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Abstract: We use agent-based methodology to simulate a labour market with on-the-job search. Workers continue to search while employed in order to find a job in a better paying firm and climb the wage ladder. In particular, we study the effect of the intensity of job search of both employed and unemployed workers on the unemployment rate and the average unemployment duration. The main result is that whenever employed workers continue to apply for new jobs intensively, *i.e.* by sending out many applications per period, it becomes very difficult for young and inexperienced workers to enter the labour market because they are never preferred over a more experienced worker. Introducing adaptive behaviour under which workers can adjust their search strategy according to whether they are successful in finding a job or not and whether they are already in a firm which offers high salaries or not, remedies to some extent the congestion effect created by the search of employed workers.

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1. Introduction

In the following paper, a labour market model with on-the-job search is considered. Empirical studies suggest that a large fraction of the separations between workers and firms occur because of job-to-job transitions. The estimates vary from country to country (see Jolivet et al. (2006)) but generally point to a high rate of job-to-job movements. Therefore, we incorporate an on-the-job search mechanism in a simple agent-based simulation of the labour market and study how workers' search intensity, both on-the-job and when unemployed, affects the labour market outcomes in terms of unemployment rate and duration until finding a job. For the purpose we test multiple theoretical scenarios which do not rely on empirical data. We investigate what the labour market outcomes will be assuming different distributions over workers' search strategies. More precisely, we are able to show how macro-level frictions emerge, preventing the market from clearing even though on the micro-level workers try hard to find a job by sending out many applications per period. This project is a first step towards developing a more comprehensive model of the labour market.

The agent-based approach is becoming an increasingly popular tool for modelling and analysis across different disciplines. Broadly speaking, agent-based models (ABMs) consist of autonomous agents who interact according to some set of rules. The modeller assigns these rules and as a result we can observe a macro level outcome arising from a micro level behavioural mechanism. Making use of the advancement in computer capabilities, the agent-based approach can be helpful in modelling various complex economic interactions. The "agents" in this context could be consumers, workers, firms but also institutions, governed by some rules of behaviour (Tesfatsion, 2006). One of the advantages of agent-based modelling over the conventional economic modelling tools is that it allows to relax some of the strong assumptions often made in theoretical economic models. For instance, we can go beyond the "representative, rational, utility-maximizing agent" framework and consider agents which are heterogeneous in one or many of their characteristics.

In this model we introduce firm heterogeneity by letting firms draw different bargaining strategies and worker heterogeneity in terms of search strategies, age and experience. The main results suggest that high search intensity is not necessarily beneficial for the workers. On the contrary, it increases the degree of friction on the labour market due to coordination failure on the side of the job-searching workers and competition for workers on the side of the firms. Similarly, Albrecht et al. (2003) find, in an analytical framework, that introducing multiple applications by unemployed workers exacerbates the coordination failure during the matching process.

Using agent-based methodology we are able to show that allowing multiple applications together with on-the-job search can considerably increase the unemployment rate and the duration until finding a job. To my knowledge, this question has not been explicitly considered in other agent-based labour market models. We find that whenever workers search very intensively for a first job or for a "better" job than their current one, they create a big queue for the available vacancies and decrease the probability of actually forming a match. More precisely, when employed workers continue to send out applications very actively they block the opportunities for young and inexperienced workers to be chosen by the firms. Allowing for multiple applications further exacerbates the market frictions because employed workers are also more picky. They accept only offers that are better than their current job, which means that they often reject offers. Once a worker rejects the job offer, the vacancy remains open until the next round of applications. The lack of coordination between workers in the application process also increases the unemployment duration of young workers. Therefore, depending on workers' search intensities, some vacancies remain open for many periods and the market cannot clear.

2. Related Literature

The implementation of on-the-job search in frictional labour market settings has a strong appeal because empirical evidence has documented that a large portion of the separations between workers and firms in the developed economies occur due to job-to-job transitions. Mattila (1974) was the first study to point out, using U.S. data, that job-to-job transitions account for 50 to 60% of job quits. Pissarides (1994) estimates that 20% of the new hired workers in the U.S. come directly from another job. In a more recent study, Fallick and Fleischman (2004) find that two-fifths of new jobs in the U.S. in the period 1994–2003 are due to job-to-job transitions.

Results for Europe point to smaller but still considerable job-to-job transition rates. Using panel data on 10 European countries and the U.S., Jolivet et al. (2006) find that one can divide the sampled countries into three categories: such with high-, middle- and low- job-to-job turnover rates. High job-to-job transition rates are estimated for the U.K. and Denmark. Germany, the Netherlands, Ireland and the U.S. fall in the middle group, while Belgium, France, Italy, Portugal exhibit lower job-to-job turnover rates. Pissarides and Wadsworth (1994) find, using data from Britain's Labour Force

Survey (1983–1984), that job-to-job transitions constituted three quarters of all job separations in the considered period.

Moreover, the introduction of on-the-job search to the standard models with search equilibrium, is shown to bring desirable features. Mortensen (1994), in one of the early contributions to the topic, finds that search during employment helps explain the Beveridge curve, the procyclical quits as well the countercyclicity of the flows in and out of unemployment. Pissarides (1994) finds that on-the-job search induces higher cyclical volatility of the vacancies and more persistent unemployment than the standard search equilibrium model. In both models the wage is a fixed split of the surplus of the match.

Numerous studies, on the other hand, focus on why workers continue searching when they are already employed. The predominant incentive assumed in the literature is that workers search on the job in order to climb a wage ladder. Mortensen (1990) (as cited in Christensen et al. (2005)) finds that the distribution of wages that on-the-job seekers face stochastically dominates the one over unemployed applicants because employed workers increase their wage by moving from job-to-job. Burdett et al. (2011) extend the model with on-the-job search by assuming that workers accumulate experience. They find that in the first 10 years of their career workers typically change several jobs and increase their wage rapidly. Moreover, the approach leads to a "desirable" wage distribution, *i.e.* humped-shaped with "fat" right tail, which is also the wage distribution shape found in many empirical studies (see, for example, Neal and Rosen (2000), Bontemps et al. (2000)).

Christensen et al. (2005) implement endogenous search effort and find that on-the-job search declines as wages increase. Workers who receive low wages have a higher incentive to search while employed because they can expect higher returns. This theoretical result is also verified by an empirical study which uses data from the Danish Integrated Database for Labour Market Research. Job tenure also reduces the probability that a worker looks for a new employer. On the other hand, younger, skilled and part-time workers are more likely to search while employed (Pissarides and Wadsworth (1994)).

Another stream of literature emphasises educational and skill job mismatches as incentives for on-the-job search. Allen and Van der Velden (2001), for example, find using a comparative international study of the labour market outcomes of people with tertiary education in Japan and eleven European countries, that skill mismatches decrease the job satisfaction and increase the incentive for on-the-job search. Educational or skill job mismatches, however, go beyond the scope of the model perused in this paper.

The labour market exhibits large heterogeneity among the participants, both employees and employers. Numerous agent-based models, some of which very large scale, have already been used to model this diversity with focus on reproducing some stylized facts in labour economics and considering what-if scenarios in order to evaluate the effects of different policies. Neugart et al. (2012) divide the labour market agent-based models into two broad categories: the so-called partial models and labour market models which are part of a larger macroeconomic framework and which investigate the interaction between several markets. One example of the second class is the EURACE model (Deissenberg et al., 2008) which is aimed at modelling the European economy (implements both real and financial markets) and reproducing empirical regularities that emerge at the macro level. The model is used to investigate the outcome of different policy scenarios.

