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# What moves the Beveridge curve and the Phillips curve: an agent-based analysis

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**Abstract**
Understanding what moves the Phillips curve is important to monetary policy. Because the Phillips curve has experienced over time movements similar to those characterizing the Beveridge curve, the authors jointly analyze the two phenomena. They do that through an agent-based macro model based on adaptive micro-foundations, which works fairly well in replicating a number of stylized facts, including the Beveridge curve, the Phillips curve and the Okun curve. By Monte Carlo experiments they explore the mechanisms behind the movements of the Beveridge curve and the Phillips curve. They discovered that shifts of the Beveridge curve are best explained by the intensity of worker reallocation. Reallocation also shifts the Phillips curve in the same direction, suggesting that it may be the reason behind the similarity of the patterns historically recorded for these two curves. This finding may shed new light on what moves the Phillips curve and might have direct implications for the conduction of monetary policy.

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## 1 Introduction

The Phillips curve, an empirical regularity characterizing the interplay between business cycles and labor market dynamics, is of the utmost importance for monetary policy. In fact, the necessity to have a deeper understanding of the causes of its historical movements has been often the major reason behind developments in macroeconomic theory (like for instance the introduction of the rational expectations hypothesis). Nonetheless, the debate about what moves the Phillips curve is still far from settled, and new explanations may be proposed.

Less attention has been drawn by another statistical regularity, the Beveridge curve, which describes a typically negative relationship between vacancy rate (number of job openings per period divided total labor force) and unemployment rate.

Historical movements of the two curves have shown similar patterns: both curves shifted outwards from the 1970s to the 1980s, and from the late 1980s on they have shifted back (Valletta, 2005). Empirical evidence, therefore, hints that the Beveridge curve (BC) may posses a natural connection with the Phillips curve (PC), and that the explanation of what moves BC may also serve to explain movements of PC, with direct implications for the conduction of monetary policy.

However, even though the opportunity of joint examination has already been suggested (Solow, 1964; Blanchard and Diamond, 1989), these curves are typically analyzed in isolation. For instance, historical shifts in PC have been usually explained in terms of changing expectations by rational price-setting agents only, without considering information coming from BC.[1] As far as the Beveridge curve is concerned, in most of empirical research outwards and inwards shifts of the curve – higher or lower vacancy rate for given unemployment rate – have been interpreted as reflecting changing microeconomic efficiency in the job matching process. Alternatively, another strand of research has suggested that shifts in BC may reflect reallocation shocks, due for instance to sectoral shocks (Abraham and Katz, 1986; Blanchard and Diamond, 1989; Valletta, 2005). In this view, the contemporaneous presence of growing sectors and declining sectors would imply a higher turnover (*i.e.* reallocation) among workers, that is a higher level for both new job openings and job destruction at a given unemployment rate.

Worker reallocation may occur also in absence of sectoral shocks, as for instance when increasing competition among firms induces them to raise wages in order to hoard labor force. If workers leap from job to job chasing after higher wages, firms are compelled to open new vacancies in order to replace job quits. Hence, reallocation activity due to rising wages can increase both vacancies and job destruction without substantially affecting unemployment - an outwards shift of BC. The causal relationship between BC shifts and wage inflation may also work the

[1] Notable exceptions in mainstream literature exploring the possible connection between the two curves, although not explicitly, are the works that incorporate labor market frictions in the determination of the New Keynesian Phillips Curve (e.g. Cooley and Quadrini, 1999; Ravenna and Walsh, 2008; Blanchard and Gali, 2010).

other way around. For example, in case of outwards shifts of Beveridge curve the increased number of vacancies for given unemployment can compel firms to engage in a tougher wage competition in order to fill in their vacancies – in other words, an outwards shift of Phillips curve. Hence, worker reallocation might jointly explain the shifts of both Beveridge and Phillips curve.

As the two curves may well be intertwined phenomena, common explanations should be sought. The main goal of this paper, therefore, is to *jointly* explain the shifts historically experienced by the two curves. At this scope we will put at test two competing hypotheses: one is the "job market efficiency" hypothesis, the other is the "worker reallocation" hypothesis. We want to stress here that by "reallocation" we do not mean a mere movement of workers across employers, but the contemporaneous occurrence of job destruction and job creation (Blanchard and Diamond, 1989).

The two hypotheses, although related, are profoundly different. Basically, what we call the "job market efficiency" hypothesis is related to how market frictions due to search costs influence the probability that unemployed workers become employed, that is the *efficiency* of the matching process between workers and firms. On the other hand, what we call the "worker reallocation" hypothesis is related to the probability for a worker to be in the position of searching for another job, that is the *frequency* of the matching process. As we will explain in detail in Section 2, in the model we will put forth there are two reasons why a worker may be in the position to search for a job: (*i*) endogenous layoffs due to the firm's inability to pay for the wage bill and (*ii*) exogenous terminations of the job contract. The frequency of exogenous terminations depends on the job contract length. Contract length contributes to determine both the number of workers who lose the job in a given period and the number of vacancies that firms need to open in order to replace quitting workers. Contract length, therefore, contributes to determine at one time flows of job destruction and job creation – in a word, the intensity of worker reallocation. To summarize, we can use the following 'matching function' representation of the gross flow of newly created jobs at time $t$:

$$J_t = Af(U_t, V_t), \tag{1}$$

where parameter $A$ denotes the matching efficiency, and $U_t$ and $V_t$ are the stock of unemployed workers and the job vacancies open at time $t$ respectively. The "job market efficiency" hypothesis is related to parameter $A$ because frictions due to search costs influence the matching efficiency, whereas the "worker reallocation" hypothesis concerns *variations* of both $U_t$ and $V_t$, that is the flows of job destruction and job creation.

As far as the analytical apparatus is concerned, existing theoretical literature still lacks micro-founded models that are able to jointly account for these two stylized facts. Fortunately, the proper methodology is in a sense called for by the very nature of the problem. In fact, insights coming from the examination of the two curves provide a picture which is very different from that of a Walrasian labor market

characterized by equilibrium and stability. As an example, outwards shifts of BC are signal of higher levels of job creation and job destruction, that is of higher "turbulence" and instability on the labor market. Empirical evidence, therefore, would suggest a view of labor markets (and of economic systems in general) as complex systems, where bounded-rational agents' micro decisions produce the emergence of unintended aggregate outcomes, and individual disequilibrium is accompanied by aggregate regularity. Thus, a methodology inspired to the science of complexity would be more appropriate than the rationality-based approach that is typical of mainstream economics, such as for instance the search-and-matching models within which the analysis of BC is usually carried out. In this paper, therefore, we will propose a model inspired to the complexity approach that is able to provide joint explanations to labor market stylized facts, and in particular to the relationship between Phillips curve and Beveridge curve movements.

Our approach to labor market, therefore, starts from the acknowledgment that any aggregate economic system is more than the sum of individual rational decisions. In fact, because of the inherent uncertainty characterizing economic environments, microeconomic decentralized interactions and out-of-equilibrium transactions create aggregate outcomes that cannot be directly traced back to individual purposes. In this view, labor market stylized facts have to be conceived as emergent properties of the system as a whole. As a consequence, partial equilibrium approaches such as search models (e.g. Diamond, 1982) and efficiency wage models (e.g. Shapiro and Stiglitz, 1984) are ill-equipped to satisfactorily explain such phenomena as the two curves under consideration because their analysis of labor market does not take into account its interactions with the other parts of the economic system.

Our approach also departs from mainstream macroeconomics, which does not allow, in general, to take into account the divergences between individual intentions and aggregate consequences. Furthermore, mainstream models merely focus on equilibrium properties. On the contrary, we are interested in the whole process that can generate unintended aggregate consequences as a sort of spontaneous social order. We point out that these are limitations that characterize also search models embedded in general equilibrium frameworks.

For all these reasons, we resort to agent-based techniques, which propose themselves as the ideal candidates to front the challenges issued by the complexity approach (Judd and Tesfatsion, 2006). The framework we employ to study labor market dynamics is a modified version of that of Gaffeo *et al.* (2008) and Delli Gatti *et al.* (2011), the main difference being the updating rule of incumbent workers' wage (aimed at removing an unrealistic feature of the original model, which we will describe later). In this model a large number of heterogeneous agents repeatedly interact on three interconnected markets for labor, consumption goods and credit. As the markets are characterized by decentralized search and matching processes, and search is costly, each searching agent can visit each period only a finite number of partners. Because of uncertainty, therefore, agents can fail to coordinate, so that searchers may visit providers with no excess supply and providers may face insufficient demand. Hence, transactions may well occur at disequilibrium prices

(i.e. out of equilibrium) even when a general equilibrium potentially exists. We want to remark that in our framework the matching process is not based on the black-box of some 'matching function' – the analytical device that couples agents on the two sides of a market in mainstream search-and-matching models – but, as we will explain later in detail, it substantiates in an explicit, numerically computed directed search.

