences than those found on the job seeker's own. Each agency gathers job offers from neighboring patches at a distance equal to the maximum number of search units at a given turn. As a result, each agency has different job offers at its disposal. The number of ALMP participants is endogenous, with the maximum determined to be 40% of the fraction of job seekers in a specific group. The ALMP participants can withdraw from the program at any given period at some exogenous rate σ.

3.3 Match creation

The search strategies of the job seekers depend on individual search intensity, which in this case is defined as the number of search units supplied by each agent (Petrolongo and Pissarides 2001). The mechanism that describes the agents' behavior is a matching function which presents the number of new matches as a result of vacancies and the unemployed (Pissarides 2000; Shimer 2005; Rogerson et al. 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:

$$M_t = m\left(sJ_t^i, V_t^i\right) \qquad (1),$$

The number of matches at a given time M_t is the result of the search 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 a job while 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 and has increasing returns to scale and decreasing marginal productivity. M is a homogeneous function of degree 1 (e.g. Petrolongo and Pissarides 2001).

Given (1), we can now define the individual meeting probability for each agent. If a single job seeker in a given time interval chooses a search strategy 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: $\theta_t = \frac{V_t^{i,ser}+V_t^{i,pro}+V_t^{i,agr}}{J_t^{i,un}+J_t^{i,ltu}+J_t^{i,em}}$. For a single agent who samples from preferred job offers at a maximum distance,[10] 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 $q(\theta)_t^i = k_t^i$, and for a job seeker: $\theta q(\theta)_t^i = h_t^i$.

I derive the behavioral algorithm that links the agents on the local labor market from modifications to the urn-ball matching model, which has been described in the economic literature several times (e.g. Butters 1977; Hall 1979; Coles and Smith 1998). In the economic adaptation of such a model, firms or vacancies play the role of the urns and the job seekers act as the balls. Consequently, the ABSAM model implementation of equation 1 for a representative agent can be described as follows: When a job seeker wakes up in the artificial world, he or she looks around

[10] 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. Implicitly, such a distribution would be different for any agent who resides in another patch.

and makes a list of potential trading partners. On the list are firms which correspond to the job seeker's preferences at a distance equal to the maximum number of search units he or she owns in a 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 higher skill requirements, the job seeker removes the firm from the list and continues the search as long as $s_t^i > 0$. When all of the job seekers have utilized their search units, the turn ends. If the job seeker's preferences and skill level are convergent with the identified 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 a 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 *(almp-bonus)* and gains the possibility of utilizing job offers gathered by the agencies. Regarding the latter, job-seekers exchange search units for the possibility of sampling from a pool of better-fitting offers *(util-prob).*

The above assumptions are compatible with search theory, in which the search intensity falls with time (Shimer 2005), and job-search assistance programs improve the search intensity (Kluve 2006; Card et al. 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 (check sections *initialize-search-process*, *search-for-job* and *almp-participate* in Pseudocode in the Appendix for the ABSAM model implementation details).

3.4 The value functions

The next step is to define the value functions for workers and firms. They 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 et al. 2005; Mortensen 2010). In this case, a job seeker who visits a given firm with the preferred type of vacancy considers whether he or she wants to continue the 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. If his or her skill level is one, payoffs are then equal to:

$$rU_t^i = b_i + l_i + h_t^i[E(w)_t^i - U_t^i] \quad (2),$$

where $E(w)_t^i$ is the gain from accepting the current job offer and r is discount factor. U_t^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. It is worth mentioning here that the unemployed person, besides receiving money from the social security 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 and Pissarides 1999a; Hagedorn and Manovskii 2008).

In turn, the value of unemployment for the job seeker with skill level > 1, who can work below qualifications should be written as:

$$rU_t^i = b_i + l_i + \bar{h}_t^i[\overline{E(w)}_t^i - U_t^i] + h_t^i[E(w)_t^i - U_t^i] \quad (3),$$

where $\bar{h}_t^i$ is the probability of finding a job below qualifications; $\overline{E(w)}_t^i$ is the gain from working below qualifications. Similarly, h_t^i and $E(w)_t^i$ are the same values for obtaining a more skill-fitted vacancy.

The most skilled vacancies can be allocated only to job seekers with the highest skill levels. Analogously, the payoff from a vacancy with skill demands = 5 would be:

$$rV_t^i = -c_i + k_t^i[F(v)_t^i - V_t^i] \qquad (4).$$

Firms try to maximize their 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 remainder, v_t^i, from the 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 (k_t^i) future trading partners' distributions at the maximum distance V_t^i. The value function of the vacant job with skills demands < 5, which can be also occupied by overeducated workers, can now be written as:

$$rV_t^i = -c_i + \bar{k}_t^i[\bar{F}(v)_t^i - V_t^i] + k_t^i[F(v)_t^i - V_t^i] \qquad (5),$$

where $\bar{k}_t^i$is the probability of matching with job seeker with skill level > skill demand, $\overline{F(v)}_t^i$is the potential gain for the firm from employing a mismatched worker. Consequently, $k_t^i$is the probability of matching with a skill-fitted worker and $F(v)_t^i$is the profit for the firm from employing a skill-fitted worker.
Thus, when a job seeker is employed, the value equation becomes:

$$rE(w)_t^i = w_t^i - \lambda\left(E(w)_t^i - U_t^i\right) \qquad (6),$$

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; λ 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 for job destruction process $\lambda\left(E(w)_t^i - U_t^i\right)$.