Some examples of agent-based models, which are confined to interactions in the labour market are Guerrero and Axtell (2013), Lewkovicz et al. (2009), Neugart (2004), Gemkow and Neugart (2011) and Richiardi (2004,2006)[1]. The labour market model presented in Ballot (2002), called ARTEMIS, is calibrated to the French labour market in the period the 1970s oil crisis and reproduces the gross flows dynamics and some labour mobility patterns observed it that period. An intermediary which assists firms and workers to meet is implemented, modelled as a temporary help firm, which offers only short term contracts. On-the-job search is also present with the assumption that the unemployed search more intensively and those who are employed under a temporary contract strive to find a permanent position. Firms' internal labour markets are also considered, as the firms' decisions on promotions, lay-offs, job creation and destruction, dismissals and hiring standards. Workers, on the other hand, make decisions about entry and exit into the labour market, applications, registration for a temporary help firm, on-the-job search and abandoning search in case of discouragement. Both firms and workers adapt their behaviour based on past experience.

Besides reproducing the empirically documented flow dynamics, the results of the simulation suggest that the intermediaries have a profound

[1] For a review of agent-based labour market models see Neugart et al. (2012).

effect on the aggregate matching in the market by reducing unemployment and enabling workers to gather experience.

Lewkovicz et al. (2009) build on the ARTEMIS model to study age discrimination on the labour market against senior workers (defined as older than 50 years) and explore how a new type of work contract, the so called Unified Contract, which is an alternative to the definite- and indefinite-term contracts, might influence the unemployment rate in this group. Very briefly summarized, the Unified Contract is indefinite, allows for accumulation of seniority and unconditional firing and does not bear legal justification costs upon firing. The main result of the simulations is that under Unified Contract the unemployment rate for young and middle-aged workers decreases, while it increases for senior workers. Moreover, the last effect is high enough so that the overall unemployment rate also slightly increases.

Neugart (2004), on the other hand, simulates the matching process between firms and workers and studies the emerging matching function. The results suggest that the matching function exhibits decreasing returns to scale which contradicts the conventionally assumed constant returns to scale matching function. Moreover, labour market policies are found to have an effect on the matching function which implies that assuming an exogenous matching technology might be inappropriate.

Gemkow and Neugart (2011) implement an endogenous social network and investigate its effects on hiring and inequality. The authors find that referral hiring decreases when the market is more volatile, *i.e.* when there is higher variability in the labour demand of firms. Sustaining the "friendships" in the network is costly and during volatile time it is more likely that the contacts of a given agent will be also searching for a job. Hence, the result shows that during such times referral hirings decrease and subsequently the distribution of individual incidences of unemployment becomes more equal.

Richiardi (2006) models a labour market with on-the-job search and entrepreneurship, which successfully reproduces some stylized facts such as the Beveridge, Wage and Okun curves. In the model workers differ with respect to their productivity and inclination to entrepreneurship. Firms, on the other hand, have differential growth potential and make decisions regarding the number of vacancies and the wages they offer. There is also a possibility of firm exit if the firm generates negative profits or if all employees leave. Dissatisfied workers may look for a new job or may decide to become employers themselves. Interestingly, Richiardi (2006) finds that a value of the search intensity of 1 application every 3 periods, where one period is one week, is appropriate. Moreover a higher search intensity is associated with lower unemployment rate under increasing vacancy cost. This result, at first glance contradictory to ours, is, however, not directly comparable since in this model we do not assume a positive vacancy cost.

With the model presented here, we aim to study the interaction of the agents confined to the labour market, which gives us the opportunity to isolate the effect of on-the-job search and the search intensity on the market outcomes. We wish to incorporate on-the-job search in a labour market with heterogeneous firms and *ex-ante* homogeneous workers. The idea is derived from the theoretical models described above, but the agent-based environment allows us to further investigate the mechanism.

3. Model Description

There are two types of agents in this model: firms and workers and we simulate a simple matching process between them. The workers want to find a job and the firms wish to fill their open vacancies. We assume that the firms are infinitely-lived and equally sized. The heterogeneity among them arises from their bargaining strategies, *i.e.* the share of the match surplus they are willing to offer to their workers. The worker and the firm are bargaining over the split of the surplus of the match similarly to Pissarides (1994) and Mortensen (1994). Workers are heterogeneous with respect to their age, experience and search strategy. In the context of the model, search strategy is defined as the number of applications each worker sends per period, where one period is defined as one quarter of a year.

The matching mechanism employed in this model is of urn-ball type. The urn-ball matching is quite intuitive in terms of understanding how coordination failure might arise[2]. As it can be inferred by the name, we can think of the firms as urns in which workers place their applications, the balls. Coordination failure comes from the fact that workers send out their applications randomly which may lead to some firms receiving too many applications per vacancy while others receive none. Hence, the lack of information about the actions of other agents creates frictions in the labour market which prevents it from clearing.

Moreover, allowing for workers to send more than one application per period does not necessarily alleviate the problem and coordination failure might persist (see Albrecht et al. (2003)). Under the case of many applica-

[2] For a comprehensive review of the types of matching functions refer to Petrongolo and Pissarides (2001).

tions per worker per period, it is more likely that all vacancies will receive an application. Nevertheless, this does not ensure that a match will be formed since now firms are competing for the best workers, which in our set-up are the most experienced ones. Hence, if a very good candidate has sent multiple applications s/he might receive several offers and reject most of them, leaving the vacancies open until the next period.

For each vacancy, the firm chooses the applicant who will generate the highest match surplus **S**, *i.e.* the one with the highest experience ($x_{i,t}$). The match surplus generated by an employed worker i at time t is an increasing, concave function of the worker's experience:

$$\mathbf{S} = \frac{x_{i,t}^{1-\sigma}}{1-\sigma}, \quad \sigma > 0 \tag{1}$$

Throughout the simulations we set $\sigma = 0.5$. Moreover, we assume that worker's experience is not job-specific and is perfectly transferable between firms. That is, the worker will generate the same surplus whenever matched with either one of the firms. The wages of workers with the same experience, however, differ between firms depending on the employer's bargaining strategy β. Hence, the wage of worker i employed in firm j at time t can be written as:

$$w_{ijt} = \phi(x_{i,t}, \beta_j) = \beta_j \left(\frac{x_{i,t}^{1-\sigma}}{1-\sigma} \right) \tag{2}$$

It follows that wage dispersion within and across firms is generated. This mechanism provides an obvious incentive for the workers to search for an employer with whom they can earn a larger share of the surplus, given that workers with the same experience produce the same match surplus in all firms. Similarly to Burdett et al. (2011), we expect that most of the young workers will start their careers in low-paying firms and will change several employers in pursuit of higher remuneration.

The wages are normalized between 0 and 1 and a "minimum wage" of 0.01 is introduced. This is done in order to avoid a wage of 0 for workers with no experience. However, given the set-up of the model, the introduction of a minimum wage does not alter the market outcomes, since the only criteria for hiring workers is the experience.

The model is created in RePast and the used programming language is Java. The next two sections describe in more detail the initial conditions of the model as well as what happens in each period.

3.1. Initial Conditions

In the beginning of the simulation the agents are created. Since firms are equally sized, it must hold that the number of workers that could be employed in one firm is: $\frac{NumberofWorkers}{NumberofFirms}$.

Additionally, firms draw their bargaining strategy from a Gaussian distribution with mean 0.5 and standard deviation 0.1. Given that the bargaining strategy is defined as a fraction of the match surplus, it can take values in the range [0,1]. If a firm draws a value outside of that range, it disregards it and makes a new draw. Further, the worker's age ($a_{i,0}$) is drawn from an uniform distribution over:

$$A = \{18 + 0.25n \mid n = 0,..., 179\}$$

and his/her experience ($x_{i,0}$) is randomly drawn from the set:

$$\{0.25\text{n} \mid \text{n} = 0, ..., 4(a_{i,0} - 18)\}.$$

In the initialization of the model, all workers are unemployed, which implies that the first few periods of the simulation should be disregarded from the analysis. Note also that the model could be calibrated to shorter periods than a quarter of a year by adjusting the age updating process, which should decrease the unemployment duration. Throughout all simulations, however, a period of a quarter of a year is assumed.