In spite of the lack of a centralized market-clearing mechanism, our virtual economy shows a tendency to self-organize towards a spontaneous order, which is however characterized by such persistent Keynesian features as involuntary unemployment, unsold production and demand-driven fluctuations. These phenomena, which in the standard macroeconomic theory are pathological deviations from a first-best equilibrium scenario, in our framework they emerge as physiological properties of the macroeconomy. In a sense, our model is closely related to the post-Walrasian disequilibrium approach (Clower, 1965; Barro and Grossman, 1971). Because of uncertainty, in fact, trade generally occurs at disequilibrium prices. Hence, market excess demands are not independent of current market transactions and current income places a restriction on individual expenditure. One consequence is the occurrence of aggregate imbalances, such as a contemporaneous presence of excess supply for both labor and goods. Another consequence is that money is not simply a veil relegated to determine absolute price levels, but it is both a medium of exchange used to implement current transactions and a store of value that can compensate individual imbalances, for example as in the case of an unemployed worker who can still act as a consumer by resorting to accumulated savings. Unlike classical disequilibrium models, however, our agent-based model needs not to be analytically solved, and its properties can be assessed by repeated simulations in a controlled environment.

The application of agent-based models to the analysis of labor markets is certainly not new. Most of these models adopt a partial-equilibrium perspective, like the pioneering model present in Tesfatsion (2001) (for a survey, see e.g. Neugart and Richiardi, 2012), and analyze the labor market in isolation. However, they fail to capture the complex nature of labor market stylized facts as this modeling approach does not take into account the feed-backs from other markets to the labor market. Conversely, our model belongs to the class of multi-market agent-based models embedding also a labor market, which has grown fast in recent years. Fagiolo *et al.* (2004) is an early work which shares various features with ours, there included some modeling assumptions and research questions. However, our model is more sophisticated and able to replicate a higher number of stylized facts. Moreover, Fagiolo *et al.* (2004) represents more of a methodological work as its computational experiments are mainly aimed at showing, by jointly replicating the Okun curve and the Wage curve, how agent-based models can be used in the analysis of the labor market. On the contrary, our paper aims at providing a clear theoretical contribution by *explaining* a real phenomenon. Another work bearing some similarities with ours is the recent Dosi *et al.* (2017), whose focus is on the assessment of the effect that different labor market rigidities have on the macroeconomy.

Other examples of macro agent-based models with a labor market include Russo *et al.* (2007), all the various incarnations of the *EURACE* simulator (e.g. Dawid *et al.*, 2009; Cincotti *et al.*, 2010), Dosi *et al.* (2013), Assenza *et al.* (2015), Delli Gatti and Desiderio (2015), Riccetti *et al.* (2015) and Riccetti *et al.* (2016). All these models were used mainly to replicate a given set of stylized facts and to assess the effect of different kinds of macro and micro policies. However, these models, with the partial exception of Fagiolo *et al.* (2004), have never been used to carry out an analysis similar to that we make in this paper, which therefore represents basically the first example of its genre.

The paper proceeds as follows. Section 2 outlines the model. Section 3 presents the general results coming from a typical simulation of the model, which is validated through a comparison with a number of stylized facts. Section 4 reports the main contribution of the paper, i.e. the outcomes from Monte Carlo simulations assessing the influence that labor market parameters exert on the Beveridge curve, the Phillips curve and the Okun curve. Section 5 concludes.

## 2 The model

As formerly hinted at in the Introduction, the present work is in a sense a continuation of Delli Gatti *et al.* (2011), and the model we employ is essentially the same as the one in the cited reference, with the exception of the rule used to update incumbent workers' wages. As a consequence, this section is almost entirely based on Chapter 3 of Delli Gatti *et al.* (2011).

We consider a dynamic model running for $T$ periods. Every period $t$ a fixed number of infinitely-lived households (workers and capitalists), firms (each owned by a capitalist) and banks get in touch with each other on the three markets for labor, credit and a homogeneous consumption good. In what follows we first provide a general overview of the actions repeated each period, and then we describe in detail each market.

### 2.1 The sequence of actions

Each firm decides the amount of output to produce and the price to charge by taking into account its expected demand and past relative prices. Expectations on future demand are updated adaptively.

The labor market opens. Firms post their vacancies at a certain offered wage, and unemployed workers contact a given number of firms to get a job. Labor contracts expire after a finite number of periods.

Firms have to pay the wage bill in order to start production and, if internal financial resources are not enough, they can borrow from the banking sector. Borrowing firms contact a given number of randomly chosen banks to get a loan. The firm borrows from the bank charging the lowest interest rate, which is an increasing function of the firm's financial fragility. If the sum of internal and borrowed financial

resources are still not enough to pay for the wage bill, the firm fires – or does not hire – some workers.

Production takes one time period. After production has been completed, the market for consumption goods opens. Firms post their offer price, and consumers contact them to purchase goods. Each consumer is allowed to visit a given number $Z$ of firms to assess posted prices, and starts to buy from the supplier that posts the lowest price. In order to minimize the probability to be rationed, the consumer adopts a sort of preferential attachment scheme, which consists in visiting the largest (in terms of production) firm visited during the previous round. The remaining $Z-1$ firms are chosen at random. If a firm ends up with excess supply, it gets rid of the unsold goods without additional costs.

Firms collect revenues and calculate gross profits. If gross profits are high enough, they meet their debt commitments paying back both principal and interests to the banks. If net profits are positive, firms pay dividends to the owners and invest in R&D, in order to increase their productivity. Retained earnings go to increase net worth. Firms and banks are financially viable – and therefore survive – if their net worth is positive, otherwise they go bankrupt and exit the market. Lenders, therefore, have to register a bad debt. In this case, new firms/banks enter the market to replace the bankrupted ones, and their size at entry is smaller than the average size of survivors.

### 2.2 The labor market

Firms and workers operate on the labor market. The generic firm $i$ sets its labor demand $L_{it}^d$ on the basis of its technology and desired level of production, $Y_{it}^d$. Production is carried out by means of a constant return to scale technology using labor $L_{it}$ as the only input:

$$Y_{it} = \alpha_{it} L_{it}, \;\; \alpha_{it} > 0 \tag{2}$$

where $\alpha_{it}$ is labor productivity. Productivity changes over time according to a first-order autoregressive stochastic process:

$$\alpha_{it+1} = \alpha_{it} + z_{it}, \tag{3}$$

where $z_{it}$ is the realization of a random variable, exponentially distributed with parameter $\frac{1}{\mu_{it}} = \frac{P_{it} Y_{it}}{\sigma_{it} \pi_{it}}$. The quantity $\sigma_{it}$ is the fraction of gross nominal profits ($\pi_{it}$) that is used to fund investments in R&D. The expected value of $z_{it}$ is therefore an increasing function of firms' R&D expenditure, which is financed out of a fraction of profits. Thus, in our setting the higher R&D expenditure, the higher on average the increase in productivity. In simulations, $\sigma_{it}$ will be modeled as an exponential function decreasing with the firmâs financial fragility, defined as the ratio between the current wage bill and internal financial resources $A_{it}$, and normalized such that $\sigma_{it}(0) = 10\%$.

From equation (2), firm $i$'s labor demand at time $t$ is given by:

$$L_{it}^{d} = \frac{Y_{it}^{d}}{\alpha_{it}} \tag{4}$$

If needed, the firm posts new vacancies $V_{it}$, equal to the difference between the desired workforce $L_{it}^{d}$ and the number of workers still employed at firm $i$ at the beginning of time $t$. Workers with an active contract can be fired only when firms' capitals are not enough to pay for the wage bill.

The wage offered by firm $i$ at time $t$ is determined according to the following rule:

$$w_{it} = \begin{cases} \max(\hat{w}_t, w_{it-1}(1+\xi_{it})) & \text{if } V_{it} > 0 \\ \max(\hat{w}_t, w_{it-1}) & \text{if } V_{it} \leq 0 \end{cases} \tag{5}$$

where $\hat{w}_t$ is a minimum wage imposed by the law, while $w_{it-1}$ is the wage offered in the previous period. The idiosyncratic shock $\xi_{it}$ is uniformly distributed on the non-negative interval $(0, h_{\xi})$. The minimum wage is periodically revised upward, in order to neutralize price inflation. Because of labor force homogeneity, wages contracted in previous periods that happen to fall below the new wage level $w_{it}$ are automatically updated to it.[2] The necessity to hire new workers, therefore, cause the average wage to rise. The design of this wage-updating rule is consistent with findings reported by numerous surveys of firms' wage-setting policies. There is in fact clear evidence of nominal wage downward rigidity. Firms are particularly reluctant to cut nominal wages even during recessions because they are afraid that lower wage rates would increase turnover and decrease labor effort (Campbell and Kamlani, 1997; Bewley, 1999). In addition, downward rigidity is observed also for the salary of the newly hired workers, probably for reasons of perceived equity (Bewley, 1999).