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

$$\overline{rE(w)}_t^i = \overline{w_t^i} - \lambda\left(E(w)_t^i - U_t^i\right) + h_t^i[E(w)_t^i - E(w)_t^i] \qquad (7).$$

The value of being employed consists of the wage minus the probability of losing the job for 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:

$$rF(v)_t^i = p_t^i x_t^i - w_t^i - \lambda\left(F(v)_t^i - V_t^i\right) \quad (8).$$

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 for the job destruction process. If a worker with an inappropriate skill level fills a given job, the Bellman equation must be rewritten as:

$$r\overline{F(v)}_t^i = \bar{p}_t^i \bar{x}_t^i - \bar{w}_t^i - \lambda\left(\overline{F(v)}_t^i - V_t^i\right) - h_t^i[F(v)_t^i - V_t^i] \quad (9).$$

The value of a vacancy filled by an overqualified worker consists of the firm's current payoff from production $\bar{p}_t^i \bar{x}_t^i - \bar{w}_t^i$, the probability of capital loss for job destruction process $\lambda\left(\overline{F(v)}_t^i - V_t^i\right)$, and the probability of a job seeker's outflow to another job and the necessity of maintaining the vacancy at cost V_t^i. Note that in that case the matches may terminate for two reasons: losing a job or moving to a better vacancy.

Check sections *update-value-functions* and *on-the-job-search* in Pseudocode in the Appendix for the ABSAM model implementation details.

3.5 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.[11] 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 gain a profit from the cooperation. To start the job, the worker resigns from U_t^i and receives $E(w)_t^i$, thus when the firm hires the job seeker it resigns from V_t^i and receives $F(v)_t^i$. The Nash solution implies

$$w_t^i = argmax(E(w)_t^i - U_t^i)^\beta (F(v)_t^i - V_t^i)^{1-\beta} \quad (10).$$

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

[11] The equal negotiation power of workers and employers is not confirmed and represents an uncertain factor on the real labor market (Mortensen and Nagypal 2007).

$$S(w,v)_t^i = E(w)_t^i - U_t^i + F(v)_t^i - V_t^i \quad (11).$$

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:

$$w_t^i = \beta S_t^i \rightarrow U_t^i(1-\beta) + \beta\left(p_t^i x_t^i - V_t^i\right) \quad (12).$$

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

$$w_t^i = U_t^i(1-\beta) + \beta p_t^i x_t^i \quad (13).$$

As value functions are endogenous, the real wage of the worker w_t^i is computed only if he or she matches the proper vacancy and starts producing $\beta p_t^i x_t^i$ and then evolves endogenously according to Eq. 13. At the stage of bargaining and computing the payoffs, the agents make use of the additional *wage-offer* variable which was described on pages 10 and 11 (check sections *update-value-functions* and *wage-bargaining* in Pseudocode in the Appendix for the ABSAM model implementation details).

Finally, the job creation condition can be derived by the combining surplus equation with (4) and (5) and by applying the free-entry conditions:

$$c_t^i \frac{1}{k_t^i} < k_t^i\left(p_t^i x_t^i - w_t^i\right) \quad (14).$$

The cost of maintaining the vacancy of each type c_t^i multiplied by the expected time of waiting for filling the vacancy $\frac{1}{k_t^i}$ 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 ABSAM 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 this by the mean recruiting cost $c_t^i \frac{1}{k_t^i}$. 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 $k_t^i\left(p_t^i x_t^i - w_t^i\right)$. 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 λ (check sections *create-vacancies* and *destroy-vacancies* in Pseudocode in the Appendix for the ABSAM model implementation details).

3.6 Calibration procedure

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

The local labor market is characterized by various empirical statistics which will be exploited to calibrate the key parameters of the model. Unfortunately, freely available data concerning low levels of aggregation are very limited in the Polish public statistical system. Therefore, the NUTS2 time series for the Wielkopolska region are used as a proxy for 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 shown in Wozniak 2015). 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[12] 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

[12] The long-term unemployment ratio was computed as the relation between the long-term unemployed and all those unemployed in the economy.

economy: the co-movements of vacancies and unemployment are known in the theory as the Beveridge curve (Shimer 2005). Empirical fluctuations of θ were measured through the coefficient of variation of the seasonally adjusted, registered unemployment monthly time series.[13] The seasonal component was removed with the Hodrick-Prescott filter, with the smoothing parameter set to 129600. The minimal coefficient of variation of θ was 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 six global parameters with uncertain values are calibrated to keep the three criteria in the selected ranges during the simulation. The Latin hypercube sampling (LHS) technique was used for this task, as it is 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 (Carnell 2016). The dimensions of the matrix constitute the number of variables (Viana et al. 2010). Admittedly, a certain degree of luck is desirable to match all criteria at one point.

The efficiency parameter of the matching function[14] has a significant impact on the job-finding probabilities and vacancy-filling probabilities, but there is no

[13] 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 low number of vacancies registered by the Public Employment Service in Poland (e.g. Wozniak 2015).

[14] A standard Cobb-Douglas shape of the matching function with constant returns to scale is assumed: M=Au^α v^(1-α), 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.

obvious way to set this 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[15] was estimated from the Labor Force Survey data as 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. Parameter beta is usually set to 0.5, thus implying the same negotiation power of both the job seeker and employer (e.g. Shimer 2005). 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 and Nagypal 2007). With 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 is one of a number of countries known for their poor labor productivity; however, during the last decade a dynamic rise of this indicator can 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 0.005–0.07 for the calibration procedure.

The minimum wage parameter, which is apparently easy to set, was another problematic issue. In Poland, the legal gross minimum wage in the economy is 1700 PLN monthly (Central Statistical Office); however, this only applies to full-time employment contracts. Many employees work on other contracts which are not affected by labor law regulations. Thus, in fact, the real minimum wage in the

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[15] The job destruction rate for the whole economy in the years 2000–2014 was estimated based on Shimer's (2005) slightly modified formula: λ_t=(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 (F_t=1-(u_(t+1)-u_(t+1)^short)/u_t). Equations S_(t) and F_t are a linear approximation for the differential equations describing probabilities (see Becker and Clerc 2012 for details).

whole economy is probably lower than that declared by government adjustments. Given these facts, I set the parameter's range at 1–1.7.