3.2. Step Dynamics

In the beginning of each period firms post vacancies if they have not already filled their positions. Workers, both employed and unemployed, follow their search strategy and send a number of applications for the open vacancies accordingly. Workers can observe the mean of the bargaining strategies across all firms but do not know *ex-ante* what is the bargaining strategy of the particular firm for which they apply.

Next, each firm gathers the list of applicants and sorts it according to workers' experience. Then, the firm chooses the most experienced applicant and offers the position to him/her. If the firm has more then one vacancy, it chooses the second most experienced applicant and offers the next vacancy to him/her and so on. Upon making an offer, the firm reveals its bargaining strategy to the worker.

At this point some workers might have received job offers and they proceed to decide whether to accept them or not. If a worker has sent out more than one application, s/he might have also received more than one offer. An unemployed worker then sorts the job offers according to the bargaining strategy of the firms. S/he chooses the employer with the highest β, *i.e.* the one who is willing to offer the biggest share of the match surplus to the employee and accepts the offer. If the unemployed worker has received only one offer, s/he takes it. In this model unemployed workers have high incentive to accept even "bad" offers because of the on-the-job search mechanism. Workers with higher experience are valued more by the firms and therefore applicants have no incentive to remain unemployed in order to wait for better offers.

Employed workers, on the other hand, also sort their job offers according to the firm's bargaining strategy. They next compare the best offer they have received with their current employers' β and change jobs if $\beta_{current}<\beta_{offer}$. Otherwise, they remain in their old position.

At the end of each period workers' age ($a_{i,t}$) is updated:

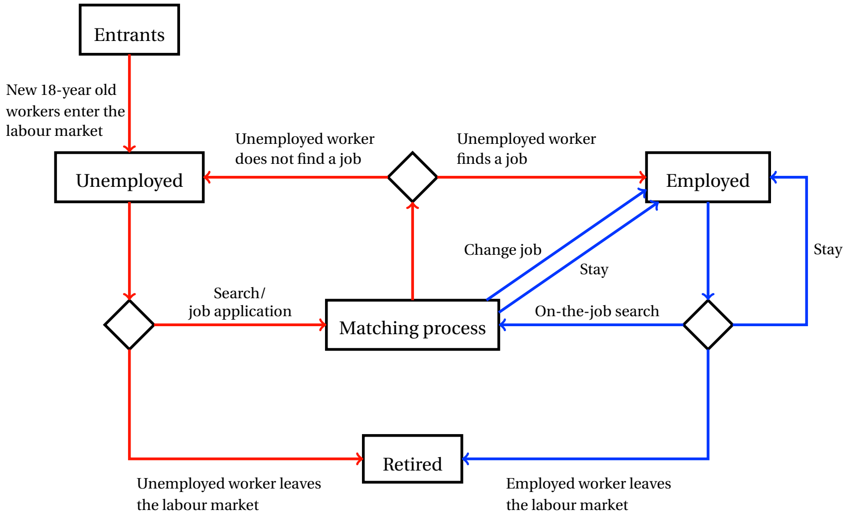
$$a_{i,t+1} = a_{i,t} + \frac{1}{4} \quad (3)$$

Whenever a worker reaches the age 63, s/he retires and a new 18-year-old unemployed worker with no experience is "born". Hence, the number of workers on the market is kept constant. Also the experience of the workers ($x_{i,t}$) is updated at the end of the period according to:

$$x_{i,t+1} = \begin{cases} x_{i,t} + \frac{1}{4}, \text{if worker } i \text{ was employed in period } t \\ \\ x_{i,t}, \text{ otherwise.} \end{cases} \quad (4)$$

Finally, data is collected and the period ends. Figure 1 depicts the described process and the next subsection presents a pseudocode of the model. In figure 1 the red arrows show the possible transitions of unemployed agents in the given period, while the blue arrows follow the possible paths of employed agents.

Figure 1: **Labour market model with on-the-job search**



3.3. Pseudocode

The following pseudocode presents in detail what happens in each period of the simulations.

1 period = 1 quarter
Initial conditions:
Create **n** infinitely-lived firms and **m** workers
Workers are allocated age ($a_{i,0}$), drawn from the set: $A = \{18 + 0.25n \mid n = 0,..., 179\}$ and experience level ($x_{i,0}$) drawn from the set $\{0.25n \mid n = 0,..., 4(a_{i,0} - 18)\}$
Firms are allocated a bargaining strategy β
Workers are assigned to the pool of unemployment
Dynamics:
for each period t
  for each firm j
    if number of workers ($numWor_j$) < $\frac{m}{n}$
      post $\frac{m}{n} - numWor_j$ vacancies
    else
      do nothing
  end for each firm j
  for each worker i
    if worker is unemployed
      observes all firms with $numWor_j < \frac{m}{n}$
      applies randomly to g of them according to the search strategy

if worker is employed in firm with bargaining strategy $\beta < \beta_{mean}$
observes all firms with $numWor_j < \frac{m}{n}$
applies to k firms according to the search strategy
if worker is employed in firm with bargaining strategy $\beta > \beta_{mean}$
observes all firms with $numWor_j < \frac{m}{n}$
applies to l firms according to the search strategy
end for each worker i
Hiring
for each vacancy of firm j
if workers apply
make an offer to the one with highest experience $x_{i,t}$
if two or more applicants have the same experience, make an offer to one of them at random
if no workers apply
vacancy remains open
end for each vacancy of firm j
Job transition
for each worker i
if unemployed worker receives job offers
chooses the firm with highest β
else
remains unemployed
if employed worker receives job offers
changes firms if $\beta_{offer} > \beta_{current}$
else
remains with current employer
end for each worker i
Market update
for each worker i
update age
if age = 63
worker is replaced by a new unemployed worker with age=18 and experience=0
else
worker remains on the labour market
if worker is employed
update experience
else
keep old experience
end for each worker i
Data collection at end of each period
end for each period t

4. Search Intensity

In this set-up, we address the question: how the search intensity affects the market outcome. Since we consider infinitely-lived firms which never lay off workers, the only options for a separation between a firm and a worker arise from the job-to-job transition of workers and from retirement. Hence, once a worker finds a job, s/he remains employed until retirement. Within the framework of the model we explore the link between search intensity and the average duration until finding the first job and between search intensity and the unemployment rate.

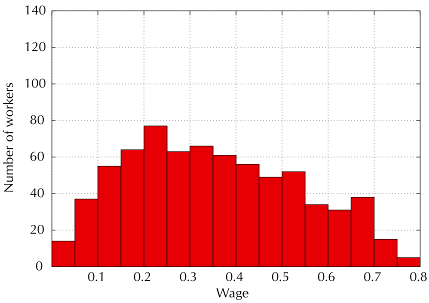
4.1. Benchmark Case

In the benchmark case we assume, rather unrealistically, that each worker sends one application per period regardless of his/her employment status. Figure 2 displays a histogram of the wages (panel a) at the end of the 400th period (equivalent to 100 years) and the hazard rates during the 400 periods (panel b). The hazard rates provide an empirical estimate of the probability of moving into employment (job-finding rate) and the probability of changing jobs (job-to-job transition rate) at a given period t. The job-finding rate is calculated as the fraction of unemployed workers who manage to find a job until the end of the period. The job-to-job transition rate, on the other hand, is estimated as the fraction of employed workers who change jobs within the period.