Each period workers supply one unit of labor at any wage rate (inelastic labor supply). Decentralized labor markets (i.e., one for each worker) are opened sequentially according to a random order. Each unemployed worker sends randomly $M$ applications to as many firms. If his/her contract has just expired, one of the applications is sent to his/her last employer. Workers are therefore characterized both by a sort of loyalty to their last employer and by the need to minimize the risk of unemployment by diversifying their portfolio of potential employers. For simplicity workers are not allowed to engage in on-the-job search activity, so that worker reallocation can occur only when workers are fired or when their job contract has expired.

Firms still characterized by some open job position will communicate to contacting workers its offered wage. Workers who receive more than one proposal accept the one paying the highest wage. When hired by a firm, the worker signs a

[2] This is the main modeling difference with respect to Delli Gatti *et al.* (2011), and is intended to remove one unrealistic feature characterizing that model, namely that newly hired workers earn more than incumbent ones.

job contract for a fixed number of periods $D$. During the employment relationship the wage paid to him by firm $i$ is given by Eq. (5).

Given that each worker is allowed to sign one labor contract per period, coordination failures can arise as the number of workers actually available to a firm does not necessarily correspond to the number of vacancies, especially for firms that pay lower wages.

### 2.3 The credit market

Firms and commercial banks operate on the the credit market. The generic firm $i$ starts at the beginning of period $t$ with an endowment of internal resources determined by retained past profits (net worth), denoted by $A_{it}$. In case its wage bill $W_{it}$ is larger than net worth, the firm applies for a bank loan $B_{it} = W_{it} - A_{it}$. Its credit demand is therefore given by:

$$B_{it} = \max(W_{it} - A_{it}, 0) \tag{6}$$

Again, because of transaction costs each firm can apply for a loan only to a fixed number $H$ of banks out of a population of $K$ banks. The $H$ potential lenders are randomly selected.

The $k$-th bank will able to extend for each period only a maximum amount of credit $C_{kt}$ equal to a multiple of its equity base: $C_{kt} = E_{kt}/v$, where $0 < v < 1$ can be interpreted as a capital requirement coefficient. The reciprocal of $v$ therefore represents the maximum allowable leverage for the bank. For simplicity, we assume that the capital requirement coefficient is constant and uniform across banks. The contacted bank $k$, conditional on the availability of credit, will offer to firm $i$ a single-period debt contract, setting an interest rate $r_{kit}$ and the repayment schedule:

$$\begin{cases} B_{it}(1 + r_{kit}) & \text{if } A_{it+1} > 0 \\ R_{it+1} & \text{if } A_{it+1} \leq 0 \end{cases} \tag{7}$$

where $R_{it+1}$ is the amount that the bank can retrieve if the firm goes bankrupt (basically, it is the residual capital the defaulting firm might own just before paying the interests). The interest rate $r_{kit}$ is determined as a mark-up over a policy rate $\bar{r}$ set by a central monetary authority:

$$r_{kit} = \bar{r}(1 + \mu(l_{it})) \tag{8}$$

The mark-up in turn is an increasing function of the financial fragility of the borrower, captured by the term $\mu(l_{it})$. So we have $\mu' > 0$, where $l_{it} = \frac{B_{it}}{A_{it}}$ is a proxy for the borrower's leverage. The last term implies that the mark-up the bank charges over the policy rate reflects a risk premium that increases with the financial fragility of the borrower because of asymmetric information and costly state verification (Bernanke and Gertler, 1989; Bernanke and Gertler, 1990; Riccetti *et al.*, 2013).

Once the $H$ banks have revealed the terms of the credit opportunities, the firm chooses the bank offering the lowest interest rate. In case the most preferred bank is in short supply of credit, the firm can resort to the remaining *H-1* banks. If total resources are still not enough after the credit market closure, the firm lays redundant workers off at zero firing costs.

### 2.4 The goods market

Firms and households operate on the consumption good market. The generic firm $i$ adjusts the price or the quantity supplied, to adapt to changing business conditions. In spite of the good being homogeneous, asymmetric information and search costs imply that the 'Law of one price' in general does not hold.

We assume that the firm cannot change price and quantity at the same time. This assumption is based on the evidence of survey data on price and quantity adjustment of firms over the business cycle (Kawasaki *et al.*, 1982; Bhaskar *et al.*, 1993). Moreover, it is reasonable because by changing one variable at time the firm can correctly ascertain its effects on consumers' demand.

Each firm has a certain degree of market power and its strategies depend on its internal conditions and on signals coming from the market environment. The relevant information for price or quantity adjustment of firm $i$ at period $t$ consists of the average market price $P_{t-1}$ and of the individual excess demand/supply recorded in the previous period. The latter is captured by inventories $S_{it-1}$.

There are four, mutually exclusive cases.

- a) If inventories are positive (excess supply) and individual price is higher than the average price, the firm reduces the price keeping the quantity unchanged;
- b) If inventories are zero (signal of excess demand) and the individual price is lower than the average, the firm increases the price keeping the quantity unchanged;
- c) If inventories are positive (excess supply) and the individual price is low with respect to the average, the firm reduces the quantity supplied keeping the price unchanged;
- d) If inventories are zero (excess demand) and the individual price is higher than the average, the firm increases the quantity keeping the price unchanged.

Cases $a)$ and $b)$ are incorporated in the following price rule:

$$P_{it}^{s} = \begin{cases} \max[P_{it}^{l}, P_{it-1}(1+\eta_{it})] & \text{if } S_{it} = 0 \text{ and } P_{it-1} < P_{t-1} \\ \max[P_{it}^{l}, P_{it-1}(1-\eta_{it})] & \text{if } S_{it} > 0 \text{ and } P_{it-1} \geq P_{t-1} \end{cases} \tag{9}$$

where $\eta_{it}$ is an idiosyncratic random variable uniformly distributed on the interval $(0, h_{\eta})$, and $P_{it}^{l}$ is the lowest price at which firm $i$ is able to cover its average costs (wages plus interests).

Cases $c)$ and $d)$ trigger quantity adjustments according to the following rule:

$$Y_{it}^{e} = \begin{cases} Y_{it-1}(1+\rho_{it}) & \text{if } S_{it} = 0 \text{ and } P_{it-1} \geq P_{t-1} \\ Y_{it-1}(1-\rho_{it}) & \text{if } S_{it} > 0 \text{ and } P_{it-1} < P_{t-1} \end{cases} \tag{10}$$

where $\rho_{it}$ is an idiosyncratic shock uniformly distributed on the interval $(0, h_{\rho})$.

The demand side of the goods market is represented by the households. In each period employed workers receive wages, whereas capitalists receive dividends from the firm they own. Household $i$ determines its desired (nominal) consumption budget as a share of its wealth $WE_{it}$:

$$C_{it} = c_{it} WE_{it}, \tag{11}$$

where $c_{it} \leq 1$ is the marginal propensity to consume (out of wealth). Consistently with the empirical evidence from the Consumer Expenditure Survey (Souleles, 1999), as well as with predictions from the theory of consumption under uncertainty (Carroll and Kimball, 1996), we assume $c_{it}$ to decline with personal wealth as follows:

$$c_{it} = \frac{1}{1 + [tanh(\frac{WE_{it}}{WE_t})]^{\beta}}, \tag{12}$$

where $WE_t$ is the average wealth at time $t$, *tanh* is the hyperbolic tangent function and $\beta$ is a tuning parameter. The marginal propensity so defined will range between 1 for the poorest consumers and 0.5 for the richest ones.

Consumers (workers and capitalists) randomly enter the goods market. Because of search costs, each consumer can visit only a fixed number $Z$ of firms, one of which is the largest (in terms of production) firm visited in the previous period. We assume consumers to adopt this sort of "preferential attachment" mechanism in order to minimize the probability to be rationed. In fact, as individual markets are small, consumers are exposed to the risk of buying from expensive producers. In order to try to minimize this risk, every period they explore the market in search of lower prices by selecting at random some of the firms. At the same time consumers face the risk of selecting small or 'popular' firms that quickly exhaust all their produce. As a consequence, consumers are exposed also to the risk of being rationed. At this point the preferential attachment mechanism enters into play in order to try to minimize this second kind of risk. Thus, the mechanism applies only to the first largest firm because of the consumer's need of balancing between two contrasting risk types.