The last ambiguous variable is the level of unemployment benefits in the economy. Depending on the duration of unemployment, previous earnings, and marital and family status, the level of the unemployment benefits differs significantly. The replacement ratio was estimated as 0.4–0.6 for 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 statistics). For the calibration procedure, I assumed the average level of the parameter to be somewhere between 0.3 and 1.2, while the mean wage was 3.29.

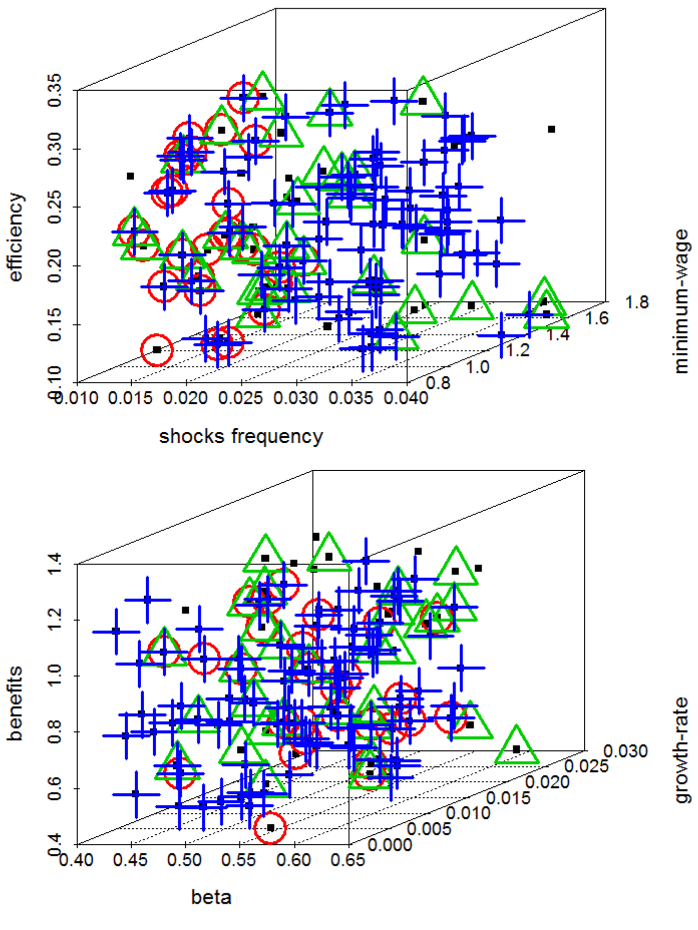
The uniform distribution with border values [0,1] was chosen for sampling with 10 repetitions and 120 samples for each parameter. The first 12 months of the simulation were deleted from the LHS analysis as the start-up period. Benchmark simulations start in the 13th month and end in the 156th month, 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 job-placement agencies. Figure 1 presents the results of the LHS for the six global parameters of the model. A summary of parameter calibration is provided in Table 2.

The LHS algorithm managed to identify a few vectors of the matching points that fulfill the calibration criteria. The job 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 negotiation process (beta < 0.5); the growth rate of productivity was set to 0.013. The level 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 depended 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 depended 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.

Figure 1. 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.

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 (λ)	**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 $(p^i_{t=1})$	**1.7 - 2.7**	draw from normal distribution *(std. = 0.2)*
9	offered wage (w^i_t)	**minimum wage + max. 1.5**	global parameter + random float
10	jobs recruiting costs (c^i_t)	**0.5 - 0.9**	draw from normal distribution *(std. = 0.2)*
11	number of search units (s^i_t)	**max. 10**	random float
12	minimum productivity $min(p^i_t)$	**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 (σ)	**0.05**	arbitrary set
15	ALMP search unit bonus *(almp-bonus)*	**max. 5**	different values are tested for evaluation
16	ALMP job advertisement utilization *(util-prob)*	**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 ignored, as they were considered to be 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 2–7 are the means of 20 model runs without ALMP support (solid lines) and 10 model runs with ALMP support (dotted lines). Note that simulation results in this section are based on a rigid setting of the parameters. Detailed analysis of the parameters contribution to the model output is considered in the Sensitivity analysis section.

The ABSAM model-generated series were plotted in the figures, i.e. unemployment rate and the long-term unemployment rate[16] (Figure 2), number of jobs and employers' skills requirements (Figure 3), jobs productivity and wages (Figure 4), labor market transition probabilities (Figure 5), number of on-the-job seekers and labor market tightness (Figure 6), duration of unemployment in the group of LTU and non-LTU job seekers (Figure 7).

Twenty 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 twenty repetitions of simulations with a rigid setting of ALMP parameters 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%, 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 activate 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, 3.7% and 6.4%). This is the consequence

[16] The long-term unemployment rate was computed as the share of the long-term unemployed in relation to the stock of all the unemployed.

of changes in 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 within a reasonable period of time.