Figure 3 shows the unemployment rate, average wage (panel a) and the average unemployment duration (panel b) generated by the simulation. We can observe that the model creates a high unemployment rate (the value stabilizes close to 30%) and a high average unemployment duration. The underlying reason for this result could be inferred from the hazard rates diagram (fig 2b). We see that the job-to-job transition rate is on average higher than the job-finding rate. Once workers become employed and start accumulating experience, they have an advantage over unemployed workers when being selected for positions. Since, in this scenario, workers search with the same intensity regardless of their employment status, it becomes easier for workers who are already employed to transition between firms then for the unemployed workers to find a job. This can be deduced from the algorithm of the matching process according to which firms offer one position to a single worker. If many workers applied the firm chooses the one with the highest experience who might then refuse the offer. Hence, no match is created for the period even though less experienced or unemployed workers might have been willing to accept the offer.

Figure 2: **Simulation results, single runs, one application *per* period: t = 400, 100 firms, 1000 workers**

(a) Histogram of the wages



(b) Hazard rates

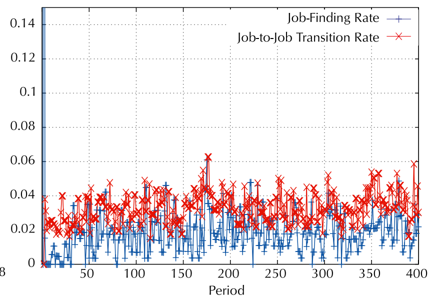
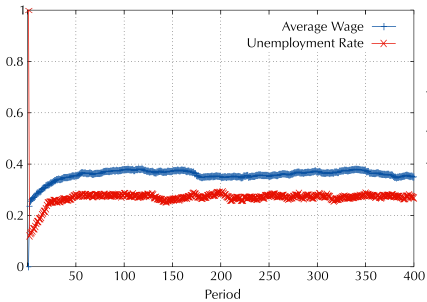


Figure 3: **Simulation results, single runs, one application *per* period: t = 400, 100 firms, 1000 workers**

(a) Unemployment and average wage



(b) Average unemployment duration

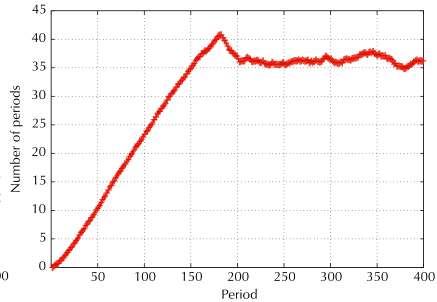
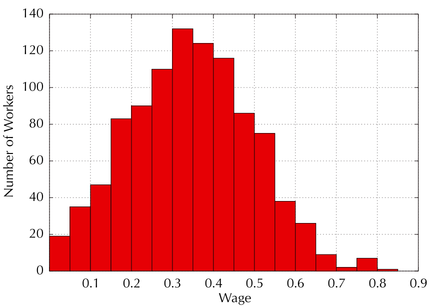
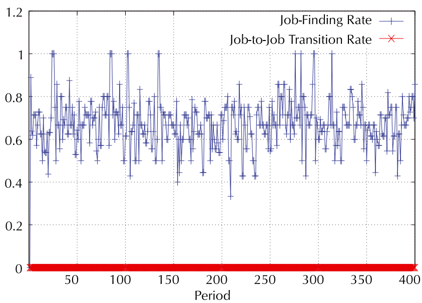


Figure 4: **Simulation results, single run, no on-the-job search: t = 400, 100 firms, 1000 workers**

a) Histogram of the wages



(b) Hazard rates



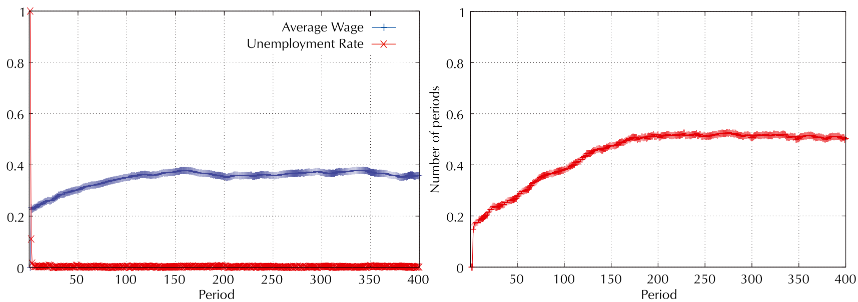
4.2. No On-the-job Search, 1 Application Per Period

To illustrate this further, in the next experiment we forbid the search while employed. Without on-the-job search, the model generates almost full employment. Since once the worker finds a job, s/he remains employed until retirement, the lack of job-to-job transitions, job destruction and competition coming from more experienced workers, create prerequisite for achieving almost full employment. On average, workers manage to find work within their first period of unemployment which implies very low degree of search frictions. The results are displayed in figures 4 and 5.

We can observe a high job-finding rate which fluctuates around 0.65. A value of 0.65 for the job-finding rate means that in the given period 65% of the unemployed agents have found a job. Comparing the hazard rates under the no job-to-job transition case with the result in the previous section where all workers send one application per period, irrespective of their employment status (see fig. 2b), we can see how much the chances of unemployed workers worsen when on-the-job search is allowed. The value of the job-finding rate in that case fluctuates between 0 and approximately 0.06, which indicates that in the "best" period of the simulation only about 6% of the unemployed agents moved into employment.

Figure 5: **Simulation results, single run, no on-the-job search: t = 400, 100 firms, 1000 workers**

(**a**) Unemployment and average wage (**b**) Average unemployment duration



If we look at the wage histograms generated from the two scenarios we can observe that the histogram from the simulation with on-the-job search is flatter, with relatively large concentration of workers with highest and lowest wages (fig. 2a), whereas when we forbid workers to change jobs, the number of workers seems more concentrated around the average wage value (fig. 4a). The underlying reason behind this result comes from the fact that in the no on-the-job search case almost all workers manage to find a job fast and begin accumulating experience. Since the wage in this model is an increasing function of the experience, most workers manage to generate enough experience so that to reach a salary close to the average, even if they are in a firm which has a low Nash bargaining coefficient.

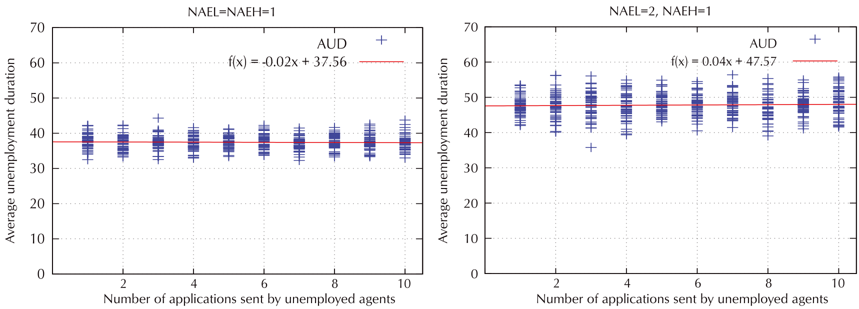
On the other hand, the case with on-the-job search allows experienced workers to move up the wage ladder relatively fast and find employment in the high-paying firms, *i.e.* the most experienced workers who will have high salaries in any firm, manage to also move to the firms with the highest Nash bargaining coefficients. This might explain the fatter right tail of the wage histogram with on-the-job search (fig. 2a). The reason why there is also a relatively high concentration of workers with the lowest salaries in this case could possibly be due to the fact that once workers begin accumulating experience, they want to move to better firms. Hence the firms with lowest Nash bargaining coefficients are constantly looking for new workers who inevitably come from the pool of unemployment, where workers have experience of 0. Since workers have no incentive to stay in the low-paying firms, such firms suffer higher worker turnover, and possibly need to constantly hire workers with no or very little experience who earn the lowest wages. This might explain why there is a relative concentration of workers in the lowest part of the histogram, whereas in the case with no on-the-job search there is a pronounced peak in the number of workers with wages closer to the mean.