Once firms have communicated their prices, the household tries to implement its desired consumption plans starting from the firm charging the lowest price among the selected firms. If goods available at the first firm are not enough, the consumer will turn to the second cheapest firm, and so on. Again, because of uncertainty market failures may arise: households may not be able to purchase all the desired quantity of goods (in which case they are forced to save more than planned) and/or firms may end up with unsold production.

### 2.5 Accounting, entry and exit

After the market for consumption goods is closed, firm $i$ has sold quantity $Y_{it}$ at price $P_{it}$. Accordingly, its revenues are $R_{it} = P_{it}Y_{it}$. If the firm remains with unsold production, it gets rid of it at zero costs.

The firm then computes its profits $\pi_{it}$ (revenues minus wage bill and interests). If profits are positive, it pays dividends $\delta\pi_{it}$ to its shareholder and undertakes R&D expenditures. Retained profits are added to net worth $A_{it}$. So, the law of motion for the net worth of firm $i$ is:

$$A_{it} = A_{it-1} + (1-\sigma_{it})(1-\delta)\pi_{it}, \tag{13}$$

where $\sigma_{it}$ is the share of profits devoted to research activity. This quantity is endogenously determined at the end of each period and declines with the firm's financial fragility.

If net worth becomes negative (because of huge losses), the firm is declared insolvent and exits the market. We assume that the bankrupt firm is replaced by a new entrant, whose initial size is set below the average size of the active firms. This one-to-one replacement of bankrupt firms is essentially a working hypothesis to keep total firms' population constant. Nonetheless, we can offer an empirical rationale for this assumption. There are, in fact, two widely accepted stylized facts (Sutton, 1997). First, in each established (mature) industry, the number of firms tend to settle down around a roughly constant level. Second, the inflow and outflow of firms are highly correlated: Geroski (1991), for example, reports a correlation coefficient of 0.796 for a sample of 95 industries in United Kingdom in 1987. Thus, here we are implicitly assuming a correlation equal to 1.

Due to firms' bankruptcies, lending banks will record non-performing loans – bad debt – $BD_{kt}$, equal to a certain share of the bankrupt firm's equity. Hence, the law of motion for bank $k$'s equity can be defined as

$$E_{kt} = E_{kt-1} + \sum_{\Theta} r_{kit}B_{kit} - BD_{kt}, \tag{14}$$

where $\Theta$ is the bank's loan portfolio, $r_{kit}$ is the interest rate charged to firm $i$ at time $t$, $B_{kit}$ is the loan extended to firm $i$ at time $t$ and $BD_{kt}$ represents the bank's bad debt at time $t$ ($BD_{kt} \leq \sum_{\Theta} B_{kit}$). If equity becomes negative, the bank gets recapitalized by a (unmodeled) Central Bank, which therefore acts as lender of last resort.

## 3 Simulation results

This section reports a general overview of the main results related to the labor market. We run a simulation with the number of workers' applications $M$ set to 4, the labor contract length $D$ set to 8 periods and the revision of the minimum wage set to 4 periods. Assuming that one simulation period corresponds to a quarter, labor contracts last two years, while the minimum wage is revised annually. The

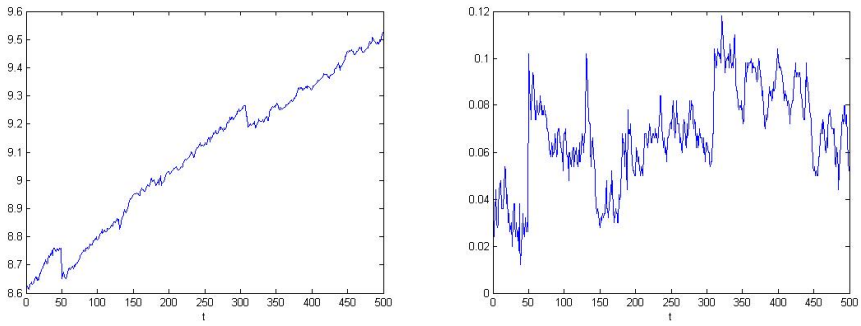
simulation lasts 1000 periods but we consider the last 500 only in order to get rid of transients. The parameter values used for the baseline simulation are shown in Table 1.

Even though the model is not calibrated on real data, nonetheless it displays a good agreement with empirical evidence. In what follows we will consider only results from a non-preselected simulation in order to give a flavor of the model properties.

Figure 1 shows two time series relative to a typical simulation. Aggregate production (Panel 1(a)) is characterized by irregular fluctuations and its autocorrelation coefficient is very close to the actual one. The model generates an alternation of prolonged periods of growth and deep but short recession phases as a non-linear combination of idiosyncratic shocks affecting individual decision-making processes. The account of business cycles offered by the present model thus is at odds with that provided by DSGE models, according to which fluctuations in aggregate activity are explained by random changes in aggregate variables such as TFP growth, or monetary, investment or mark-up shocks. In our model recessions are essentially triggered by bankruptcies of big firms, which affect the economy as a whole through two channels. One is the loss of employment and the subsequent reduction in aggregate demand that negatively reverberates on other firms' sales and profits. The other is a financial accelerator mechanism operating through the banks' balance sheets: bankruptcies, in fact, cause lending banks to record non-performing loans and consequently to reduce their credit supply to other firms. This means that also other firms may eventually reduce production and lay workers off.

**Table 1:** Parameters.

| Parameter | Description | Value |
|---|---|---|
| $T$ | Number of periods | 1000 |
| $I$ | Number of firms | 100 |
| $N$ | Number of workers | 500 |
| $K$ | Number of banks | 10 |
| $Z$ | Number of firms visited by a consumer | 2 |
| $M$ | Number of labor applications | 4 |
| $H$ | Number of banks visited by a firm | 2 |
| $D$ | Job contract length | 8 |
| $h_\eta$ | Maximum growth rate of prices | 0.1 |
| $h_\rho$ | Maximum growth rate of quantities | 0.1 |
| $h_\xi$ | Maximum growth rate of wages | 0.05 |
| $\sigma$ | Maximum profit share devoted to R&D | 0.1 |
| $\delta$ | Dividend payout ratio | 0.1 |
| $\bar{r}$ | Policy rate | 0.02 |
| $\nu$ | Bank capital requirement coefficient | 0.08 |
| $\beta$ | MPC tuning parameter | 7 |




(a) (b)

**Figure 1:** (a): real output (logarithmic scale), (b): unemployment rate.

The unemployment rate (Panel 1(b)) periodically ranges between 1% and 12% and closely follows the business cycle. This cyclical behavior obviously cannot be explained in terms of microeconomic frictions due to search costs, which are fixed over the whole simulation and may have a role in determining frictional unemployment only. Furthermore, the close similarity between the time series of unemployment and unsold production (that we do not report) signals the contemporaneous occurrence of excess supply for both labor and goods, which is a clear symptom of coordination failures. According to the post-Walrasian disequilibrium approach, which our model closely relates to (see Section 1), such a situation is the distinctive feature of Keynesian unemployment, as opposed to 'Walrasian' unemployment where excess demand on one market corresponds to excess supply on another market. Consequently, this suggests for our model a Keynesian (demand-driven) interpretation of unemployment.

We now show the model properties at business-cycle frequencies. We compare artificial and empirical cyclical components of four variables: GDP, unemployment rate, CPI and labor productivity. Cyclical components are extracted by applying the Hodrick-Prescott filter with parameter set at 1600. Empirical data are post-war U.S. seasonally-adjusted quarterly time series, retrieved from FRED database.[3] Table 2 reports first-order autocorrelations of the four variables, showing that the agreement between simulated and real data is not very satisfactory for the CPI only. Figure 2 shows results from a traditional co-movement analysis exercise: against each value of *lag* on the *x*-axis we plot the correlation between the cyclical component of GDP at time *t* with the cyclical component of the other variables at time *t*+*lag* (a negative *lag* corresponding to a *lead*). We can see that, at least qualitatively, the pattern of the artificial cross-correlograms grossly follow the observed ones, in particular for GDP and productivity. Unemployment (Panel 2(b)) is strongly anti-cyclical and contemporaneous, whereas its empirical counterpart is lagging with respect to GDP (higher correlation for $lag = 1$). The agreement is less satisfactory, once again,

[3] We used the files GDPC1, UNRATE, PCECTPI and CE16OV.