Figure 2: Unemployment and long-term unemployment rates

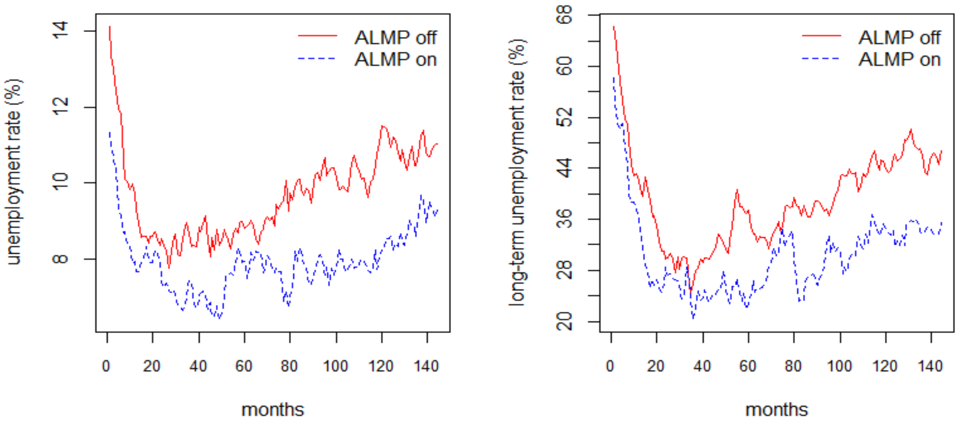
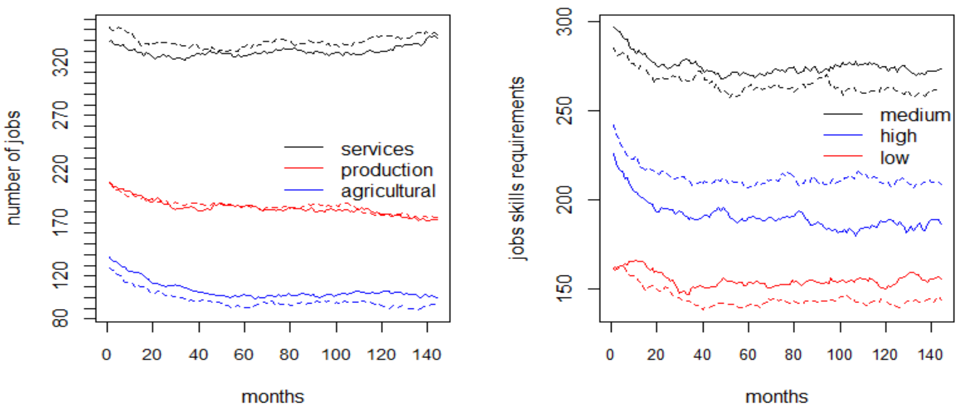


Figure 3: Number of jobs in the three sectors of the economy and distribution of job skills requirements



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.

Figure 4: Wages and productivity. The dotted lines are the results with ALMP support

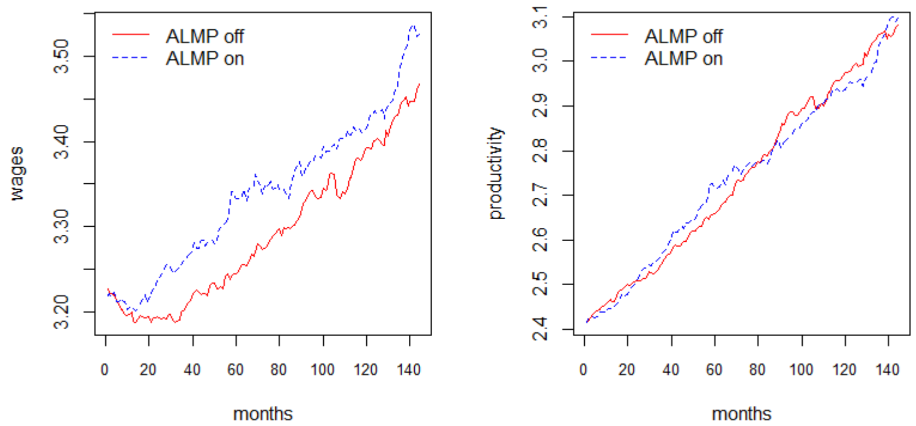


Figure 5: Probabilities of finding a job

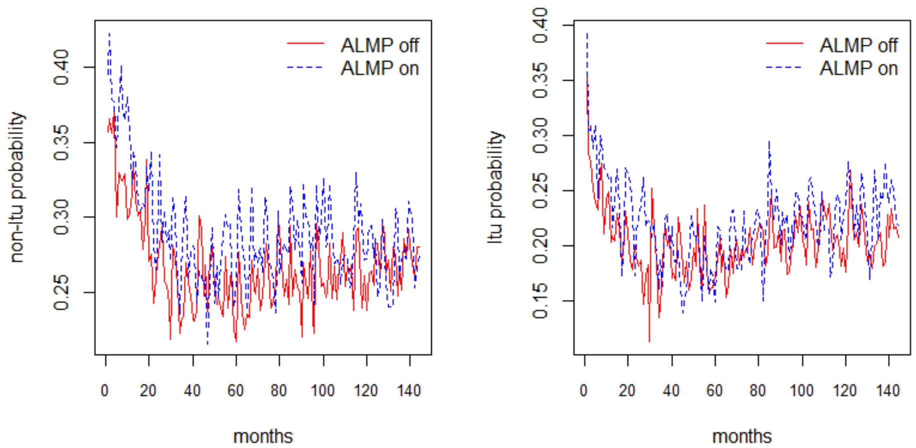


Figure 6:. On-the-job seekers and labor market tightness

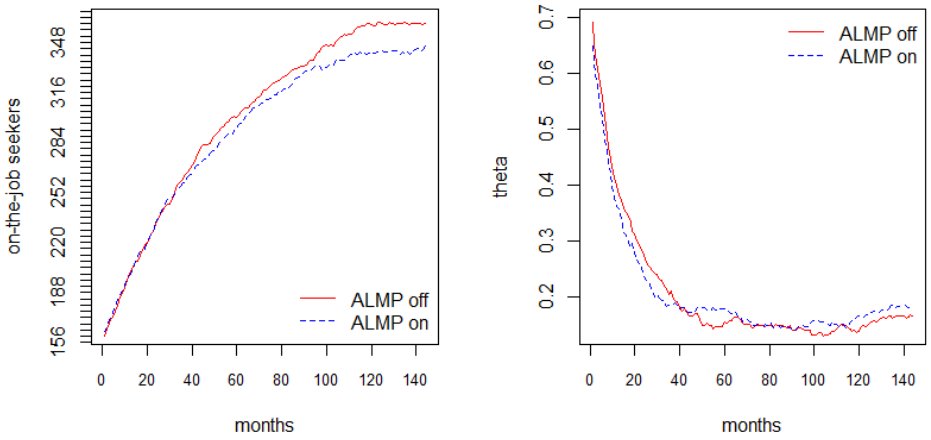
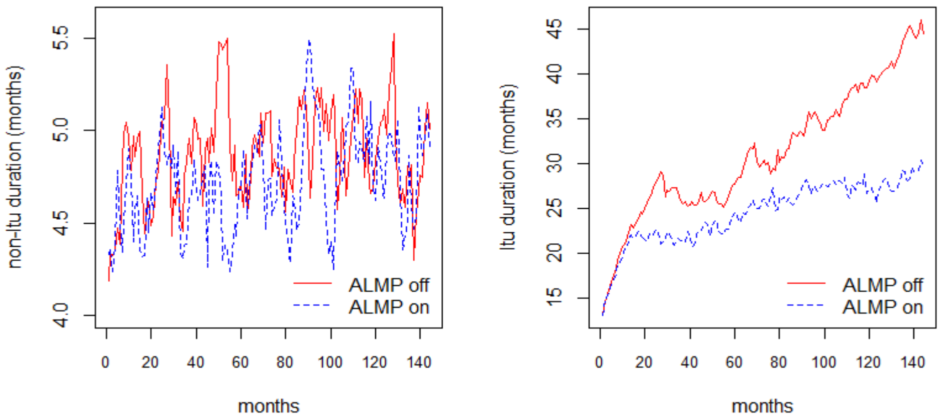