This experiment shows how important on-the-job search is in this model and how it can create a very high degree of frictions and subsequently high unemployment rate and high average unemployment duration. In the next sections we explore further how different search intensities alter the results. For the purpose we run multiple simulation altering the search strategies of workers, whereby we will distinguish between unemployed workers, workers employed in "worse than average" firms and workers employed in "better than average firms".

Figure 6: **Average unemployment duration *vs.* search intensity of unemployed agents**

(a) One application *per* employed worker *per* period

(b) One application per period *per* worker employed in a "good" firm, two applications *per* period *per* worker employed in a "bad" firm



4.3. On-the-job Search With Multiple Applications

For the simulations, we alter workers' search intensity, *i.e.* the number of applications they send per period. Unemployed workers send between 1 and 10 work applications. The assumption is that unemployed workers always apply for jobs. On the other hand, workers employed in both better and worse than average firms send between 0 and 10 applications per period. Starting with the first value of the parameters, they are incremented by one for each run. All possible combinations are replicated 50 times. There are 100 workers and 10 firms and firms can employ up to 10 workers. The values of the variables at the 250th period of each run are reported. 250th period is chosen based on the observation from the single runs that all variables have stabilized by that time.

Worse than average firms are the ones with bargaining strategy β lower than the mean of bargaining strategies across all firms while better than average firms are the ones with bargaining strategies above the mean. Workers can observe the mean and also know the value of the β of their current employer. Intuitively, we can think that workers who know that they are already in a "good" firm will reduce the number of applications they send per period or will stop searching altogether. This possibility is explored in section 6. For the moment we assign a search strategy for each worker and vary it exogenously, depending on whether or not the worker has a job and the type of firm s/he is employed in.

Figure 6 shows the result of the simulation runs for average unemployment duration of unemployed workers for different search intensity, holding the search intensity of employed workers constant. Table 1 summarizes the used abbreviations.

Table 1: **Variables**

Abbreviation	Description
aud	average unemployment duration
nau	number of applications sent by unemployed workers per period
nael	number of applications per period sent by workers employed in "worse than average firms"
naeh	number of applications per period sent by workers employed in "better than average firms"
jtj	job-to-job transition rate
jf	job-finding rate
avewage	average wage
nael_sq	nael squared
naeh_sq	naeh squared

From figure 6a we can see that, whenever the search intensity of employed workers is held constant, at one application per period, increasing the number of applications of unemployed workers has almost no effect on the average unemployment duration. The slope of the fitted line is negative but very close to zero. Repeating the same experiment, but this time increasing the number of applications of workers employed in worse than average firms to two per period, reveals similar pattern. The search intensity of the unemployed agents does not seem to have an impact on the average unemployment duration and in this case the slope of the fitted line is even positive (and again very close to 0).

Next, the output of the simulations is used in OLS regression models in order to study the correlation between workers' search intensity and average unemployment duration and unemployment rate, respectively. In table 2 the dependent variable in all 4 regression models is average unemployment duration, while in table 3 the dependent variable is the unemployment rate. Plotting the data revealed a curvilinear relationship between both the average unemployment duration and the unemployment rate and the number of applications sent by employed workers (nael and naeh), see Appendix A. Therefore, also a squared terms of the two variables is included.

Table 2: **Regression results, 50 replications of each case, dependent variable: average unemployment duration**

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
nau	0.0343*** (0.0125)	0.0353*** (0.0117)	0.0383*** (0.0117)	0.0370*** (0.0106)
nael	1.889*** (0.0146)	1.755*** (0.0134)	1.718*** (0.0134)	5.220*** (0.0523)
naeh	3.157*** (0.0137)	3.046*** (0.0132)	3.005*** (0.0133)	5.102*** (0.0447)
jtj		15.84*** (0.836)	17.26*** (0.836)	4.872*** (0.731)
jf		-57.54*** (1.147)	-57.20*** (1.130)	-46.08*** (0.960)
avewage			11.67*** (0.633)	7.416*** (0.597)
nael_sq				-0.346*** (0.00442)
naeh_sq				-0.207*** (0.00396)
Constant	42.89*** (0.160)	44.20*** (0.156)	40.01*** (0.282)	33.21*** (0.293)
Observations	60,500	60,500	60,500	60,500
R-squared	0.635	0.676	0.678	0.735

Robust standard errors in parentheses

***p<0.01, ** p<0.05, * p<0.1

The search intensity of employed workers has a significant, positive impact on the unemployment rate. On the other hand, the search intensity of unemployed workers has a very little (coefficients close to 0, see table 3) and insignificant effect on the unemployment rate. This results indicates that higher search activity of employed workers increases the unemployment rate, while increasing the search intensity of the unemployed can do very little to counteract this effect. Moreover, the results in table 2 suggest that unemployed workers cannot reduce the time until finding their first job by increasing the number of applications sent per period. On the contrary, the variable “number of applications sent by unemployed workers” (nau) has a positive and significant effect on the average unemployment duration (table 2). Even though the estimated coefficients are statistically significant, they are close to 0 in all four specifications of the regression. This indicates that although statistically significant, this values are not economically significant. The high significance level could also be driven by the large number of observations generated by the simulations.

Table 3: **Regression results, 50 replications of each case, dependent variable: unemployment rate**

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
nau	7.27e-05 (0.000127)	8.17e-05 (0.000120)	0.000154 (0.000118)	0.000139 (0.000104)
nael	0.0236*** (0.000150)	0.0222*** (0.000140)	0.0213*** (0.000137)	0.0616*** (0.000522)
naeh	0.0423*** (0.000139)	0.0414*** (0.000136)	0.0404*** (0.000136)	0.0640*** (0.000443)
jtj		0.269*** (0.00842)	0.303*** (0.00826)	0.161*** (0.00676)
jf		-0.540*** (0.0127)	-0.532*** (0.0122)	-0.405*** (0.0103)
avewage			0.278*** (0.00649)	0.229*** (0.00593)
nael_sq				-0.00397*** (4.35e-05)
naeh_sq				-0.00233*** (3.91e-05)
Constant	0.365*** (0.00162)	0.375*** (0.00161)	0.275*** (0.00293)	0.198*** (0.00292)
observations	60,500	60,500	60,500	60,500
R-squared	0.743	0.770	0.776	0.826

Robust standard errors in parentheses

***p<0.01, **p<0.05, * p<0.1

Nevertheless, one possible reason why there is a positive correlation between the average unemployment duration and the search intensity of unemployed workers might also stem from a congestion effect that unemployed workers create by being "too active" in their search. If a worker with no experience is lucky enough to be selected by more than one firm at a given period s/he is preventing another unemployed worker from finding a job. However, the search intensity of employed workers has a far higher impact on the average unemployment duration which can be seen by comparing the coefficients of the independent variables in table 2 (nau *vs*. nael and naeh). The result suggests that on-the-job search considerably worsens the market outcome for unemployed workers and that increasing the search intensity of young and inexperienced workers cannot counterbalance this effect.

4.4. Single Runs with Different Distributions over Workers' Search Intensity

A further experiment that could be conducted with the model is to see how the unemployment rate and the average unemployment duration change with different choices of distributions over workers' search intensity. In the presence of empirical data on this distribution, the model could be calibrated to closer simulate the effect of workers' search intensity on the market outcomes. For now, we consider different theoretical distributions over the search strategies of the workers and compare the results. For this purpose we assume that whenever the worker is "born" s/he draws his/her search intensity strategy from some discrete distribution and sticks to this strategy until retirement. As above, the search strategy is defined as the number of applications the worker sends per period.