**Table 2:** First-lag autocorrelation of cyclical components.

| | GDP | Unemployment | CPI | Productivity |
|---|---|---|---|---|
| Observed | 0.8771 | 0.8979 | 0.8688 | 0.7536 |
| Simulated | 0.7624 | 0.8029 | 0.4658 | 0.8273 |

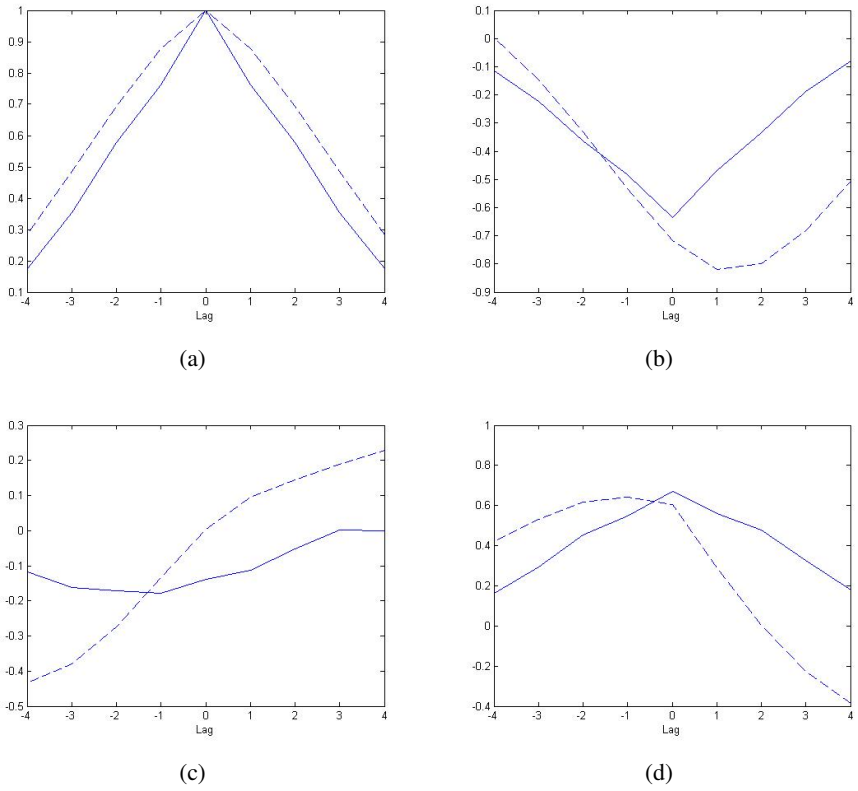



**Figure 2:** Cross-correlations for simulated (continuous line) and observed time series (dashed line). The pictures show the correlation between the cyclical component of GDP at time $t$ with those at time $t$+*lag* of (a): GDP, (b): unemployment, (c): CPI, (d): labor productivity.

for the CPI: real data are strongly anti-cyclical and *leading* (higher correlation for negative values of *lag*), whereas simulated data can be considered only weakly anti-cyclical (but still *leading*) or even a-cyclical.

Figure 3 depicts interesting results that emerge from simulations related to the interplay between labor market and business fluctuations. Panel (a) shows a negative relationship between the rate of wage inflation and the rate of unemployment, i.e. a standard Phillips curve. The negative correlation between the two variables is not very strong (–0.29) but statistically significant. Panel (b) shows a negative relationship between the output growth rate and the unemployment growth rate – i.e. an Okun curve (correlation of –0.86). A third emerging regularity regarding the labor

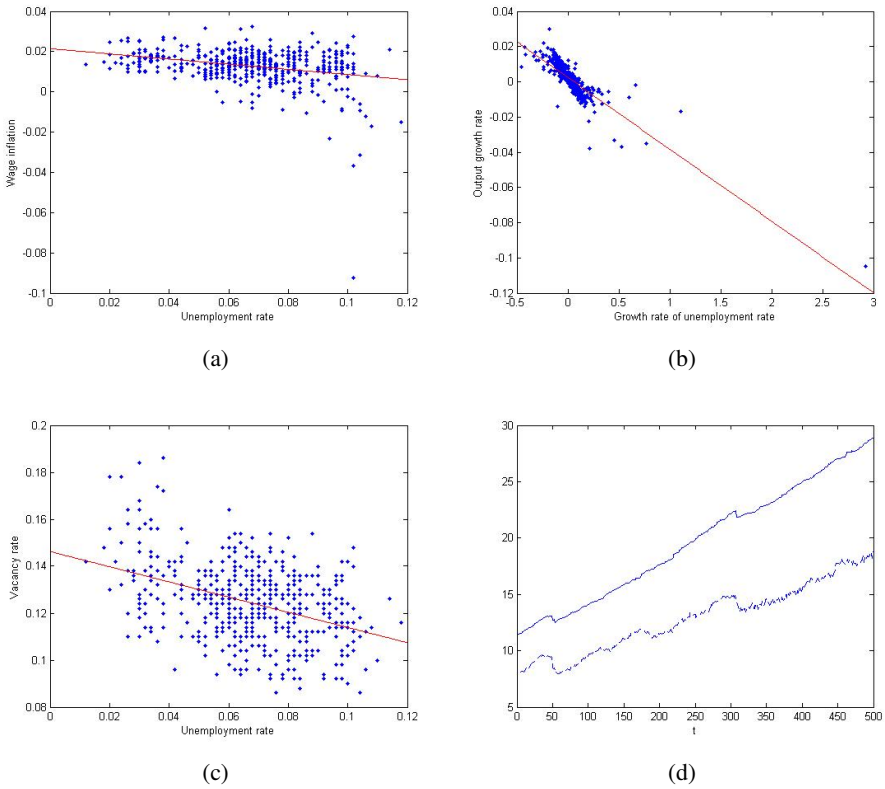



**Figure 3:** (a): Phillips curve, (b): Okun curve, (c): Beveridge curve, (d): productivity and real wage (dashed line).

market is the Beveridge curve reported in Panel (c), showing a negative relationship between the rate of vacancies (the ratio between the number of job openings and the total number of workers) and the rate of unemployment. In this case the goodness of fit is less satisfactory than in the case of the Okun curve, but the negative correlation between the two variables, albeit not so strong (–0.41), is once again statistically significant. In addition, Panel (d) shows that the average real wage and productivity follow similar patterns, whose ratio settles around a long run constant value of approximately 2/3. Since we do not impose any aggregate equilibrium relationship between the two variables, the (on average) constancy of income shares over time is just an emerging feature produced by the self-organization of the system.

The model also replicates, at least qualitatively, well-known empirical regularities concerning job flows. We find that unemployment is positively correlated to long-term unemployment,[4] which means that higher unemployment rates are associated to longer unemployment duration and to lower turn-over rates among

[4] We classify as long-term unemployed all the workers who have been inactive for more than three periods, that is, in our interpretation of a period, for more than three quarters.

workers. Moreover, layoffs and hirings, i.e. job destruction and job creation, have strong positive correlation both in levels and in differences. Finally, layoffs show higher volatility and are more correlated to unemployment than hiring (Blanchard and Diamond, 1990; Davis *et al.*, 1996), suggesting that production downscaling might be the major force behind unemployment fluctuations. This corroborates the already proposed Keynesian interpretation of unemployment, whose dynamics must ultimately be determined by the combination of fluctuations in aggregate demand and productivity growth and not by microeconomic frictions.

The joint emergence of many stylized facts indicates that the complexity approach is indeed a good way to analyze labor market dynamics. Hence, in the next section we are going to employ the model as a computational laboratory to perform virtual experiments on the labor market.

## 4 Beveridge and Phillips curves

In this section, which is the major contribution of our work, we perform local sensitivity analysis exercises aimed at understanding the mechanics lying behind the Beveridge curve and the Phillips curve. The parameters involved are those regulating the labor market, namely the number of workers' applications ($M$) and the job contract length $D$. Parameter $M$ defines the size of the individual labor markets and, therefore, captures labor market rigidities due to search costs. Parameter $D$ tunes the flexibility of job contracts and, therefore, the intensity of worker reallocation. When, in fact, labor contracts are short ($D$ small) the search and matching process between workers and employers occurs more frequently and the reallocation of workers is more intense, whereas the opposite is true when $D$ is large.

In order to disentangle likely joint effects (which will be considered in the last sub-section as a robustness check), we choose to change one parameter at time, and we run several simulations of 1000 periods to quantify how variations in the value of the input parameter affect the output. For each parameter value we run 100 independent simulations, each one for a different sequence of random numbers.

For each simulation $i$ we estimate by OLS the two curves of interest in the following way:

$$y_{ti} = \alpha_i + \beta_i x_{ti} + \varepsilon_{ti}, \tag{15}$$

where variables $y$ and $x$ are two time series. So, for example, if $y$ stands for the wage inflation rate and $x$ stands for the unemployment rate, then we are estimating the PC relative to a single simulation $i$.

Once we get the OLS estimates $\hat{\alpha}_i$ for the intercept and $\hat{\beta}_i$ for the slope, we compute the ensemble means across 100 simulations $\bar{\alpha}$ and $\bar{\beta}$. As the value of these means depends on the particular choice of the parameter vector, by changing values to $M$ or $D$ we will get different $\bar{\alpha}$ and $\bar{\beta}$.

The numerical results are reported in Tables (3) and (4).