Figure 7: Duration of the unemployment spells in the two groups of job seekers



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 160 and 360 workers with a mean of 285. This means that, on average, 50% 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 decreased by 4%. Labor market tightness (theta) did not change in the economy with ALMP support and held its value, 0.20.

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 28.2 months to 24.5 months with ALMP support.

5 Sensitivity analysis

For 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 an investigation of 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 analyzes (Frey and 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 initially used 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.

5.1 Morris method results

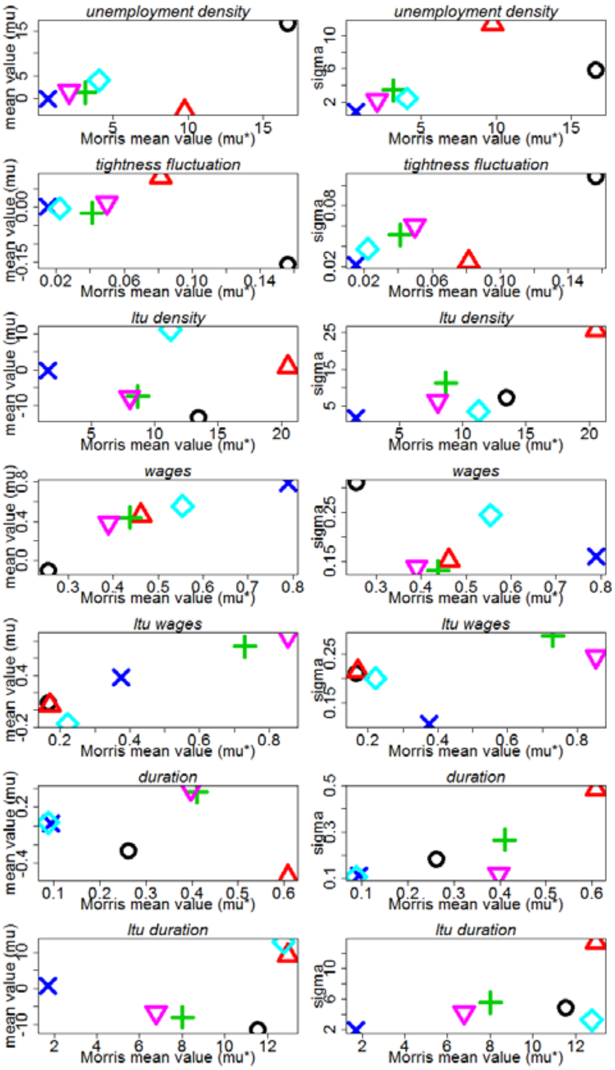
The Morris screening method performed a global sensitivity analysis by making *r* changes in *k* number of parameters. The algorithm samples some initial values in given parameter ranges, then the value for one of the parameters is changed and the model response is calculated. In the next step, the value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

The Morris method is easy to implement and is not demanding concerning 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 et al. (2007) proposed using μ^*, which is the absolute mean value of the distribution of elementary effects. Such a modification prevents the canceling of the influence of the overall parameter 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 8), while in the second the focus was on the six ALMP parameters (Figure 9). 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 *6 levels* and *3 steps*. The former is the number of levels of the design, the latter is the value the algorithm increased/decreased the number of levels for computing the effects (Morris (1991) suggests *steps = levels/2*).

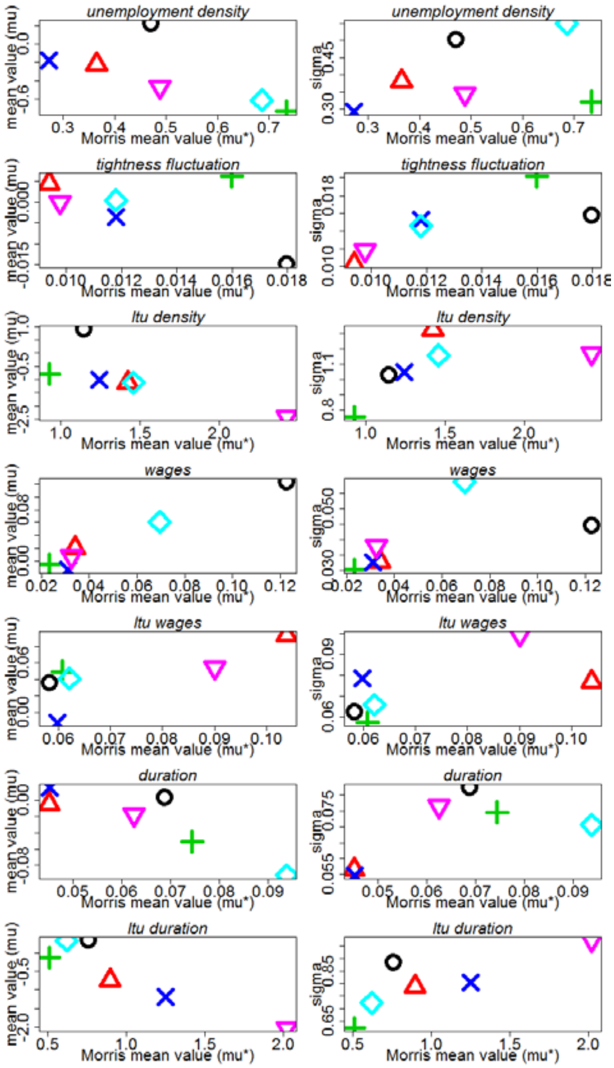
The left column shows the general importance of the parameters and the right column shows the interdependencies among the parameters. The analysis of the general impact on the unemployment density criterion (mu, mu*) shows that the most significant of the global parameters are the job destruction rate 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