We assume a uniform distribution over the search strategy as the benchmark case and then also test the outcomes under Poisson and Binomial distributions. In the first scenario "newborn" workers draw randomly a search strategy from the interval {1,2}. In this case there are only two possible search strategies: low- and high search intensity. We compare this set-up with a scenario in which we add one more option for search strategy, *i.e.* new workers draw a their strategy from the interval {1,2,3}.

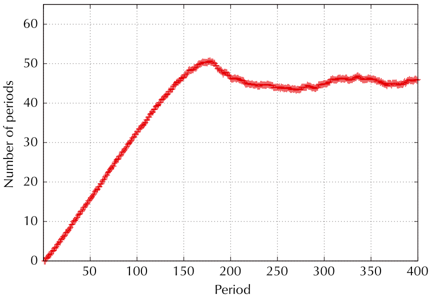
For the Poisson distribution also two scenarios are considered. In the first case, young workers draw their search strategy from a Poisson distribution with mean $\lambda = 1$, while in the second case we consider a mean of $\lambda = 2$. It must be noted, however, that in both cases a search strategy of 0 applications per period is possible, hence the unemployment rate and average unemployment duration might be higher due to workers whose strategy is to not participate in the labour market.

Last but not least, we consider a binomial distribution with parameters $n = 10$, $p = 0.1$ and $n = 10$, $p = 0.2$. This discrete probability distribution is generated as the outcome of 10 failure/success experiments, where the probabilities of success in each experiment is given by the parameter p. Once again, the probability of 0 as a search strategy is not ruled out.

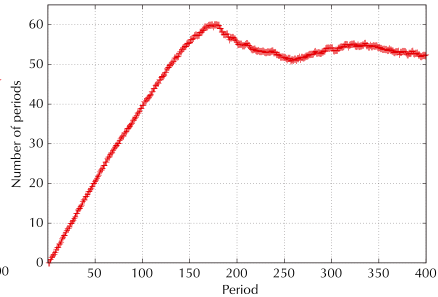
The following figures displays the outcomes for single runs under the different scenarios. Figure 7 shows the average unemployment duration during the 400 periods of the single runs in the six considered cases, figure 8 depicts the unemployment rate and the average wage, figure 9 displays the hazard rates and figure 14 in the appendix shows the wage histograms. What we observe can be inferred also from the results in the previous section: perhaps a bit counter-intuitively, distributions with higher mean, *i.e.* the ones that generate larger search intensity, also lead to higher unemployment and higher average unemployment duration. This result seems robust to the choice of distribution over the search intensities.

Figure 7: **Average unemployment duration, simulation results, single runs, 100 firms, 1000 workers, t = 400**

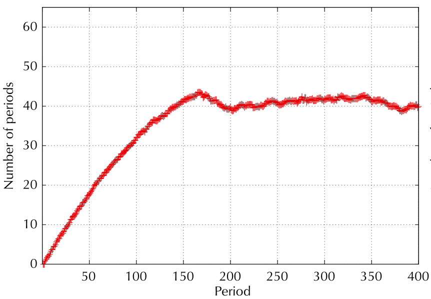
(a) Uniform distribution in the interval [1,2]



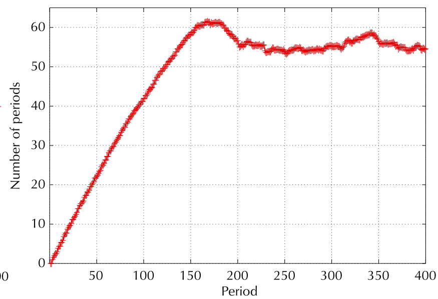
(b) Uniform distribution in the interval [1,3]



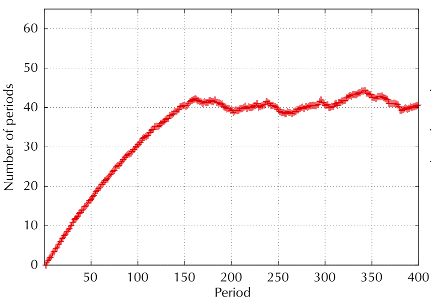
(c) Poisson distribution with λ = 1



(d) Poisson distribution with λ = 2



(e) Binomial distribution with $n = 10$, $p = 0.1$



(f) Binomial distribution with $n = 10$, $p = 0.2$

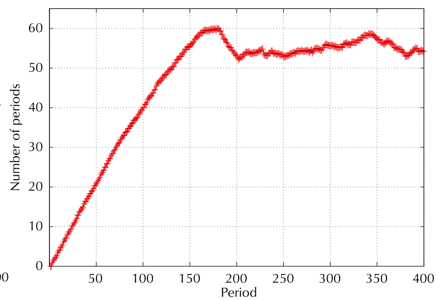
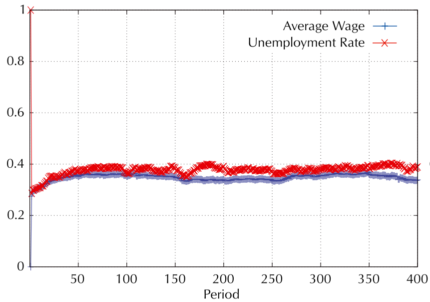
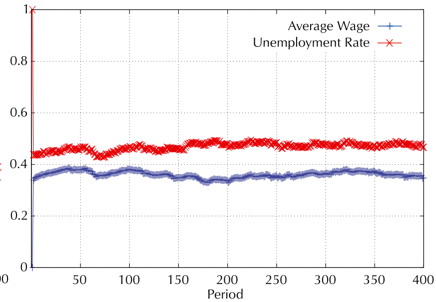


Figure 8: **Unemployment and average wage, simulation results, single runs, 100 firms, 1000 workers, t = 400**

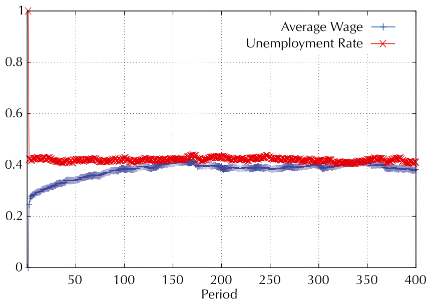
(a) Uniform distribution in the interval [1,2]



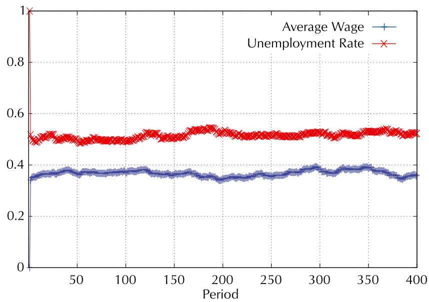
(b) Uniform distribution in the interval [1,3]



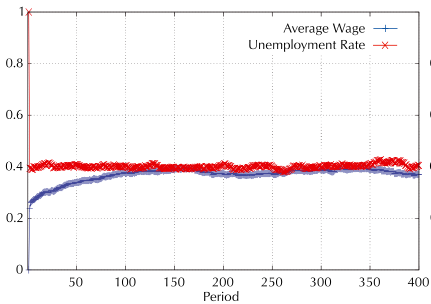
(c) Poisson distribution with $\lambda = 1$