**Table 3:** Effect of $M$ on the three curves ($D = 8$). Standard errors in parentheses.

| | *Beveridge* | | *Phillips* | | *Okun* | |
|---|---|---|---|---|---|---|
| M | $\bar{\alpha}$ | $\bar{\beta}$ | $\bar{\alpha}$ | $\bar{\beta}$ | $\bar{\alpha}$ | $\bar{\beta}$ |
| 2: | 0.1496 | −0.2743 | 0.0213 | −0.0980 | 0.0139 | −0.074 |
| | (0.0037) | (0.0366) | (0.0019) | (0.0256) | (0.0039) | (0.0551) |
| 3: | 0.1491 | −0.3011 | 0.0222 | −0.1256 | 0.0044 | −0.0533 |
| | (0.0038) | (0.04) | (0.0021) | (0.034) | (0.0037) | (0.0486) |
| 4: | 0.1473 | −0.3135 | 0.0223 | −0.1479 | 0.0162 | −0.0465 |
| | (0.0048) | (0.0591) | (0.0021) | (0.0405) | (0.005) | (0.0439) |
| 5: | 0.1452 | −0.3183 | 0.0223 | −0.1699 | 0.0166 | −0.0280 |
| | (0.0038) | (0.0613) | (0.0022) | (0.0461) | (0.0049) | (0.0324) |
| 6: | 0.1457 | −0.3492 | 0.0227 | −0.2125 | 0.0196 | −0.0276 |
| | (0.0039) | (0.0626) | (0.002) | (0.0515) | (0.0055) | (0.0313) |
| 7: | 0.1443 | −0.3484 | 0.0223 | −0.2311 | 0.0196 | −0.022 |
| | (0.0040) | (0.0762) | (0.0021) | (0.0612) | (0.0054) | (0.0274) |

**Table 4:** Effect of $D$ on the three curves ($M = 4$). Standard errors in parentheses.

| | *Beveridge* | | *Phillips* | | *Okun* | |
|---|---|---|---|---|---|---|
| D | $\bar{\alpha}$ | $\bar{\beta}$ | $\bar{\alpha}$ | $\bar{\beta}$ | $\bar{\alpha}$ | $\bar{\beta}$ |
| 2: | 0.5205 | −0.5722 | 0.0735 | −0.1795 | 0.0098 | −0.1238 |
| | (0.0179) | (0.0754) | (0.2442) | (0.2497) | (0.0055) | (0.1061) |
| 3: | 0.3540 | −0.4284 | 0.0329 | −0.0723 | 0.011 | −0.1112 |
| | (0.0099) | (0.0532) | (0.013) | (0.0579) | (0.0057) | (0.1418) |
| 4: | 0.2738 | −0.3791 | 0.026 | −0.0716 | 0.0119 | −0.0699 |
| | (0.0063) | (0.0451) | (0.003) | (0.03) | (0.0044) | (0.0779) |
| 5: | 0.2246 | −0.3567 | 0.0248 | −0.0962 | 0.013 | −0.0673 |
| | (0.0054) | (0.0445) | (0.0025) | (0.0308) | (0.0046) | (0.0697) |
| 6: | 0.1904 | −0.3332 | 0.0237 | −0.1151 | 0.0136 | −0.0443 |
| | (0.0041) | (0.0369) | (0.0022) | (0.0325) | (0.004) | (0.0489) |
| 7: | 0.1652 | −0.3136 | 0.023 | −0.1324 | 0.0151 | −0.0603 |
| | (0.0037) | (0.0391) | (0.0019) | (0.0323) | (0.0047) | (0.0634) |
| 8: | 0.1473 | −0.3135 | 0.0223 | −0.1479 | 0.0162 | −0.0465 |
| | (0.0048) | (0.0591) | (0.0021) | (0.0405) | (0.005) | (0.0439) |
| 9: | 0.1346 | −0.3272 | 0.0221 | −0.1729 | 0.0171 | −0.0362 |
| | (0.005) | (0.0738) | (0.0025) | (0.053) | (0.004) | (0.0383) |
| 10: | 0.1247 | −0.3345 | 0.021 | −0.171 | 0.0193 | −0.0343 |
| | (0.0052) | (0.1062) | (0.0026) | (0.0614) | (0.0042) | (0.0371) |
| 11: | 0.1138 | −0.2810 | 0.0193 | −0.15 | 0.0206 | −0.0385 |
| | (0.0078) | (0.1753) | (0.0038) | (0.0907) | (0.0048) | (0.0373) |
| 12: | 0.1025 | −0.2054 | 0.0176 | −0.1225 | 0.0218 | −0.0316 |
| | (0.0111) | (0.2109) | (0.005) | (0.1098) | (0.005) | (0.0347) |
| 13: | 0.0903 | −0.1174 | 0.0132 | −0.0769 | 0.0220 | −0.029 |
| | (0.0214) | (0.2372) | (0.0216) | (0.1231) | (0.007) | (0.0582) |
| 14: | 0.0847 | −0.1066 | 0.0147 | −0.0717 | 0.0217 | −0.0648 |
| | (0.0261) | (0.2409) | (0.0448) | (0.1249) | (0.0075) | (0.2082) |

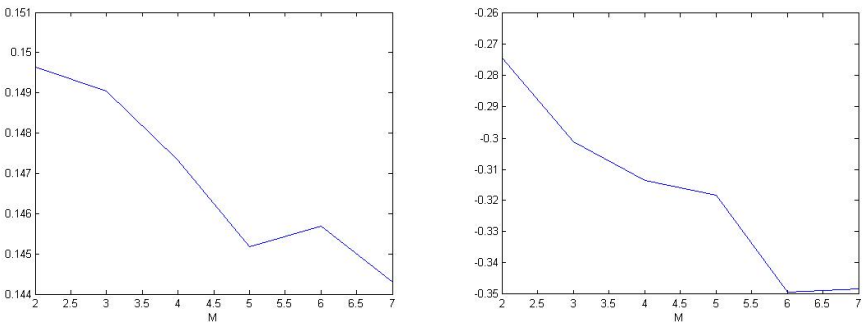
### 4.1 The Beveridge curve

As explained in Section 1, variations in search costs are often regarded as a potential cause for Beveridge curve shifts. In particular, increasing (decreasing) frictions should cause outwards (inwards) shifts of BC. Hence, the first battery of Monte Carlo experiments is devoted at assessing the likelihood of this hypothesis. The parameter involved will be therefore $M$.

In Figure 4 we can appreciate the influence exerted by search costs upon the BC. As parameter $M$ increases from 2 to 7, the ensemble mean of the estimated intercept ($\bar{\alpha}$) monotonically declines (Panel (a)), implying that for a given vacancy rate average unemployment is lower. This reveals that increasing market efficiency indeed provokes inwards shifts of BC as predicted by the "frictions" hypothesis. However, the magnitude of these shifts is rather small, as the mean $\bar{\alpha}$ goes only from 0.1496 to 0.1443 - a modest decline of about 3.5%.

More sensible is the effect of $M$ on the slope of BC (Panel 4(b)): as search costs reduce, $\bar{\beta}$ steadily declines from –0.2743 to –0.3484 – a decline of about 27%. We interpret this behavior as a stronger statistical correlation between unemployment and current vacancy rates. If search costs decline, in fact, frictional unemployment decreases and the observed unemployment rates necessarily come to depend more on contingent factors such as the behavior of aggregate demand, that is on the number of vacancies (see Eq. 4).

In Section 1 we also argued that reallocation activity may be an explanation to the observed shifts of BC alternative to the "frictions" hypothesis. In what follows, therefore, we are going to test whether this may actually be the case by performing Monte Carlo experiments involving the parameter $D$. In fact, by changing value to $D$ we are also able to control the intensity of reallocation activity. In order to consider both flexible and rigid labor contracts, we run simulations with $D$ taking on values from 2 to 14. Interpreting each simulation period as a quarter, the considered contract durations range from one semester to three years and half.