Figure 8: Results of the Morris screening method for the 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.

Figure 9: Results of the Morris screening method for the 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.

of the labor market, the level 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 increases 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 level of the unemployment benefits or the efficiency parameter contribute to an increase in the unemployment rate – this influence is relatively low and non-monotonic.

Labor market tightness fluctuations are mostly affected 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 impact of the other two parameters is low and closely depends on the other input values. The LTU rate is mostly affected by minimum wage, the job destruction rate and the growth rate of productivity. Minimum wage increases 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. 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: this increases mean wages in the economy monotonically. The higher the beta, the bigger the part of the surplus from the Nash negotiation that reaches the worker. The growth rate of productivity, minimum wage and unemployment benefits also increase wages linearly, but their impact is not as strong. In contrast, LTU wages are mostly affected by the main effects of the unemployment benefits parameter, which increases 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. A rising minimum wage can potentially lower the non-LTU duration of unemployment. If the LTU parameter has an opposite effect, it may increase 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.

Almost all of the ALMP parameters affect the unemployment density criterion negatively, so we can conclude that, in general, ALMP decreases the unemployment rate on the local labor market. Both the *non-LTU ALMP inflow rate* and the *non-LTU probability job agency advertisement utilization* are among the most influential parameters, which decrease the criterion, but a comparison of the sigma value shows that their influence is strongly associated with other inputs. The next influential parameters are the *LTU inflow rate* and the *LTU search unit bonus*, which also negatively impact the unemployment rate. *The LTU probability of job agency advertisement utilization* is the next to decrease the criterion; however, with little strength. *The non-LTU search unit bonus* may have a positive impact on the criterion, which indicates that counseling programs for non-LTU job seekers may be ineffective.

Labor market tightness fluctuations mostly depend on: the *non-LTU search unit bonus* and *the non-LTU probability of job agency advertisement utilization*. The first parameter affects the criterion negatively, while the second parameter's impact is positive. In addition, *the LTU probability of job agency advertisement* utilization negatively influences the fluctuations of theta.

The LTU rate is mostly affected by *the LTU inflow rate to ALMP* – this is likely to decrease the criterion monotonically. The next parameters are *LTU search unit bonus* and *LTU probability of job agency advertisement utilization*. The influence of these parameters is negative and mostly monotonic; however, it is strongly reliant on the values of the other inputs. Among the most influential parameters decreasing the LTU rate is also *the non-LTU ALMP inflow rate*. This phenomenon can be interpreted as the prevention effect of such a program which protects the non-LTU from extending unemployment duration and the possibility of replenishing the LTU group in the future. In turn, *the non-LTU search unit* bonus may explicitly increase the LTU rate.

ALMPs may affect wages in both groups of unemployed persons. The strongest parameters that have a positive impact on wages are *the non-LTU search unit bonus* (in the non-LTU group) and *the LTU search unit bonus* (in the LTU group). In turn, *the LTU probability of job agency advertisement utilization* may have a slight negative impact on wages in both groups of job seekers. 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 lower. Regarding the non-LTU duration criterion, the most influential parameters are *the non-LTU inflow rate to ALMP* and *the non-LTU probability of job advertisement utilization*. Both parameters affect the criterion monotonically and negatively. The other parameter which may decrease the criterion is *the LTU inflow rate to ALMP*. In turn, the impact of the non-LTU search unit bonus is strong but not monotonous, while *the LTU probability of job agency advertisement utilization* may slightly increase the criterion.

The LTU inflow rate to ALMP is the parameter which most affects the LTU duration criterion and decreases it monotonically. *The LTU search unit bonus* and *the LTU probability of job agency advertisement utilization* influence the criterion negatively, but slightly less significantly. *The non-LTU search unit bonus* and *non-LTU inflow rate to ALMP* may increase the criterion monotonously, thus implying an extension of the LTU's unemployment duration.

Some interesting phenomena can be observed when comparing the Morris screening for the ALMP parameters with screening for global parameters regarding LTU density and the unemployment density criterion. While ALMP parameters play an important role in decreasing the LTU rate, their impact on decreasing the non-LTU rate is lower (Figure 9). More influential in this case are hard policy settings, such as minimum wage and unemployment benefits (Figure 8).