(d) Poisson distribution with $\lambda = 2$



(e) Binomial distribution with $n = 10$, $p = 0.1$



(f) Binomial distribution with $n = 10$, $p = 0.2$

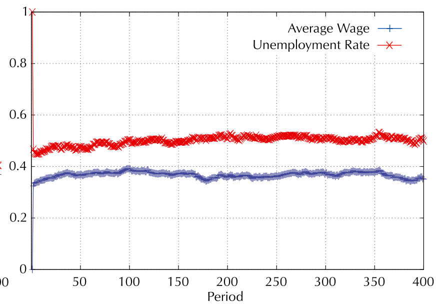
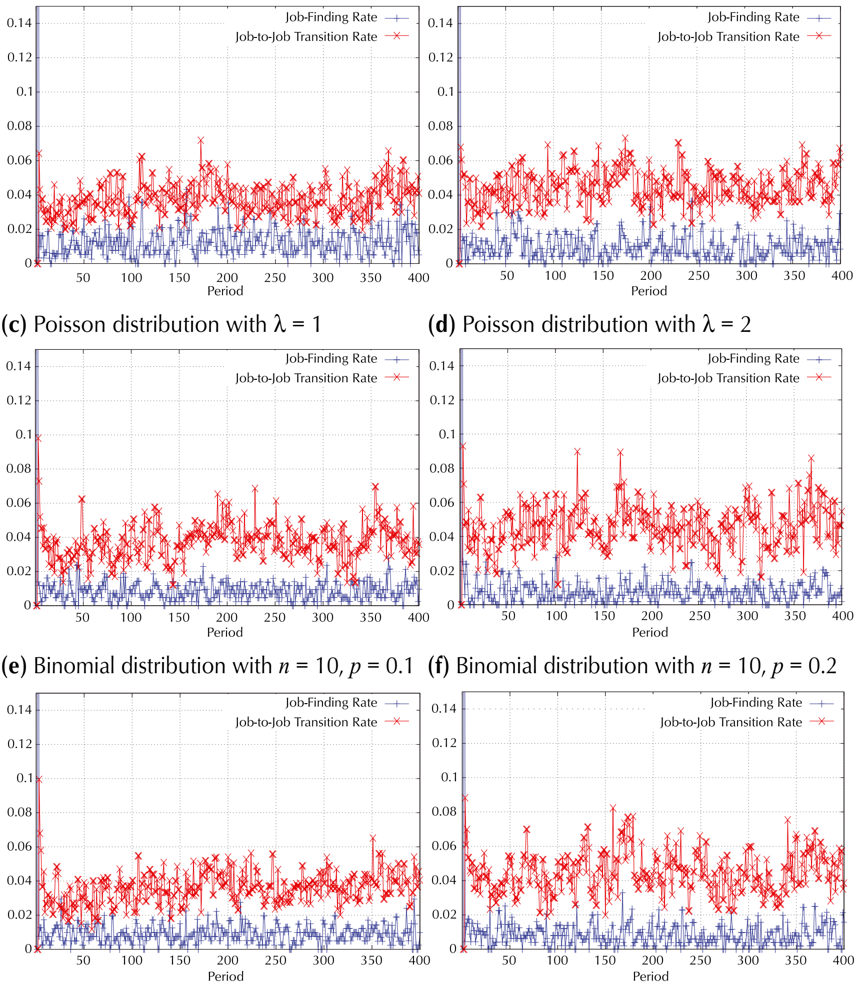


Figure 9: **Job-finding rate and job-to-job transition rate, simulation results, single runs, 100 firms, 1000 workers, t = 400**

(a) Uniform distribution in the interval [1,2] **(b)** Uniform distribution in the interval [1,3]

(c) Poisson distribution with λ = 1 **(d)** Poisson distribution with λ = 2

(e) Binomial distribution with n = 10, p = 0.1 **(f)** Binomial distribution with n = 10, p = 0.2



5. Adaptive Behaviour

Last but not least, we assume that workers do not stick with their search strategy throughout their life on the labour market. Instead, workers who are unsuccessful in finding a first job can increase their search intensity. This is modelled in the following way: all initial workers draw their search intensity from a uniform distribution in the interval [1,3]. If a worker did not manage to find a job in the current period, s/he increases his/her search intensity by sending an additional application in the next period. An unemployed workers might increase his/her search intensity up to 20 applications per period if s/he is not successful in finding a position. For modelling the search strategy of employed workers, we rely on the empirical findings, according to which workers who earn high wages are less likely to search on-the-job (see section 2).

Since the wage in the model is an increasing function of the firm's bargaining strategy β, the probability that an employed worker sends out applications in a given period is decreasing in the bargaining strategy of the worker's current employer. More precisely, in each period an employed worker in firm j refrains from applying for new jobs with a probability βj, where βj was the Nash bargaining coefficient of firm j. The higher the βj, the lower the probability that the worker will search for a new job in the current period. On the other hand, with probability $(1 - \beta j)$ the employed worker sends out between 1 and 3 applications in the given period, where s/he draws the search intensity from an uniform distribution. In each period employed workers who continue their search make a new draw from the distribution. Hence, agents who already have a job will not necessarily search in each period and the ones that are employed in the best firms will be less likely to apply for new positions.

The results from the simulation are displayed in figures 10 and 11. We can compare them to the case in which new workers draw their search strategy randomly from the interval [1,3] and stick to it until retirement (figures 7b, 8b, 9b, 14b). While in the former case, the unemployment rate and the average unemployment duration fluctuate around 45–50% and 55 periods, respectively, under adaptive behaviour both variables drop significantly. The unemployment rate fluctuates between 25 and 30% and the average unemployment duration moves between 35 and 40 periods.

One of the underlying reasons for this result is that inexperienced workers do not compete with all employed workers in each period which gives them a better chance to get a job offer. Moreover, unemployed workers have the ability to increase their search which also raises the probability that they will send an application to a firm that has not received applications from experienced workers. Comparing the hazard rate figures, 9b and 11a, is indeed indicative of the described phenomenon. While in the former, the job-to-job transition rate lies above the job-finding rate in almost all periods, in the latter we can observe quite a few periods in which the fraction of unemployed workers who moved into employment is higher than the fraction of employed workers who changed jobs. Nevertheless, the unemployment rate remains fairly high.

Figure 10: **Simulation results, single run: t = 400, 100 firms, 1000 workers**

(a) Histogram of the wages **(b)** Average unemployment duration

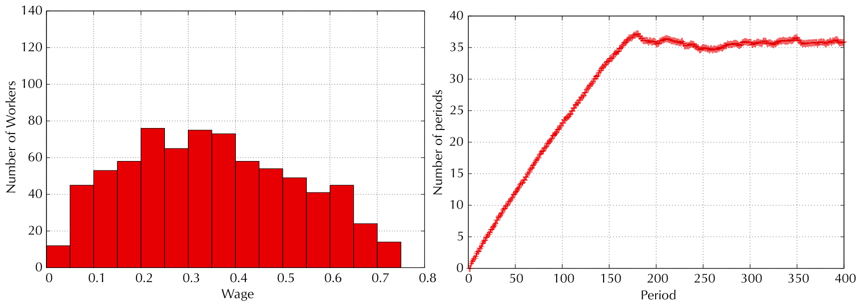
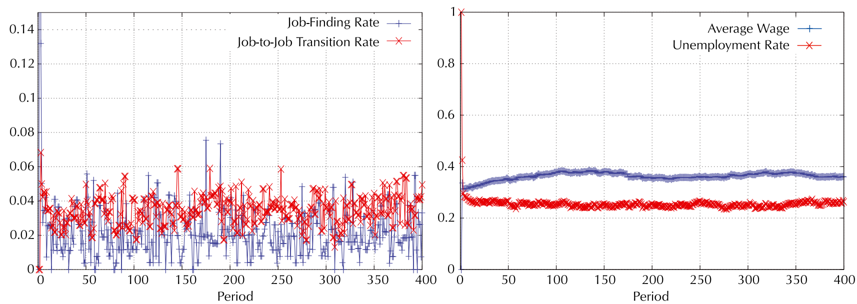


Figure 11: **Simulation results, single run: t = 400, 100 firms, 1000 workers**

(a) Hazard rates: Job-finding rate and job-to-job transition rate **(b)** Unemployment rate and average wage



6. Concluding Remarks and Possible Extensions of the Model

The model presented in this paper hints towards the possibilities that the agent-based methodology can offer as a modelling tool and is a first step towards creating a fuller labour market model with more realistic features. We investigated how the search intensity of both employed and unemployed workers affects the market outcomes in terms of unemployment and duration until finding a first job. Perhaps a bit counter-intuitively, the model suggests that very high search intensity is "bad" for the market since it creates a lot of congestion and increases the unemployment duration. Moreover, if employed workers are very active in searching for positions in better-paying firms, it takes considerably longer for the young and inexperienced workers to find a job. In this set-up of the model high search intensities aggravate the coordination failure in the market.