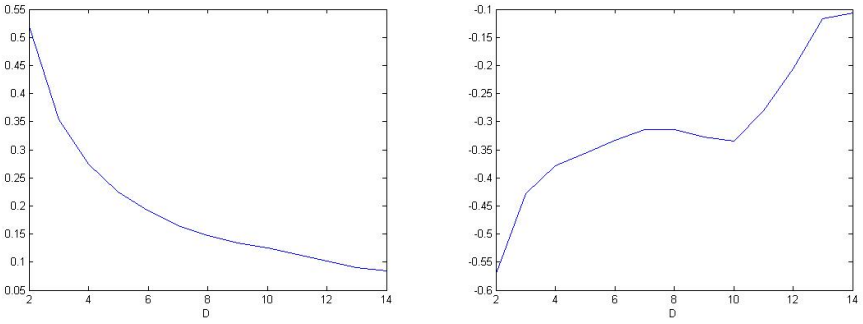

(a) (b)

**Figure 4:** Effect of increasing values of $M$ on BC. (a): intercept, (b): slope.

Panel (a) of Figure 5 shows that the intercept $\bar{\alpha}$ declines as job contracts become longer and worker reallocation loses intensity. Thus, when the labor market becomes more rigid (flexible) BC shifts inwards (outwards), that is both job creation and job destruction become smaller (bigger). If job contracts are long, in fact, for a given unemployment rate firms on average need to open fewer vacancies because job quits are less frequent. Moreover, as firms cannot easily resort to firing during downturns, they also do not need to replace fired workers when the economy starts to grow again. On the contrary, if contracts expire quickly job quits become more frequent, as well as layoffs during downturns. As a consequence, firms have to constantly open new vacancies in order to replace job quits and previously fired workers. This result, therefore, suggests that (intensity of) reallocation may indeed be regarded as a cause behind the shifts of BC.

Employment contract length exerts an influence on BC also through the slope. Panel 5(b) shows that, as the labor market becomes more rigid, $\bar{\beta}$ increases from –0.5722 to –0.1066. A flatter BC can be interpreted as a weaker correlation between current unemployment rate and current vacancies. If contract duration is higher, in fact, the stock of currently employed workers – and thus the unemployment rate – depends more on how many workers have been hired in past periods and the weight of newly employed workers on total employment is smaller. On the contrary, if contracts last less, jobs are terminated more often. So, current employment – and therefore unemployment – strictly depends on the number of current vacancies. Hence, the correlation between current unemployment rate and current vacancies is stronger.

In conclusion, from our simulations market frictions appear to tilt more than shift the Beveridge curve. As empirical observations reveal that BC has mostly a tendency to shift, with the awareness that our results are merely qualitative we could therefore infer that the role of search costs behind BC movements may be only a minor one. On the contrary, worker reallocation, in our model depending on job contract duration, seems a more convincing explanation for BC shifts.




(a) (b)

**Figure 5:** Effect of increasing values of $D$ on BC. (a): intercept, (b): slope.

### 4.2 The Phillips curve

As far as the Phillips curve is concerned, Figure 6 reports its relationship with parameter $M$. We found that PC becomes sensibly steeper as search costs vanish, whereas no clear pattern emerges for the intercept (not reported here). In other terms, wage inflation becomes more correlated to unemployment. Interpreted as a causal relationship, this result implies that a 1% decrease in the unemployment rate will impress a higher *acceleration* upon nominal wages. We have already pointed out in Section 2.1 how hiring in general raises the average wage. But why does wage grow faster as $M$ increases (for a given 1% reduction of unemployment)? The explanation might be the following: when workers send more job applications they have on average a higher probability of coming across firms paying higher wages. In principle, if each worker were able to visit all the firms, high-wage employers would surely fill all their vacancies. So, for a given decrease in the unemployment rate (that is an increase in the number of jobs) firms offering high wages will attract more workers than other firms when $M$ is larger. If this is the case, therefore, for a given number of newly created jobs the percentage of new jobs paying high wages will be on average higher – a larger positive wage variation. This argument works also the other way around. When $M$ is small, in fact, firms are on the same footing as higher wages do not guarantee a higher probability to fill in the vacancies, and the allocation of workers among firms becomes more a matter of chance (the reader can think about the extreme case when workers send only one job application per period). Among new jobs, therefore, there will not be a higher percentage of jobs paying high wages. Thus, a reduction of unemployment will still in general increase the average wage but with a lower acceleration – a flatter PC.

An alternative explanation refers to the feedbacks existing between labor and goods markets. It could be, in fact, that lower search costs decrease frictional unemployment, generating therefore higher demand for consumption goods, which on its turn may increase labor demand and wages.

Our result (a flatter PC associated to higher search costs) is consistent with the fact that in the last few decades the Phillips curve appears to have become flatter in the U.S. and in Europe (Blanchard *et al.*, 2015). In fact, because of globalization the integration of international goods markets has rapidly increased, whereas local labor markets have remained relatively isolated in spite of increasing immigration flows. Consequently, American and European economies can be conceived as a single large economy whose labor market is characterized by high search costs.

It is interesting to note that our result may be opposite to findings in mainstream literature. For example, Ravenna and Walsh (2008) find that the elasticity of inflation with respect to unemployment decreases (a flattening PC) as the probability to fill in vacancies increases (in our setting represented by an increase in $M$). However, the stark differences in the theoretical frameworks make it arduous to provide a rationale for such contrasting results.

The Phillips curve is influenced also by parameter $D$. From Figure 7(a) we can see that the intercept declines as labor contracts become longer – the same behavior

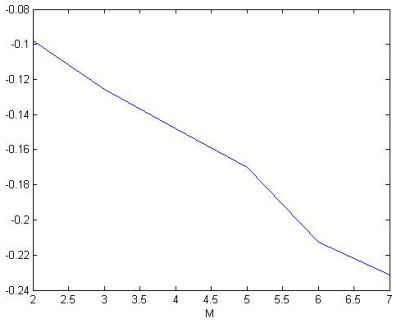
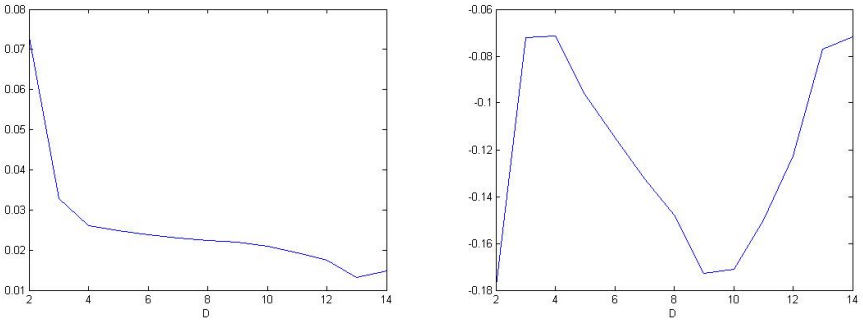



**Figure 6:** Effect of increasing values of $M$ on the slope of PC.




(a) (b)

**Figure 7:** Effect of increasing values of $D$ on PC. (a): intercept, (b): slope.

we observed for BC. Inwards (outwards) shifts of PC mean lower (higher) wage inflation rates for a given unemployment rate. This happens for at least two reasons. First reason: if jobs terminate more (less) often, then firms need to open more (less) vacancies and, according to Eq. 5, to raise more (less) frequently their wage offer in order to prevent their workers from choosing another employer. Hence, in general we can say that, *ceteris paribus*, longer (shorter) contracts reduce (increase) wage competition among firms, causing inwards (outwards) shifts of PC. Second – albeit less important – reason: if the reallocation activity occurs more frequently, workers have more opportunities to find jobs paying higher salaries. For a given level of employment, therefore, the average wage will grow more if workers have the possibility to leap from firm to firm more frequently, in principle even if no firm is rising its offered wage. Obviously, the opposite is true if contract duration is longer. This argument is more convincing when pushed to the extreme: if no reallocation occurs, in fact, each worker would keep the same job at the same salary, and the sole inflationary pressure would come from the exogenous minimum wage adjustment.

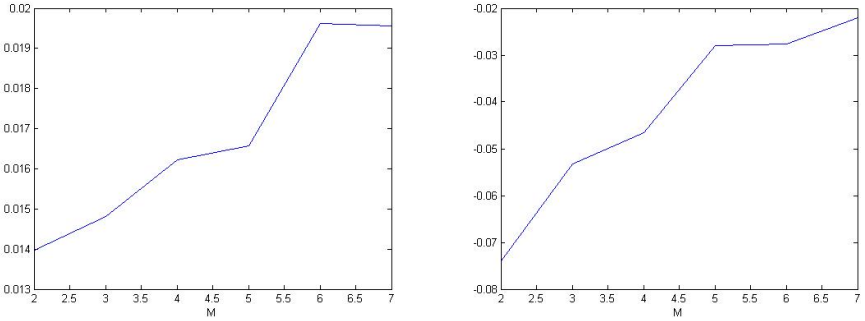
Finally, Panel 7(b) shows that the relationship between $D$ and the slope of PC is non-linear: if we exclude the case for $D = 2$ (in which case the coefficients are not even statistically significant), PC first becomes steeper ($\bar{\beta}$ from –0.0723 to –0.1729) and then flat again ($\bar{\beta}$ drops to –0.0717, which is not statistically different from zero). In other words, a 1% decrease in the unemployment rate will accelerate wages more for intermediate values of $D$ and less for its extreme values. When $D$ is very high, wage competition among firms is always very weak, so wage inflation is insensitive to the level of unemployment (slope small in absolute value) and is almost totally due to the exogenous minimum wage – intercept small, Panel 7(a). On the opposite, when $D$ is very small competition is always very tough because of intense reallocation of workers. Wage inflation, therefore, will always be high (intercept large, Panel 7(a)) regardless of the unemployment rate (slope small in absolute value, Panel 7(b)).