5.2 Sobol method

The Sobol method has become popular due to its precision, robustness and successful application in complex models (Glen and 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: $ST_j > S_j$ (Saltelli et al. 1997). Let us consider the vector of model parameters: $Y = \{X_1, X_2, \dots, X_n\}$. 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 contribute to the model output. For the *i* parameter they can be written as:

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

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

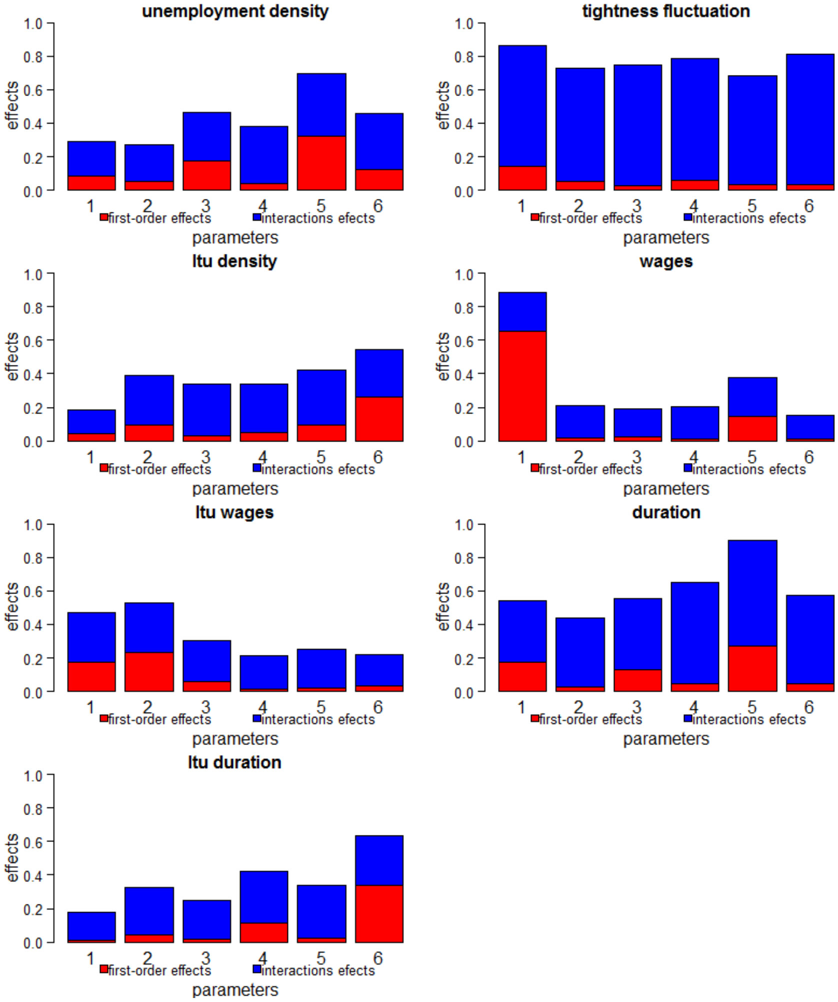
The general importance of $ST_{i,j}$ is higher as it captures first-order and higher-order effects. The method demands substantial computing power due to the large amount of iterations with total cost (k+1)N, where N is the recommended sample size and k are the impact factors. Saltelli and Saisana (2008) suggested that sample size should be about 500–1000, 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 et al. (1997) 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 10.

A cursory overview of the Sobol indices shows that large interactions occur between the parameters. It is worth noticing that all of the ALMP parameters to an extent affect the criterion variances. A detailed analysis of the contribution of the ALMPs to the variance of the unemployment rate shows that there are two most influential parameters (3 and 5). Both of these are responsible for variation above 24% of the output (main effects) and, respectively, 46% and 69% 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 institutional job offer postings for this group of unemployed persons.

Besides the LTU inflow rate to the ALMP, which in total affects almost 54% of variation in the LTU rate, the other parameters which have the strongest impact on its fluctuations are: 2 and 5 (both parameters have a total contribution equal to 40%). Estimation of the Sobol indices shows that a strong cross-effect exists between ALMP programs: parameter 3 is responsible for 33% variation of the criterion.

Figure 10: Results of the estimation of the main effects and interaction effects with the extended Fourier amplitude sensitivity test



The contribution of parameter 1, which affects wages positively, is the strongest (65% of the main effects and 88% of total effects contribution). The next influential parameter is 5 (14% of first-order effects and 37% of total effects contribution). In turn, parameter 4, which may affect wages, negatively contributes 20% to the fluctuations of the criterion. 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 to a degree and is responsible for 17% of the main effects and 47% 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 a prolonged spell of unemployment and flow into the LTU group (prevention effect).

Parameter 5 has the biggest contribution to the variation of unemployment duration (it is responsible for 27% of the main effects and 89% of the total effects of changes in the criterion). The next influential parameter is 4, with total impact explaining 65% of the fluctuations and parameter 3 which affects 55% of criterion variation: both parameters decrease the duration. However, the positive effect of parameter 1 and 2 is also significant and explains 54% and 43%, respectively, of the fluctuations in criterion variance.

The LTU duration criterion is strongly influenced by parameter 6, which explains 34% of the main effect and 63% of the total effect changes in the criterion. Parameters 2 and 4 affect the variation with, respectively, 33% and 42% of total effect contributions. This time the counteracting impact of parameters 1 and 5 explains 35% of variation of the LTU duration criterion.

6 Conclusions

In this paper, an agent-based search and matching (ABSAM) 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. Benchmark simulation and global sensitivity analysis methods allowed an evaluation of the contribution of each of the parameters to the model output. Particular emphasis was placed on the ALMP parameters; however, I also paid attention to the minimum wage and unemployment benefit parameters.

Our results provide some interesting connections to aspects of the literature on labor market policy evaluation and long-term unemployment. As opposed to the Ljungqwist and Sargent (1998) results, the ABSAM model shows that rising LTU benefits may positively influence the LTU unemployment exit rate. An important extension of the paper in relation to Dolado, Jansen and Jimeno (2009) is the addition of the ALMP analysis in the context of on-the-job searches. With reference to the paper, I found that counseling may decrease flows on-the-job and may suppress worker turnover. Furthermore, the ABSAM model complements the general results obtained by Stavrunova (2007) and Neumark (2009) regarding the fact that ALMPs may induce wage increases. The detailed analysis shows, however, that unless search assistance unequivocally raises wages, institutional job offer postings may have a slight but negative effect.