Under no on-the-job search scenario, the model creates almost full employment. It takes very few periods for new workers to get hired because they do not face competition from older workers. When we allow for on-the-job search, however, it becomes increasingly more difficult for the inexperienced, young workers to find a job since they are never preferred over a workers who has at least a little bit of work experience. Moreover, increasing worker's search intensity, *i.e.* allowing for multiple application per worker per period leads to very high degree of frictions caused by coordination failure on both sides of the labour market. Employed workers do not know which are the "better" firms and send applications randomly, hence blocking the entrance of young workers into the market and on the other hand, firms are competing for the best workers which leaves some vacancies unfilled due to the fact that firms make offers which are ultimately rejected.

There are several directions in which the current model can be augmented and made more realistic. First of all, in its current state the model generates unemployment rate that is too high compared to real-world data. There are several reasons for the high level of unemployment generated in the simulations which in further stages of the model can be corrected.

The first one lies in the assumption that the experience of workers is perfectly transferable between firms. Hence, the on-the-job search mechanism leaves little chance for the new workers to enter the market. If the older, more experienced workers are too active in their search, the young and inexperienced ones "get stuck" on the queue of applicants and rarely receive an offer. If there is some kind of penalty for switching jobs in terms of loss of experience, this effect might be reduced. Also, including a search cost in terms of loss of leisure time should conceivably reduce the search intensity of employed workers under adaptive behaviour because their spare time is already scarce in comparison to that of unemployed workers.

Moreover, we can consider a two-step offering process, in which firms who have received a rejection in the current period, make an offer to the next best applicant from their application list. In this case the model might be brought closer to reality since usually firms would not wait until the next quarter to make a new offer for their vacancy. Such mechanism is expected to generate more plausible outcomes. It can be also extended to a multi-step process in which firms continue offering the position to next best applicant upon rejection.

Last but not least, we can consider the possibility to fire workers and to incorporate firm exit. Both of which would further augment the model and introduce the possibility to analyse various array of research questions.

Nevertheless, in its current version, the model provides some insight into two frictions that act simultaneously on the labour market. Not only are workers competing for the available positions but also firms are competing for the best workers which makes the formation of an actual match more difficult. On the one hand, a coordination failure arises from the urn-ball type matching in which workers send out their applications randomly. Hence, some firms receive more applications than vacancies they have while others receive less, which prevents the market from clearing. And on the other hand, allowing for multiple applications and on-the-job search introduces a further source of friction in the labour market which is shown to substantially increase the unemployment rate and the duration until finding a first job.

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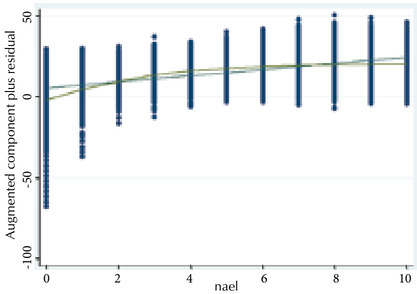
A. Appendix

Figure 12:

(a) Average unemployment duration (aud) and Number of applications per period sent by workers employed in "worse than average firms" (nael)



(b) Average unemployment duration (aud) and Number of applications per period sent by workers employed in "better than average firms" (naeh)

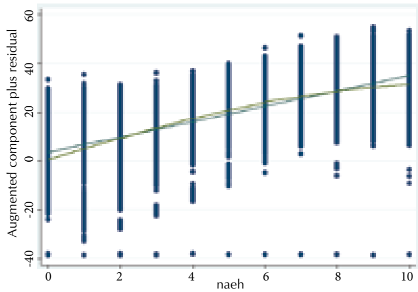
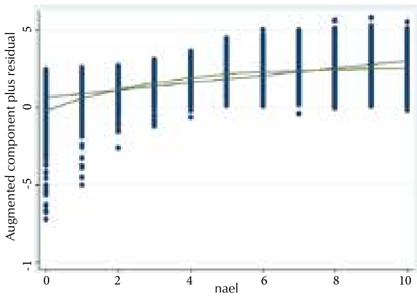


Figure 13:

(a) Unemployment rate (ur) and Number of applications per period sent by workers employed in "worse than average firms" (nael)



(b) Unemployment rate (ur) and Number of applications per period sent by workers employed in "better than average firms" (naeh)

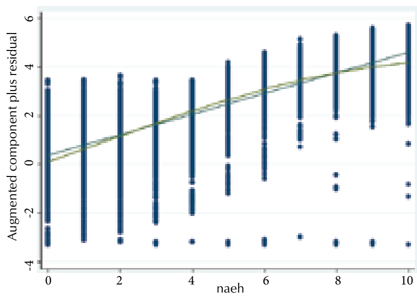
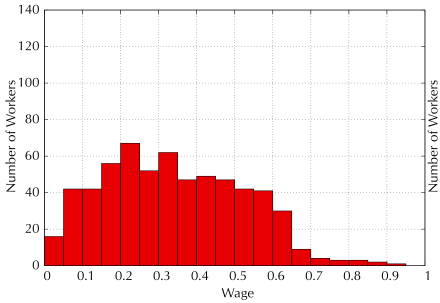
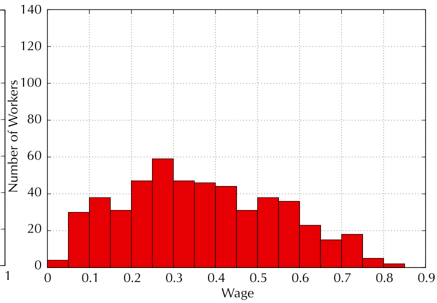


Figure 14: **Wage distribution at the 400th period, simulation results, single runs, 100 firms, 1000 workers, t = 400**

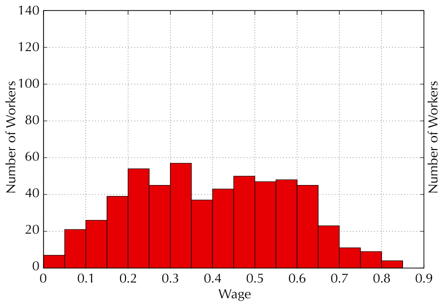
(a) Uniform distribution in the interval [1,2]



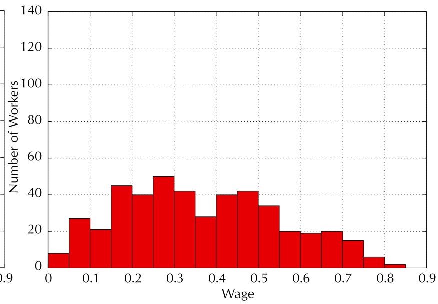
(b) Uniform distribution in the interval [1,3]



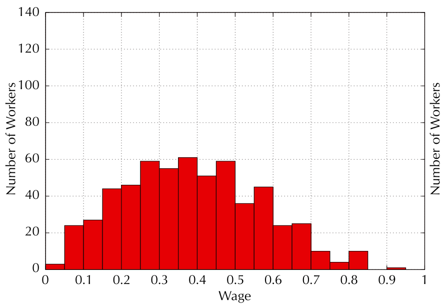
(c) Poisson distribution with $\lambda = 1$



(d) Poisson distribution with $\lambda = 2$



(e) Binomial distribution with $n = 10$, $p = 0.1$



(f) Binomial distribution with $n = 10$, $p = 0.2$