### 4.3 The Okun curve

For completeness, through the same kind of sensitivity analysis we will devote the penultimate session to the study of a “difference" version of Okun curve, where the dependent variable is the real output growth rate and the independent variable is the growth rate of the unemployment rate. Results are depicted in Figures (8) and (9).

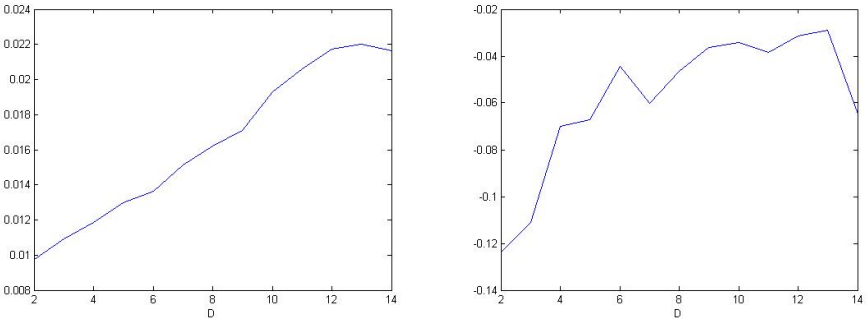
Parameters $M$ and $D$ seem to exert the same effect on both intercept and slope of OC. In particular, when frictions vanish ($M$ increases) the average intercept gets higher – outwards shifts of the curve. In other words, for a given variation of unemployment output grows faster. This is not surprising and confirms the negative impact of frictions on economic growth. The explanation may be that when workers send more applications they have more probabilities to be hired by firms paying high wages (see above discussion about Phillips curve). Since in general firms with higher wages are also more productive, the average productivity of employed workers will be higher, thus accelerating output growth. The role of productivity can be understood also from another angle. In fact, the intercept is nothing else that the growth rate associated with constant unemployment (zero growth rate of unemployment). Thus, an increasing intercept means that higher growth is needed to keep unemployment constant. And this happens precisely when labor productivity grows faster. As far as the slope is concerned, OC becomes flatter as $M$ increases. Interpreted as a causal effect, this behavior means that a given increase in output growth rate will be associated to a larger negative variation of unemployment. Basically, lower search costs allow economic growth to have a stronger positive impact on employment.

As for parameter $D$, when job contract duration becomes longer the intercept increases – again, outwards shifts of OC. In other terms, for given variation of unemployment output grows faster. This implies that increasing intensity of reallocation due to short contracts, that is a higher frequency of the matching process between employees and employers, has a negative impact on growth. The reason may be simple: longer contracts prevent firms from firing during downturns and sustain




(a) (b)

**Figure 8:** Effect of increasing values of $M$ on OC. (a): intercept, (b): slope.




(a) (b)

**Figure 9:** Effect of increasing values of $D$ on OC. (a): intercept, (b): slope.

aggregate demand. Moreover, longer contracts flatten the OC. We interpret this phenomenon as a weaker correlation between current variations of output and current variations of unemployment. If contracts are longer, in fact, when the economy slows down firms are forced to keep their employees (unless they are financially distressed) and, as a consequence, when output grows again firms not necessarily need to hire additional workers because their workforce may be sufficient to expand production (see above discussion about Beveridge curve). Basically, when contracts are longer firms adjust their workforce less frequently so that the number of employees tends to be less affected by short-run output fluctuations.

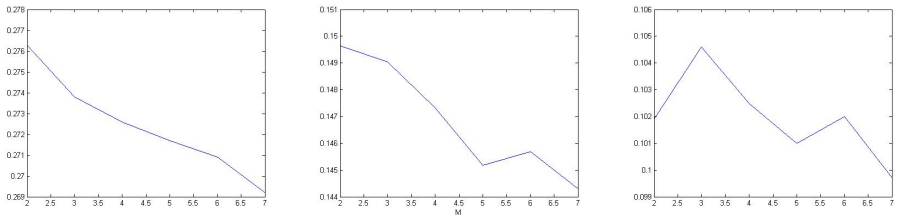
### 4.4 Interaction between search costs and contract duration

So far we have performed local sensitivity analysis exercises aimed at isolating the role of search costs and job contract length. However, the effect of one mechanism might well be influenced by the other one. In order to discover whether such an interaction exists, therefore, in this subsection we will repeat the same kind of

analysis over each parameter for different values of the other parameter. Basically, we will assess the effect of parameter $M$ on intercept and slope of both Beveridge and Phillips curve for different degrees of job contract flexibility ($D = 4, 8, 12$), and then we will assess the effect of parameter $D$ for different degrees of search costs ($M = 2, 4, 6$).

In general we can say that the two mechanisms do not interact significantly. In particular, for different degrees of search costs the effect of parameter $D$ on the Monte Carlo intercept $\bar{\alpha}$ of both curves is almost the same. Analogously, contract duration exerts the same kind of effect also on the Monte Carlo slopes $\bar{\beta}$ (see Fig. 5(b) and Fig. 7(b)). However, with decreasing search costs the relationship between $D$ and the slopes translates in parallel downwards, which simply means that, for given $D$, the absolute value of the slopes increases with $M$ (see also Fig. 4(b) and Fig. 6).

On the other hand, job contract duration appears to change to some extent the effect of frictions. In Fig. 10 we can see that the relationship between $M$ and the Monte Carlo intercept of the Beveridge curve gets lower and flatter as $D$ increases. In particular, fitting the three relationships with a straight line we get a slope of –0.0013, –0.0010 and –0.00058 for $D = 4, 8$ and 12 respectively. This means that when contract duration is longer, that is when worker reallocation is less intense, frictions due to search costs lose importance in determining Beveridge curve shifts. Conversely, the effect of $M$ on the slopes turns out to be rather insensitive of parameter $D$.



(a) (b) (c)

**Figure 10:** Effect of $M$ on Beveridge curve Monte Carlo intercept for different contract durations. (a): $D = 4$, (b): $D = 8$, (c): $D = 12$.

## 5 Conclusions

The observation of labor market empirical regularities suggests that these may be better understood as the emergent product of a complex system than as the result of the optimal choice of a representative individual. In a complex system heterogeneous micro units provided with limited information and bounded rationality interact and react to the stimuli coming from the environment in a continuous process of adaptation and discovery. Thus, we set up an agent-based macro model based on

adaptive micro-foundations, where a large number of firms, households and banks interact on the basis of simple rules-of-thumb and on the stock of small amounts of private information. Without a centralized coordination mechanism, agents are immersed in a truly uncertain environment and may fail to coordinate. The model works fairly well in replicating a number of stylized facts related to long-run, business cycle, industrial and labor market dynamics. In particular, the Beveridge curve, the Phillips curve and the Okun curve jointly emerge from simulations. The model also reproduces typical correlations that can be observed between job flows and between unemployment rates and unemployment duration.

Through a series of Monte Carlo experiments, we used the model as a virtual laboratory to understand the possible determinants of Beveridge curve and Phillips curve movements. We discovered that BC shifts are more convincingly explained by the intensity of worker reallocation (in our model captured by labor contract flexibility) than by job search costs. Consistently with what is argued in Section 1, we found that a more intense reallocation activity shifts BC outwards. We also found that both increasing search costs and increasing contract rigidity (i.e., a weakening reallocation) cause BC to become flatter.

As far as the Phillips curve is concerned, we found that outwards shifts of this curve are produced by increasing levels of worker reallocation, whereas search costs appear not to have any role. Thus, reallocation shifts PC and BC in the same direction. As the historical shifts of PC, at least in the U.S.A., have actually paralleled those of BC (outwards in the 1970s and 1980s, inwards in the late 1980s and 1990s; Valletta, 2005), with the highest prudence we could therefore ascribe such joint movements to reallocation of workers. The Phillips curve is affected by reallocation also through its slope. This relationship, however, is non-monotonic: a decreasing reallocation intensity first makes PC steeper, and then flatter. Furthermore, we found that decreasing search costs cause PC to become steeper. All these findings may shed new light on what moves the Phillips curve and might have direct implications for the conduction of monetary policy.

Finally, both decreasing search costs and increasing contract duration (i.e. increasing efficiency and decreasing frequency of the matching process on the labor market) produce outwards shifts of the Okun curve and also make it flatter.

Several modeling improvements and policy analysis are left for future work. In particular, a stock-flow consistent version of the model should be developed, and global sensitivity analysis exercises (unlike ours, which are local) carried out.

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