In terms of closely related studies, the ABSAM model enriches the Cahuc and Le Barbanchon (2010) results by assessing the indirect impact and cross-effects of counseling in a strongly heterogeneous framework. Besides, I complemented the authors' derivations and clearly showed when the counseling effect is positive and when it is negative. The paper also contributes to the ABM literature and significantly extends the Gaudet et al. (2014) study, in which despite developing the ABM labor market the authors ignore the ALMP framework. As opposed to Baruffini (2014), I paid much more attention to the calibration procedure and focused on statistical techniques for the ABSAM model simulation and sensitivity analysis. Finally, the derivations enrich the ALMP debate via an evaluation of institutional postings of job offers which has been marginalized and contributes to the issue of an appropriate discussion and design of ALMP programs for the LTU, as was raised by Meager and Evans (1997) or Card et al. (2015).

Below are some key findings which result from the ABSAM model simulation results with regard to the evaluation of labor market policies addressed at the non-LTU and LTU:

1) ALMP programs significantly affect the local labor market; however, the overall impact of the ALMP parameter is significantly stronger among LTU job seekers. In contrast, the impact of the minimum wage and unemployment benefits parameters is stronger among the non-LTU group.
2) 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.

3) 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.
4) Counseling programs for the non-LTU group have no positive effect on the labor market. On the contrary, they can induce wage increases, increase the unemployment rate and prolong unemployment duration. In turn, regarding ALMPs, the non-LTU group may benefit more when agencies share job advertisements.
5) The LTU group experiences more gain from participating in programs enhancing search effectiveness; however, the positive effect of institutional job advertisement postings is also significant.
6) In general, ALMP may induce endogenous wage growth while it does not affect productivity in the economy. As a result, employers must bear higher costs of maintaining jobs and be less likely to open up new vacancies. This is primarily because of higher wages among the non-LTU ALMP participants.
7) A general prevention effect of ALMPs was identified for the non-LTU: such programs protect the unemployed from prolonged unemployment spells and decrease the probability of flow into the LTU group.
8) 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.
9) Programs for the non-LTU that enhance search effectiveness 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 exclusion of some part of the LTU group from the labor market and may deepen unemployment persistence among these individuals.
10) Programs for the unemployed affect skill demand distribution. In an economy with permanent ALMP support, employers open up more skilled job vacancies. Simultaneously, they resign from creating lower skilled job vacancies.
11) ALMPs may suppress flows on-the-job and decrease worker turnover.

Summing up, as is proven in this paper, labor market search theory can be easily and effectively adapted to an agent-based framework and be used to evaluate labor market policy. The flexibility of the developed ABSAM model allows easy modification, addition, enabling, and disabling of other ALMPs into the model code. According to the needs, the model presented here can also be enriched by business cycle fluctuations, bank institutions, the endogenous job destruction processes, other elements of the social policy, or more diverse sectors of the economy.

There are some technical remarks that need to be mentioned at the end. The *RNetLogo* and *NetLogo-R* extensions provide a powerful link in both directions with the R programming language. The statistical tools and graph capabilities of R enhance the scientific value of NetLogo models. However, the thousands of iterations of the simulations in the calibration procedure and the sensitivity analysis implied a very long computation time (at least for more complex models). There is no doubt that combining *NetLogo* with the R programming language opens up new, powerful possibilities in computational agent-based models analysis.[17]

[17] Some external readings may be recommended here. Please see Thiele and Grimm (2010), Thiele et al. (2014) or Thiele (2016) for excellent guides for the sensitivity analysis of *NetLogo* models with *R*. In turn, Iooss (2016) provides implementation details of sensitivity routines within the *R sensitivity package*.

Appendix – The Pseudocode of ABSAM model

to-initialize-model {
[create-job-seekers]
[create-firms]
[create-vacancies]
[create-job-placement agencies]
for each agent [setup parameters]
}

to-go
for each time step {

initialize-search-process {
[draw-search-units *and* update-list-of-firms *and* update-probs *and* decide-if-almp]
}

search-for-job {
while search-units > 0 [move-to-the-nearest-firm] **[**
If meet-agent with [sector = my-sector and skills =< my-skills]
[stop-searching]
[update-value-functions] **]**
}

update-value-functions {
[scan neighborhood in search of other-agents with
[sector = my-sector and skills =< my-skills] **]**
If any? other-agents
[set value-of-unemp = income + next-period- firm-wage-offer]
[set vacant-value = -(search-costs) + next-period-seeker-wage-offer]
[set value-of-employ = firm-wage-offer – payoff-lost-prob
[set filled-value = firm-wage-offer – seeker-wage-offer – payoff-lost-prob]

```
                                        wage-bargaining {
If [ filled-value > vacant-value and unemp-value < employ-value ]
                                                  [ set wage ]
                                                      else [ continue to search ]
                          }
}
almp-particiapate {
                  ask agencies [ for each sector [
identify vacancies in-cone = max-search-units ] ]

ask job-seekers [
if almp? = TRUE [ set search-unit-bonus ]
if any? agency-here [ draw job-offers with sector = my-sector ] ]
}

        on-the-job-search {
if working?=TRUE and my-skills > my-job-skills
[ identify vacancies in-cone = max-search-units with skill-level            >
my-job-skill and skill-level <= [ skills ] of myself ] [
                          if any? fitted-vacancy and
filled-value > vacant-value and unemp-value < employ-value
                                  [ move-to new-job ]
                                          [ set new-wage ] ]
```

}

create-vacancies {
if my-vacancies < 3 and if
[expected-profit > expected-cost]
[create-new-vacancy]
}

destroy-vacancies {
ask firms [
if random-number < job-destruction-frequency or recruitment-duration > 6
[destroy-vacancy]
else [set skill-demands = skill-demands -1]
}

update-cv {
[update-employment *and* unemployment duration]
[update-wage-offer *and* productivity]
[update skills]
every 6 months **[**
if random-number < probability [change preferences] **]**
}

end **}**

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